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Performances Evaluation of Advanced Sugarcane Genotypes (CIRAD 2013) at Metahara Sugar Estate, Ethiopia

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Abstract

The study was conducted at Metahara to evaluate the performance of eleven introduced advanced sugarcane genotypes on the two major soil types for Plant Cane (PC) and first ratoon (R-I). The experimental design used was Randomized Complete Block Design (RCBD), laid out in three replicates. Data were collected for number of tillers, millable stalk, plant height, stalk diameter, single stalk weight, cane yield, brix % juice, pol percent, sugar recovery percent and sugar yield. The differences among soil types, genotypes and genotype by soil type's interactions were significant ($P \leq 0.05$) for quantitative traits analyzed except stalks diameter, cane length and sugar recoverable percent which were significantly different only for genotype and soil types. CPCL 02 926 showed significantly highest number of stalks over eight genotypes including MEX 54-245 and CP 04 1935 showed significantly highest number of stalks over all genotypes evaluated except with NCO 334 under light soils. The Thailand genotypes MPT 97 203 and MPT 96 273 showed significantly highest cane diameter under both soil types. The Philippines genotypes VMC 96-120 and VMC 96-89 showed highest cane lengths. Highest single stalk weights were obtained in genotypes MPT 97 203 and MPT 96 273 under both soil types. Cane yield was highest in genotypes VMC 96-120, B 52-298, MPT 96 273 and CPCL 02 926 under heavy soils and NCO 334, CP 96 1252, B 52-298 and MEX 54/245 under light soils. The highest sugar yield were obtained in genotypes B 52-298, MPT 96 273, CP 04 1935 and VMC 96-120 under heavy soils and NCO 334, B 52-298, CP 96 1252 and CPCL 02 926 under light soils. Sugar recovery is more important in determining sugar yield under heavy soils. Under light soils sugar yield is determined mainly by cane yield.. Therefore, MPT 96-273, CP 04-1935 and VMC 96-120 under heavy, CP 96 1252 and CPCL02 926 under light soil types, were found promising genotypes in plant cane and Ratoon I for sugar yield. Thus, selected genotypes had been recommended for further verification on large commercial fields under their best performing soil types of Metahara Sugar Estate.

Keywords: Sugarcane, Genotypes, PC, R-I, Soil

1. Introduction

Sugarcane (*Saccharum* ssp) is one of the most important crops in tropical and sub-tropical countries, is the first major sugar crop worldwide. The crop belongs to the genus Saccharum and is a grass, like most of the world's grain crops. However, instead of storing starch in seed heads like the grain crops, sugarcane has evolved to store sugar (sucrose) in its stalk. The soft and sweet chewing 'noble canes' belong to the species *Saccharum officinarum*, which appears to have evolved from its wild relatives in Papua-New Guinea (Glyn, 2004).

The present day sugar cane varieties (*S. officinarum*) have been the subject of many improvements. The original *S. spontaneum* and S. *robustum* were replaced by *S. barberi* and *S. sinense*, but were themselves ousted later by *S. officinarum* or noble cane (Terry, 2000). Generally, sugarcane is a tall perennial crop that tillers at the base, grows three to four meters tall and about five cm in diameter (Singh, 2003).

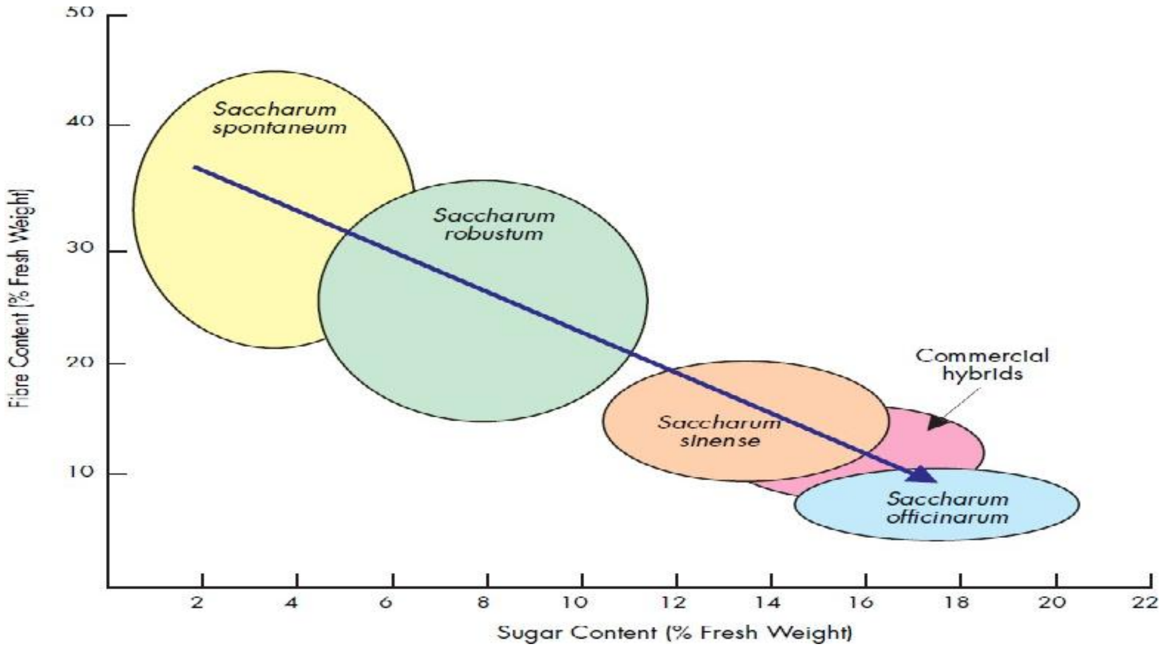

Figure 1 Progressive change in fiber and sugar levels from wild to noble canes (Terry, 2000).

Sugar cane is a warm-temperate and sub-tropical crop which requires a warm, sunny and moist climate and fertile, deep and well aerated soils. It grows in countries within latitudes of 37^0 N and 32^0 S of the equator and on soils varying in texture from light sands to heavy clays provided that it is supplied with the required elements. It is also tolerant to wide variations in acidity and alkalinity (growing in soils with pH in the range of 5 to 8.5) (Blackburn, 1984).

In Ethiopia so far the industry has been dependent on crop improvement through introduction and selection of sugarcane varieties for their growth and sugar yield performances in the sugar estates and projects. There is no hybridization of sugarcane in Ethiopian sugar estates and projects. In the Sugar Estates the need for improved varieties is the basic issue to increase production of sugar per unit area. The limited varietal base, diverse topographic and edaphic conditions calls for the need for searching and widening the genetic base by conducting continuous evaluation and adaptability trail in the sugar estates and projects. Therefore, Screening of indigenous and exotic sugarcane germ-plasm to identify donors for yield, juice quality, biotic and a-biotic stresses is very important for the introduction of *Saccharum officinarum* varieties and for inclusion in the breeding programme. Conducting studies aimed at improving the productivity of plant cane and ratoon crops through breeding *i.e.* by selecting clones/genotypes with ratoonability capabilities coupled with high yield and high juice quality. Ratooning ability in sugarcane varieties is the ability to maintain yield as the number of Rattoons increase, and depends on genotype, environment and crop management (Chapman *et al*., 1992). King *et al.*, 1965 acknowledged that ratooning increased profits in a sugarcane growing cycle.

However, selection for high yield is made difficult because yield per unit area is the end product of the combined effects of several characters, which are polygenic in inheritance and thus are highly influenced by environment. Therefore, only little progress could be made over along span of time through direct selection for yield (Ford, 1964). This selection criterion takes into account the information on interrelationship among agronomic characters, their relationship with yield as well as their direct influence on sugar yield. Information on the extent and nature of interrelationship among characters help in formulating efficient scheme of multiple trait selection (Mohammadi *et al*., 2003). For any planned breeding program aimed to improve yield potential of crops, it is necessary to obtain adequate information on the magnitude and type of genetic variability and their corresponding heritability. This is because selection of superior genotypes is proportional to the amount of genetic variability present and the extent to which the characters are inherited (Falconer and Mackay, 1996).

Therefore this study were conducted to evaluate the performance of Eleven advanced sugarcane genotypes, investigate the nature of correlation, genetic and phenotypic variability for important traits under two soil types for plant cane and Rattoon I at Metahara Sugar Estate.

2. Materials and Methods

The experiment was conducted at Metahara sugar estate. Metahara sugar estate is located in the Upper Awash Plain (UAP) in the Oromia Regional State of Ethiopia. It is located at about 206 km East of Addis Ababa, 8° N latitude and 39° 52' E longitude with an elevation of 950 m asl. Metahara receives about 554 mm annual average rainfall with mean maximum and mean minimum temperature of 32.8°C and 17.5°C, respectively.

Eleven introduced advanced sugarcane genotypes from CIRAD in 2013 designated as CP 96 1252, CP 00 2180, CP 04 1935, CPCL 02-926, VMC 96-61, VMC 96-89, VMC 96-120, FG 06-622, FG 04-356, MPT 96-273 and MPT 97-203 were evaluated along with standard checks NCO 334, B 52- 298 and Mex 54/245 on two major soils of the sugar estate. The genotypes were imported by following the standard quarantine procedures. At their center of origin they were found to be higher in cane and sugar yield and were moderately to highly resistant to major diseases; smut, brown rust, leaf scald, mosaic, ratoon stunt, orange rust, leaf scorch, yellow spot and red rot (CIRAD, 2012).

The experiment was conducted during October 2014 to June 2017 in plant cane and Rattoon I in Randomized Complete Block Design (RCBD) with three replications. A plot consisted of 6 rows each 6 m long and spaced 1.45 m apart. The spacing between sub-blocks and replications were 1.5 m and 3 m, respectively, and 3 m border was maintained on all sides. Field managements were as per the plantations.

Data was collected from the four central rows for sprouting percentage, number of tillers, stalk count, stalk Length (cm), stalk diameter (mm), single stalk weight, cane yield (tons/ha), brix percent juice, recoverable sugar percent, pol percent and sugar yield (tons/ha).

The quantitative data recorded in this study was subjected to analysis of variance using statistical procedures described by Gomez and Gomez (1984) with the help of statistical analysis software (SAS, 2002). Least significance difference (LSD) mean comparison method at 5% level of significance was used to separate the treatment means and compare the effects of soil types.

The phenotypic and genotypic variances for each trait were estimated from the CRBD analysis of variance. The expected mean squares under the assumption of random effects model was computed from linear combinations of the mean squares and the phenotypic and genotypic coefficient of variations as per Burton and Devane (1953).

Genotypic variance ($\sigma^2 g$) = (MSg – MSe)/r
Environmental variance ($\sigma^2 e$) = Mse

Where, MSg and MSe are the mean sum of squares for the genotypes and error in the analysis of variance, respectively r is the number of replications.

The phenotypic variances were estimated as the sum of the genotypic and environmental variances. Phenotypic variance ($\sigma^2 ph$) = $\sigma^2 g + \sigma^2 e$

The genotypic and phenotypic coefficients of variability were calculated according to the formulae of Singh and Chaundary (1977).

Genotypic Coefficient of Variation (GCV) = (σg/grand mean) * 100
Phenotypic Coefficient of Variation (PCV) = (σph / grand mean) * 100

Table 1: Analysis of Variance

Source of Variation	Degree of Freedom	Mean Square	Expected Mean Square
Replication	r-1	Msr	$\sigma^2 e + g\sigma^2 r$
Genotypes	g-1	MSg	$\sigma^2 e + r\sigma^2 g$
Error	(r-1)(g-1)	Mse	$\sigma^2 e$

Where r=number of replications, g=number of genotypes Msr= mean square due to replications, MSg= mean square due to genotypes; Mse=mean square of error; σ2g, σ2r and σ2e are variances due to genotype, replication and error.

3. Results and Discussion

The differences among the 14 genotypes were highly significant for all analyzed quantitative traits indicating the availability of high genetic variability among the genotypes studied. The Soil effect was also significant for all quantitative traits except for stalk diameter. The Genotype by Soil type's interaction was also statistically significant for all traits examined except stalk diameter, cane length and recoverable sugar percent pointing to the differential response of genotypes under the soil types and the possibility that some genotypes are specifically adapted to a specific soil type (Table 2).

Table 2 Combined analysis of variance for 14 sugarcane genotypes under heavy and light soils

S. Variation	Tiller	Stalk count	Diameter	Cane length	S. Stalk Weight	Cane yield	Sugar recovery	Sugar Yield
Genotypes (G)	***	***	***	***	***	***	***	***
Soils (S)	***	***	ns	****	****	****	****	***
Crop cycles	***	***	ns	****	****	****	****	*
G x S	***	*	ns	ns	***	***	ns	*
Mean	682	367	2.68	2.35	1.24	144.1	10.7	15.05
CV	14.54	11.54	6.33	11.06	17.15	18.77	10.35	25.06

Where, ***=significant at ($p \leq 0.001$), **= significant at ($p \leq 0.01$) and *=significant at ($p \leq 0.05$).

The presence of significant G x S interaction for number of tillers, stalk count, single stalk weight, cane yield and sugar yield showed the inconsistency of sugarcane genotypes performances across soil types. The larger the relative size of the interaction indicated the problem in selecting broadly adapted genotypes but favors to select well adapted to specific soil types.

Under light soils analysis of variance showed significant differences for genotypes (G), crop cycles (C) and C x G for characters of number of tillers, stalk count, cane diameter, cane length, single stalk weight cane yield, recoverable sugar percent and sugar yield except stalk count for crop cycle and single stalk weight for the interaction of genotypes by crop cycles. Under heavy soils there was significant differences for genotypes in stalk counts, single stalk weight, cane diameter, cane length, cane yield, recoverable sugar percent and sugar yield; for crop cycle in tiller production, stalk counts, cane length, cane yield and recoverable sugar percent and for C x G single stalk weight, cane yield, recoverable sugar percent and sugar yield at 5% level of significance (Table 3).

Table 3 Analysis of variance for 14 sugarcane genotypes under heavy and light soils

S. Variation	Tiller	Stalk count	Stalk Diameter	Cane length	S. Stalk Weight	Cane yield	ERS	S. Yield
Heavy soils								
Genotypes	ns	***	***	**	***	***	***	*
Crop cycle	***	***	ns	*	***	***	***	ns
G x C	ns	Ns	ns	ns	**	*	*	**
Mean	750	429	2.64	2.88	1.47	193.76	10.07	19.33
CV	14.64	10.76	7.67	11.37	13.74	17.88	13.72	25.22
Light soils								
Genotypes	***	***	***	***	***	***	***	***
Crop cycle	***	Ns	***	***	***	***	***	***
G x C	***	***	***	***	ns	***	***	***
Mean	613	305	2.73	1.83	1.02	94.43	11.34	10.78
CV	13.90	13.03	3.87	9.83	22.41	18.17	5.76	20.58

Where, ***=significant at ($p \leq 0.001$), **= significant at ($p \leq 0.01$) and *=significant at ($p \leq 0.05$).

Performances of the Genotypes in Plant Cane and Rattoon I under Heavy and Light Soils

The check NCO 334 showed significantly highest for stalk count in both plant cane and Rattoon I under light soils. The Thailand genotypes MPT 97 203 and MPT 96 273 were significantly highest in cane diameter for plant cane and ratoon I under both soils. MPT 96 273 produces highest cane length for Rattoon I under heavy and light soils. VMC 96 89 and FG 06-622 also produce significantly higher cane length over B 52 – 298. CPCL 02 926 showed significantly highest in number of tillers under light soils for Rattoon I from the three standard checks and in number of millable stalks from the two standard checks B 52-298 and Mex 54/245 (Table 4).

Table 4 Tillering, stalk count, cane diameter and cane length performances of genotypes under two soils

Genotypes	Tillering				Stalk Count			
	Plant Cane		Rattoon I		Plant Cane		Rattoon I	
	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light
CP 96 1252	836.3^{cd}	769^{bcd}	620.3^{ab}	510.3^{cd}	520.3^{abc}	368.7^{bc}	415.7^{bcd}	347.3^{bc}
NCO 334	953.0^{ab}	964^{a}	750^{a}	622.7^{b}	587.7^{a}	510.7^{a}	469.7^{ab}	434.0^{a}
MPT 97 203	728.0^{e}	482.67^{ef}	495.0^{b}	264.7^{f}	341.3^{g}	208.3^{fgh}	273.0^{g}	191.0^{h}
VMC 96 61	948.3^{ab}	589.33^{de}	540.3^{ab}	605.3^{b}	445.7^{de}	149.7^{h}	356.7^{cdef}	296.7^{de}
FG 04 356	983.3^{a}	896.33^{ab}	683.3^{ab}	557.7^{bc}	499.7^{bcd}	329.7^{bcd}	399.3^{bcde}	345.3^{bc}
MPT 96 273	832.3^{d}	356^{f}	565.7^{ab}	421.0^{e}	374.3^{efg}	181.0^{gh}	327.3^{efg}	242.3^{fg}
CP 04 1935	968.3^{ab}	900^{ab}	607.3^{ab}	488.7^{cde}	577.7^{a}	371.7^{bc}	501.7^{a}	357.3^{b}
CPCL 02 926	966.7^{ab}	812..67^{abc}	523.0^{ab}	784.7^{a}	550.0^{ab}	372.3^{bc}	439.7^{ab}	469.3^{a}
B 52-298	944.3^{ab}	974^{a}	670.3^{ab}	623.0^{b}	545.0^{ab}	388.3^{b}	435.7^{abc}	356.7^{b}
VMC 96-120	923.0^{abc}	698^{cd}	511.7^{ab}	494.0^{cd}	536.7^{ab}	301.3^{cde}	429.0^{abc}	307.3^{cd}
VMC 96-89	930.3^{ab}	580.33^{de}	572.7^{ab}	282.7^{f}	452.7^{cd}	283.3^{def}	319.0^{efg}	205.0^{gh}
FG 06-622	838.7^{cd}	660^{cde}	580.3^{ab}	450.0^{de}	432.3^{def}	240.7^{efg}	345.7^{defg}	263.7^{def}
CP 00-2180	888.0^{bcd}	647.67^{cde}	608.0^{ab}	469.7^{de}	369.3^{fg}	185.3^{gh}	295.3^{fg}	251.7^{efg}
MEX 54/245	955.7^{ab}	813.33^{abc}	585.7^{ab}	439.0^{de}	435.7^{def}	284.0^{def}	348.3^{defg}	302.0^{cd}
Mean	906.9	724.55	593.86	500.95	476.3	298.21	382.57	312.12
LSD	88.405	188.85	245.27	72.015	74.358	81.27	80.556	47.966
CV	5.8	15.53	24.61	8.565	9.3	16.24	12.55	9.154

Table 4 Continued

Genotypes	Cane diameter				Length			
	Plant Cane		Rattoon I		Plant Cane		Rattoon I	
	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light
CP 96 1252	2.67^{b}	2.84^{cde}	2.38^{fg}	2.57^{fg}	2.87^{ab}	1.72^{bc}	2.70^{c}	2.04^{bc}
NCO 334	2.44^{bc}	2.37^{g}	2.41^{efg}	2.63^{ef}	2.85^{ab}	1.91^{ab}	2.80^{bc}	2.18^{b}
MPT 97 203	3.16^{a}	3.12^{a}	3.04^{a}	3.23^{a}	2.75^{ab}	1.49^{d}	2.97^{bc}	1.88^{bcd}
VMC 96 61	2.71^{b}	2.92^{abc}	2.75^{abcd}	2.78^{cd}	2.09^{c}	0.94^{f}	2.89^{bc}	1.62^{d}
FG 04 356	2.54^{bc}	2.67^{ef}	2.36^{fg}	2.40^{h}	2.81^{ab}	1.52^{d}	2.69^{c}	1.97^{bcd}
MPT 96 273	2.78^{ab}	3.08^{ab}	2.95^{ab}	3.08^{b}	3.03^{a}	1.20^{e}	3.56^{a}	2.56^{a}
CP 04 1935	2.27^{c}	2.61^{f}	2.34^{g}	2.44^{gh}	2.76^{ab}	1.56^{cd}	3.01^{bc}	2.14^{b}
CPCL 02 926	2.71^{b}	2.33^{g}	2.23^{g}	2.20^{i}	2.97^{ab}	1.46^{d}	3.03^{bc}	2.26^{ab}
B 52-298	2.63^{bc}	2.74^{cdef}	2.68^{bcde}	2.82^{c}	3.08^{a}	1.75^{bc}	2.83^{bc}	2.04^{bc}
VMC 96-120	2.59^{bc}	2.88^{bcd}	2.93^{abc}	2.73^{cde}	3.04^{a}	1.61^{cd}	3.25^{ab}	2.13^{b}
VMC 96-89	2.63^{bc}	2.78^{cdef}	2.73^{bcd}	2.74^{cde}	2.99^{ab}	1.95^{a}	3.15^{abc}	2.05^{bc}
FG 06-622	2.65^{bc}	2.84^{cde}	2.64^{edf}	2.57^{fg}	3.04^{a}	2.00^{a}	2.85^{bc}	2.17^{b}
CP 00-2180	2.73^{b}	2.94^{abc}	2.78^{abcd}	2.72^{cde}	2.44^{bc}	1.27^{e}	2.80^{bc}	1.68^{cd}
MEX 54/245	2.62^{bc}	2.68^{def}	2.64^{cdef}	2.66^{def}	2.58^{abc}	1.97^{a}	2.77^{bc}	2.05^{bc}
Mean	2.65	2.77	2.632	2.683	2.81	1.60	2.95	2.055
LSD	0.382	0.204	0.2922	0.145	0.5811	0.1945	0.5153	0.379
CV	8.57	4.38	6.616	3.221	12.34	7.25	10.41	10.99

For single stalk weight MPT 97 203 and MPT 96 273 in plant cane under heavy soils and MPT 96 273 in ratoon I under both soils were showed significantly higher over the checks. CPCL 02 926 in plant cane and VMC 96 120 in ratoon I under heavy soils over NCO 334 and MEX 54/245 and CP 96 1252 over B 52-298 and MEX 54/245 in plant cane under light soils were showed significantly higher for cane yield.

Higher recoverable sugar percent were recorded under light soils except for the varieties NCO 334 and B 52-298, they were showed almost equal in both soils (9 and 10 respectively). CP 96 1252, MPT 97 203, FG 04 356, CP 04 1935, CPCL 02 926 and FG 06 622 had significantly higher recoverable sugar % in plant cane under light soils (Table 5).

Table 5 Stalk Weight, Cane Yield, Sugar Recovery and Sugar Yield performances of genotypes under two soils

Genotypes	Single Stalk Weight				Cane Yield (tons/ha)			
	Plant Cane		Rattoon I		Plant Cane		Rattoon I	
	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light
CP 96 1252	1.34^{c}	1.06^{ab}	1.03^{f}	0.93^{de}	240.8^{abcd}	134.5^{a}	123.70^{e}	92.87^{cdef}
NCO 334	1.06^{de}	0.76^{bc}	1.25^{ef}	1.15^{bcde}	212.0^{bcdef}	134.3^{a}	168.37^{bcde}	143.51^{a}
MPT 97 203	1.64^{ab}	1.08^{ab}	2.15^{ab}	1.23^{bcde}	191.6^{cdef}	76.0^{def}	168.87^{bcde}	69.25^{f}
VMC 96 61	1.36^{bc}	0.69^{bc}	1.66^{cd}	1.01^{bcde}	208.9^{cdef}	35.7^{h}	170.38^{bcde}	85.9^{cdf}
FG 04 356	1.23^{cd}	0.79^{bc}	1.19^{ef}	0.91^{de}	213.3^{abcdef}	88.4^{cde}	136.22^{de}	91.1^{cdf}
MPT 96 273	1.71^{a}	1.06^{ab}	2.23^{a}	1.92^{a}	218.2^{abcde}	65.0^{fg}	210.73^{abc}	133.43^{ab}
CP 04 1935	0.89^{e}	0.77^{bc}	1.31^{def}	0.97^{cde}	178.0^{ef}	97.7^{bc}	189.35^{bcd}	99.72^{bcdef}
CPCL 02 926	1.41^{bc}	0.57^{c}	1.18^{ef}	0.88^{e}	265.0^{a}	73.5^{ef}	148.67^{cde}	119.15^{abc}
B 52-298	1.29^{cd}	0.72^{bc}	1.77^{bc}	1.34^{b}	241.8^{abc}	96.1^{bc}	222.67^{ab}	138.74^{a}
VMC 96-120	1.42^{bc}	0.92^{abc}	2.12^{ab}	1.24^{bcd}	262.2^{ab}	91.2^{bcd}	260.81^{a}	109.91^{abcde}
VMC 96-89	1.40^{bc}	0.94^{abc}	1.78^{bc}	1.27^{bcd}	219.5^{abcde}	91.3^{bcd}	163.91^{bcde}	76.83^{f}
FG 06-622	1.47^{abc}	0.87^{abc}	1.55^{cde}	1.04^{bcde}	219.2^{abcde}	70.3^{f}	156.53^{cde}	78.71^{df}
CP 00-2180	1.48^{abc}	0.81^{bc}	1.65^{cd}	1.05^{bcde}	188.4^{edf}	51.6^{gh}	138.88^{de}	76.95^{df}
MEX 54/245	1.05^{de}	1.27^{a}	1.44^{cde}	1.30^{bc}	161.6^{f}	108.5^{b}	145.93^{de}	113.73^{abcd}
Mean	1.34	0.88	1.595	1.16	215.74	86.74	171.787	102.1295
LSD	0.274	0.407	0.392	0.3588	52.71	17.279	63.12	36.87
CV	12.21	27.57	14.63	18.43	14.56	11.87	21.89	21.51

Genotypes	Recoverable sugar percent				sugar yield			
	Plant Cane		Rattoon I		Plant Cane		Ratoon I	
	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light
CP 96 1252	10.7^{ab}	12.24^{a}	10.92^{ab}	11.71^{ef}	25.71^{a}	16.5^{a}	13.61^{e}	10.86^{cd}
NCO 334	9.0^{abcd}	8.99^{cd}	10.54^{ab}	12.30^{bcd}	19.0^{abcd}	12.08^{b}	17.47^{cde}	17.70^{a}
MPT 97 203	9.8^{abc}	11.55^{a}	11.60^{a}	12.95^{a}	18.85^{abcd}	8.78^{cde}	19.86^{bcde}	8.99^{d}
VMC 96 61	6.78^{de}	9.62^{cd}	11.29^{ab}	12.04^{cde}	14.15^{cd}	3.43^{g}	19.12^{bcde}	10.39^{d}
FG 04 356	11.19^{a}	12.22^{a}	11.58^{ab}	11.16^{f}	24.13^{ab}	10.78^{bc}	15.77^{de}	10.11^{d}
MPT 96 273	10^{abc}	10.03^{bc}	11.87^{a}	12.40^{abcd}	21.88^{abc}	6.51^{ef}	25.19^{ab}	16.63^{ab}
CP 04 1935	11.18^{a}	12.11^{a}	11.81^{a}	12.46^{abc}	20.1^{abcd}	11.85^{b}	22.54^{abcd}	12.42^{bcd}
CPCL 02 926	10.2^{ab}	11.75^{a}	10.53^{ab}	12.83^{ab}	26.06^{a}	8.66^{cde}	15.63^{de}	15.27^{abc}
B 52-298	10.3^{ab}	10.1^{bc}	11.33^{ab}	12.84^{ab}	24.88^{ab}	9.73^{bcd}	24.99^{abc}	17.78^{a}
VMC 96-120	5.42^{e}	8.82^{cd}	10.88^{ab}	11.28^{f}	14.10^{cd}	8.04^{def}	28.37^{a}	12.32^{bcd}
VMC 96-89	7.39^{cde}	9.66^{cd}	11.23^{ab}	11.97^{cde}	16.19^{bcd}	8.91^{cde}	18.37^{bcde}	9.21^{d}
FG 06-622	8.3^{bcd}	11.88^{a}	10.24^{ab}	11.19^{f}	18.39^{abcd}	8.39^{cde}	16.17^{de}	8.81^{d}
CP 00-2180	9.73^{abc}	11.29^{ab}	11.22^{ab}	11.88^{de}	18.48^{abcd}	5.84^{fg}	15.63^{de}	9.15^{d}
MEX 54/245	6.89^{de}	8.57^{d}	9.91^{b}	11.66^{ef}	12.50^{d}	9.3^{cd}	14.02^{e}	13.33^{abcd}
Mean	9.06	10.63	11.07	12.05	19.6	9.20	19.054	12.36
LSD	2.811	1.4433	1.687	0.567	8.729	2.42	7.594	4.6757
CV	18.47	8.09	9.08	2.80	26.53	15.67	23.75	22.55

MPT 97 203 also gave higher sugar recovery over NCO 334 and MEX 54/245 in Rattoon I under light soils. Significantly higher sugar yield were found in genotypes CP 96 1252 under light soils in plant cane over the three checks and VMC 96 120 under heavy soils in ratoon I over NCO 334 and MEX 54/245 (Table 5).

Plant cane or Rattoon I performances of the genotypes is not enough for to screen the best genotypes over the standard checks. Therefore the average performances for traits studied are presented as follows.

Average Performances for Plant Cane and Rattoon I under Heavy and Light Soils

Highest number of tillers production was recorded in genotypes NCO 334, followed by FG 04-356 and B 52-298 under heavy soils and for the genotypes CPCL 02 926, followed by B 52-298 and NCO 334 under light soils. The lowest tillers production was observed in MPT 97 203 under both soil types. Genotypes NCO 334 and CPCL 02 926 showed significantly highest number of stalks over 8 genotypes including MEX 54-245 under light soils. Genotype CP 04 1935 showed significantly highest number of stalks over all genotypes evaluated except with NCO 334. The lowest number of stalks was observed in MPT 97 203 under both soil types. Significantly highest cane diameters were obtained in genotypes MPT 97 203 and MPT 96 273 under both soil types followed by VMC 96 61. Highest cane lengths were obtained in genotypes MPT 96 273, VMC 96-120, VMC 96-89 and CPCL 02 926 under heavy soils and FG 06-622, NCO 334, MEX 54/245 and VMC 96-89 under light soils while the lowest cane height was recorded in VMC 96 61 under light soils. Highest single stalk weight were obtained in genotypes MPT 97 203 and MPT 96 273 under both soil types and the lowest was from CP 04 1935. Cane yield was highest in genotypes VMC 96-120, B 52-298, MPT 96 273 and CPCL 02 926 under heavy soils and NCO 334, CP 96 1252, B 52-298 and MEX 54/245 under light soils (Table 6).

Table 6 Average Performances of Sugarcane Genotypes under Heavy and Light Soils for Seven Quantitative characters at Metahara

Genotypes	Stalk Count		Cane Diameter		Cane Length		S. Stalk Weight	
	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light
CP 96 1252	468	358	2.53	2.71	2.79	1.88	1.19	1.00
NCO 334	528.7	472.35	2.43	2.5	2.83	2.05	1.16	0.96
MPT 97 203	307.15	199.65	3.1	3.18	2.86	1.69	1.90	1.16
VMC 96 61	401.2	223.2	2.73	2.85	2.49	1.28	1.51	0.85
FG 04 356	449.5	337.5	2.45	2.54	2.75	1.75	1.21	0.85
MPT 96 273	350.8	211.65	2.87	3.08	3.30	1.88	1.97	1.49
CP 04 1935	539.7	364.5	2.31	2.53	2.89	1.85	1.1	0.87
CPCL 02 926	494.85	420.8	2.47	2.27	3.00	1.86	1.30	0.73
B 52-298	490.35	372.5	2.66	2.78	2.96	1.90	1.53	1.03
VMC 96-120	482.85	304.3	2.76	2.81	3.15	1.87	1.77	1.08
VMC 96-89	385.85	244.15	2.68	2.76	3.07	2.00	1.59	1.11
FG 06-622	389.00	252.2	2.65	2.71	2.95	2.09	1.51	0.96
CP 00-2180	332.30	218.5	2.76	2.83	2.62	1.48	1.57	0.93
MEX 54/245	392.00	293.0	2.63	2.67	2.68	2.01	1.25	1.29
Mean	429.44	305.17	2.64	2.73	2.88	1.83	1.47	1.02
LSD	34.70	96.23	0.31	0.25	0.45	0.51	0.45	0.37
CV	10.75	13.03	7.66	3.87	11.37	9.83	13.74	22.41

Table 6 continued

Genotypes	Cane Yield		Sugar Recovery		Sugar Yield	
	Heavy	Light	Heavy	Light	Heavy	Light
CP 96 1252	182.25	113.69	10.81	11.98	19.66	13.68
NCO 334	190.19	138.91	9.77	10.65	18.24	14.89
MPT 97 203	180.24	72.63	10.70	12.25	19.36	8.89
VMC 96 61	189.64	60.80	9.04	10.83	16.64	6.91
FG 04 356	174.76	89.75	11.39	11.69	19.95	10.45
MPT 96 273	214.47	99.22	10.94	11.22	23.54	11.57
CP 04 1935	183.68	98.71	11.50	12.29	21.32	12.14
CPCL 02 926	206.84	96.33	10.37	12.29	20.85	11.97
B 52-298	232.24	117.42	10.82	11.47	24.94	13.76
VMC 96-120	261.51	100.56	8.15	10.05	21.24	10.18
VMC 96-89	191.71	84.07	9.31	10.82	17.28	9.06
FG 06-622	187.87	74.51	9.27	11.54	17.28	8.60
CP 00-2180	163.64	64.28	10.48	11.59	17.06	7.50
MEX 54/245	153.77	111.12	8.40	10.12	13.26	11.32
Mean	193.76	94.43	19.33	11.34	10.07	10.78
LSD	60.36	44.34	2.25	2.49	10.29	6.43
CV	17.88	18.17	25.22	5.76	13.72	20.58

Highest recoverable sucrose per cent was obtained in genotypes CP 04 1935 and FG 04 356 under heavy soils and CPCL 02 926, B 52-298 and MPT 97 203 under light soils. The highest sugar yield were obtained in genotypes B 52-298, MPT 96 273, CP 04 1935 and VMC 96-120 under heavy soils and NCO 334, B 52-298 and CP 96 1252 under light soils (Table 6).

The highest expression of all traits except juice quality traits was observed under heavy soils, while the highest sugar purity, pol and recovery percent was observed under Light soils. On the contrary; the highest sugar yield was observed under heavy and the lowest at light soil types. These were because of highest cane yield and its related components for the genotypes grown under heavy soils than light soil types. The lowest sugar recovery percent under heavy than Light soil types might be due to the higher residual soil moisture under heavy soil type. Although water initiates plant growth and development, it affects negatively the quality of the plant products especially when the yield is a chemical constituent such as sugar recovery, pol percent, etc. (Ramulu, 1998).

Correlations under Heavy and Light Soils

Under heavy soils number of millable stalks was significantly and negatively correlated with stalks diameter (r=-0.82***) and with single stalk weight (-0.67**) and positive correlation between cane diameter and single stalk weight (0.91***) which indicated that thicker genotypes had lower number of millable stalks. There were also significant and positive correlation of stalk length with cane yield (0.67**) which means longer genotypes tend to produce higher cane yield. Sugar yield were significantly correlated with stalk length (0.62*), cane yield (0.69**) and sugar recovery (0.57*). Under light soils, number of millable stalks was significantly and negatively correlated with stalks diameter and single stalk weight. Cane diameters were highly correlated with single stalk weight. Cane yield were mainly affected by cane length and sugar yield were by cane length, cane yield and sugar recovery (Table 7).

Table 7 Pearson correlation coefficients for genotypes grown under heavy (above diagonal) and light (below diagonal) soil type at Metahara

Quantitative Characters	Stalk Count	Cane Diameter	Cane Length	Single Stalk weight	Cane Yield	Sugar Recovery	Sugar Yield
Stalk Count		-0.82***	0.09	-0.67**	0.35	0.11	0.36
Cane Diameter	-0.8***		0.15	0.91***	0.14	-0.2	-0.009
Cane Length	0.43	-0.3		0.47	0.67**	0.05	0.62*
Single Stalk weight	-0.46	0.67**	0.3		0.43	-0.16	0.25
Cane Yield	0.78**	-0.39	0.65*	0.17		-0.18	0.69**
Sugar Recovery	0.09	-0.11	-0.16	-0.4	-0.23		0.57*
Sugar Yield	0.82**	-0.42	0.59*	0.06	0.95***	0.07	

The correlations between cane yield and its components (number of tillers and millable stalks, and plant height) were positive in all soil types except with cane diameter under light soils where this correlation was negative but statistically non-significant (r = -0.39). Under heavy soils the only significant correlation was that with plant height. Genotypes with many tillers and many long millable stalks produce high cane yield; the relationships being stronger under light soils. The correlation between sucrose recovery and sugar yield was positive under all soil types but significant only in heavy soils (r = 0.57*** and 0.07 respectively). However the correlation between cane yield and sugar yield was statistically significant under both soils (r = 0.69* and 0.95*** respectively). Sugar recovery is more important in determining sugar yield under heavy soils. Under light soils sugar yield is determined mainly by cane yield. There was almost zero correlation between cane yield and sucrose recovery (r =-0.1 in all soils) indicating the possibility of simultaneous improvement of both traits.

The genotypes with highest in number of millable stalk, plant height and stalk diameter produced higher cane yields across all soil types, while the genotypes with the lowest in number of millable stalks, resulted in low cane yield. The higher plant height and stalk diameter in some genotypes were insufficient for a remarkable cane and sugar yield. Thus, highest number of millable stalks, plant height and stalk diameter could be selection criteria for highest cane and sugar yield (tons/ha). Rehman *et al*. 1992 and Khan *et al*. (2003) reported that increase in cane yield might be due to maximum plant height and cane diameter. Similarly, Javed *et al.* (2001) reported that cane yield tons per hectare depends upon number of stalks per hectare and weight per stalk. The cane weight per stalk, consequently, depends upon stalk length and stalk girth. Habib, *et al.* (1991) stated that number of millable stalks per plot and stalk diameter are most important components of cane yield. Sharma and Agarwal (1985) suggested that good numbers of millable canes of average thickness are desired selection parameters to evaluate the agronomic performance of sugarcane varieties. Similarly, Khan *et al.* (2007) and Feyissa and Zinaw (2014) demonstrated that number of millable stalks, plant height, cane yield and recoverable sugar percent possessed highly positive correlation with sugar yield. Therefore, more emphasis should be given on number of tillers, millable cane, cane height, cane yield, recoverable sugar percent and those traits positively correlated with them, by compromising for traits negatively correlated with them during phenotypic selection for developing high sugar yielding genotypes of sugarcane.

Genetic and Phenotypic Variability and Heritability under Heavy and Light Soils at Metahara

In both soils the genotypic variance were higher than the corresponding environmental variance for number of millable stalks, single stalk weight, cane diameter and cane yield signifying the existence of sufficient genetic variability among the studied genotypes for these traits. The genotypic variance were however lower than environmental variance for number of tillers, cane length, recoverable sugar percent and sugar yield under heavy soils indicating a low genetic diversity and a greater influence of the environment on the phenotypic performance of these traits (Table 8).

The relatively smaller difference between PCV and GCV for the traits stalk diameter and number of millable stalks in both soils indicates a high contribution of genotypic factor to the phenotypic performance and a low influence of the environment on these traits, suggesting higher gains from selection for these characters, while the relatively large difference between PVC and GVC for single stalk weight, cane and sugar yield suggests a high influence of the environment on their expression. As stated by Shivasubramanian and Menon (1973) the PCV and GCV values are ranked as low, medium and high with 0 to 10%, 10 to 20% and > 20% respectively. Accordingly, high GCV were recorded for number of millable stalks and single stalk weight; medium GCV for cane diameter in both soil types. The higher PCV and GCV values for number of millable stalks and single stalk weight indicates that selection may be effective based on these characters and their phenotypic expression would be good indication of the genotypic potential (Singh *et al.*, 1994) (Table 8).

Table 8 Variability and Heritability for 14 Sugarcane Genotypes under Heavy and Light soils

Variability	Mean	$\sigma^2 g$	$\sigma^2 E$	$\sigma^2 p$	PCV	GVC	$H^2 b$	GAM
Heavy soils								
Tillers	750.00	3278.00	12066.00	15344.00	16.52	7.63	0.21	7.27
Stalk Count	429.00	10214.67	2133.00	12347.67	25.90	23.56	0.83	44.14
Single Stalk Weight	1.47	0.14	0.04	0.18	28.86	25.45	0.78	46.48
Cane Diameter	2.64	0.07	0.04	0.11	12.56	10.02	0.64	16.47
Length	2.88	0.05	0.11	0.16	13.89	7.76	0.33	9.34
Cane Yield	193.76	1141.75	1200.40	2342.15	24.98	17.44	0.49	25.08
Sugar Recovery	10.07	1.69	1.91	3.60	18.84	12.91	0.47	18.24
Sugar Yield	19.33	10.28	23.76	34.04	30.18	16.59	0.30	18.78
Light soils								
Tillers	613.00	39028.67	7251.00	46279.67	35.09	32.23	0.84	60.97
Stalk Count	305.00	13934.67	1581.00	15515.67	40.84	38.70	0.90	75.56
Single Stalk Weight	1.02	0.06	0.05	0.11	32.52	24.01	0.54	35.98
Cane Diameter	2.73	0.11	0.01	0.12	12.69	12.15	0.91	23.90
Length	1.83	0.09	0.03	0.12	18.93	16.39	0.73	28.57
Cane Yield	94.43	868.24	294.32	1162.56	36.11	31.20	0.75	55.55
Sugar Recovery	11.34	1.01	0.43	1.44	10.58	8.86	0.70	15.27
Sugar Yield	10.78	10.03	4.92	14.95	35.87	29.38	0.67	49.57

Heritability values are categorized as low (0-30%), moderate (30-60%) and high (60% and above) as stated by Robinson *et al.*, (1949). Accordingly high heritability estimates were obtained for the trait number of millable stalks and cane diameter indicates a greater contribution of the genotype to the trait expression. Estimated heritability of cane length, cane yield, recoverable sucrose and sugar yield were medium while, it is low for number of tillers under heavy soils while they were higher under light soils. Thus simple selection for the traits with high heritability would be effective method of sugarcane variety breeding program as they are highly heritable from parents to progenies, and therefore, selection can be done to improve those traits (for higher gains from selection). However, selections might be considerably difficult for a character with low heritability (less than 0.4) due to the masking effect of environment on genotype effects (Singh, 1993) (Table 8).

According to Johnson *et al.* (1955), genetic advance as percent of mean (GAM) was categorized as high (>20%), moderate (10-20%) and low (0-10). Accordingly, high GAM was obtained for number of millable stalks, single stalk weight, and cane yield in both soils. GAM was moderate for cane diameter, recoverable sugar percent and sugar yield under heavy soils while only recoverable sugar percent was low under light soils (Table 8).

Conclusion

The Thailand genotypes MPT …. Series showed lowest number of tillers and millable stalks but highest in cane diameter, length and single stalk weight under both soil types. Significantly highest cane diameters were obtained in genotypes MPT 97 203 and MPT 96 273 under both soil types. Cane yield was highest in genotypes VMC 96-120, B 52-298, MPT 96 273 and CPCL 02 926 under heavy soils and NCO 334, CP 96 1252, B 52-298 and MEX 54/245 under light soils. Highest recoverable sucrose per cent was obtained in genotypes CP 04 1935 and FG 04 356 under heavy soils and CPCL 02 926, B 52-298 and MPT 97 203 under light soils.

The highest sugar yield were obtained in genotypes **B 52-298, MPT 96 273, CP 04 1935** and **VMC 96-120** under heavy soils and **NCO 334, B 52-298**, **CP 96 1252** and **CPCL02 926** under light soils.

Sugar recovery is more important in determining sugar yield under heavy soils. Under light soils sugar yield is determined mainly by cane yield. There was almost zero correlation between cane yield and sucrose recovery in all soils indicating the possibility of simultaneous improvement of both traits. The higher genotypic variances, heritability and smaller differences between PCV and GCV for stalk diameter and number of millable stalks signifying the existence of sufficient genetic variability and their phenotypic expression would be good indication of the genotypic potential.

Therefore, MPT 96-273, CP 04-1935 and VMC 96-120 under heavy soils, CP 96 1252 and CPCL02 926 under light soil types of Metahara Sugar Estate, were found promising genotypes in plant cane and Ratoon I for sugar yield. Thus, these selected genotypes had been recommended for further verification on large commercial fields under their best performing soil types of Metahara Sugar Estate.

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