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Performance evaluation of locally collected and advanced sugarcane (*Saccharum officinarum* L.) genotypes for their yield performance and juice quality under different salinity levels at Metahara Sugar Estate, Ethiopia

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Abstract

Ten locally collected sugarcane (*Saccharum officinarum* L.) genotypes and two checks (NCO 334 and B52-298) were evaluated for their yield and juice quality under three different salinity levels (1.3, 4.4, and 6.5dsm^{-1}) using Randomized complete block design with three replications in 2014/2016 at Metahara Sugar Estate. The experiment was conducted to determine yield performance and juice quality of the genotypes, to estimate the magnitude and nature of the GxS interaction of cane yield and yield components and to identify promising genotypes for specific and wider adaptation across salinity levels. The analyses of variance showed that there was significant difference among the genotypes under 1.3ds/m, 4.4ds/m and 6.5ds/m salinity levels for most of the traits indicating the presence of ample genotypic variation among the studied genotypes. The genotype by salinity interaction was also significant for most of the traits showing the inconsistency of performance of genotypes expressed as rank change over salinity levels. Five stability parameters identified the two checks (NCO 334 and B52-298) followed by Holland as the most stable genotypes for sugar yield. GGE-biplot identified genotype Nech Ageda as specifically adapted to non-saline soils (1.3 ds/m) while Moris was specifically adapted to saline soils (4.4 to 6.5 ds/m). Therefore, NCO 334, B52-298 and Holland can be recommended for wider adaptation, for further study of ratoon crops and then for verification on larger commercial plots.

Keywords: Juice quality, Salinity, Genotype x Salinity interaction, GGE bi-plots

Introduction

Modern cultivated sugarcane (Saccharum officinarum L.) is a complex inter specific hybrid of five different species of Saccharum genus. Sugarcane belongs to the Poaceae family and is normally propagated by stem cuttings (Khan *et al*., 2013). 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).

Commercial production of sugar in Ethiopia has started in 1954 owned by the Dutch company called Handels-Vereening Amsterdam (HVA) in Wonji. The company has begun the development of plantation on 5,000 ha. Later in 1962, the company constructed the second sugar factory in Wonji Shoa with the cane plantation of 2000 ha. Other sugarcane plantations were established at Metahara (> 10,000 ha) in 1969 and Finchaa (> 8000 ha) in 1998 (Abera and Tesfaye, 2001).

The rapid increase in salinization of the soil has been a threat causing great reduction in plant growth by hampering various physiological phenomena of the plant (Maas, 1986). Plant tolerance to salinity is usually appraised as the absolute/relative growth or yield of a crop in saline conditions (Wahid et al., 1997). This depiction is also a useful criterion for expression of the extent of salt tolerance in plants (Maas and Hoffman, 1977). Soils with electrical conductivity (EC) less than 1.7 dSm^{-1} do not induce yield reduction in sugarcane. In other words, the soils with EC greater than $5dSm^{-1}$ result in a significantly reduced yield of this crop (Mass, 1986). The saline soils are wide spread in sugarcane growing areas of the world, which are also reported in most sugarcane producing parts of Ethiopia (Maas, 1986).

Poor irrigation and drainage management are normally the main causes of salinization and, as the water table rises, salts dissolved in the ground water reach the soil surface by capillary movement. The accumulated neutral soluble salts impede soil fertility (Sarig and Steinberger, 1994) and plant growth as the ions hinder water uptake may also be phototoxic (Zaharan, 1997). The control of salinity is mainly a matter of controlling water movement (Vander Meden, 1996), devising optimum irrigation strategies that will help improve water use efficiency, reduce deep drainage and runoff minimize salinity risks (Ali *et al*., 2000).

Lowering the water table below two meters by artificial drainage and regular leaching every three months to flush the excess salts from the soil surface in to the drainage is one of the strategies of rehabilitating saline soils. But these methods are very expensive and require a long period of time (Ali *et al*., 2000).

Breeding crops for salt tolerance would likely provide economic benefit in overcoming problems of saline soils. Such a crop improvement and selection program must be based on adequate variability for salinity tolerance and such variation has been observed within sugarcane (Vasantha *eta l*., 2009). Genotype by Environment interaction (GXE) interaction plays a major role in evaluation of genotypes under different environments (Salinity stresses) (Munns and James, 2003). To recommend suitable genotypes to be released as variety, yield trials are conducted with a set of genotypes at different salinity stress environments which is always affected by GXE interaction (Zobel, 1988). Effect of soil salinity has been studied by different workers on sugarcane (Rizk and Normand, 1969; Syed and Swaify, 1973).

Some areas of the Ethiopian sugar estates have salt affected soils specifically Metahara, Tendaho and Kessem as reported in Booker Tate (2009). As reported by Booker Tate (2009), over 250 fields are affected by patchy cane growth, where spots of dead or stunted cane occur at Metahara sugarcane plantations specifically the North, Abadir, and East sections. At Metahara sugar factory, salinity is the major production problem due to flow out of Besseka Lake and inefficient irrigation. It is displacing many hectares of cane plantation (makes out of production). It is estimated that about 23% (2354.05 hectares) of the total area (10,235 ha) of the plantation is affected by salinity (Mebrathom *et al.*, 2014). Breeding of sugarcane for salt tolerance through hybridization is difficult whereas selection of tolerant genotypes may help in sustaining the cane yield and juice quality under such situations (Rozeff, 1995).
Keeping in view the importance of varietal aspect in sugarcane, the present study was conducted to evaluate the yield performances and juice quality of advanced sugarcane genotypes collected from different parts of Ethiopia along standard varieties under different salinity levels at Metahara Sugar Estate.

Materials and Methods

Description of Study area

The experiment was carried out from November 2014 to February2016 at Metahara sugar estate. It is at situated 8^0 21’ to 8 ^{0}29$^{'}$ N and 39 ^{0}18^0 E with an altitude of 1500 meters above sea level. The average rainfall is 543mm. the mean annual maximum and minimum temperature are 32.8^0 C and 17.5^0C respectively. The annual mean rainfall of this area is about 550mm/annum, and the mean maximum and minimum relative humidity is 88 and 37.7%, respectively (Ambachew, 2005). The clay soil cover more than 90% of the estate and it is grouped into four distinct textural groups as heavy clay, clay, clay over loamy and loamy soil (Tate, 2009).

Experimental Materials and Design

Ten locally collected sugarcane genotypes (Nech Ageda, Kay Ageda1, Andegna Dereje Canada Shenkora, Engda, Moris, Holland, Yemilat Nech

Shenkora, Kay Ageda 2, Nech Shenkora and Kay Ageda/Shenkora) were evaluated along with standard checks NCO 334 and B52-298 under three salinity levels of the sugar estate. These advanced genotypes were found to be the best performing genotypes among the locally collected and characterized genotypes.

Experiment was laid out in randomized complete block design with three replication on three different sites situated far away from each other within the plantation and selected based on three salinity levels 1.3, 4.4 and 6.5 dSm^{-1}. Each experimental plot had six rows with 6 meters length and 1.45 meter width (52.2 m^2). The distance between adjacent plots and replications was 2.0 and 3.0 meters, respectively. The genotypes were planted in October 2014 and were grown using furrow irrigation. All agronomic practices were kept normal for the three salinity levels.

Prior to planting, soil samples were collected from the experimental fields. The soil samples were analyzed for salinity in dSm^{-1}, exchangeable sodium percentage and pH.

Data Collected and analysis

Data were collected from the four central rows for sprouting percentage, number of tillers, stalk count, stalk length (m), stalk diameter (cm), single stalk weight (kg), cane yield(ton/ha),brix% juice, pol%, recoverable sugar percent and sugar yield.

The data collected data was subjected to the analysis of variance (ANOVA) of the Randomized Complete Block Design (RCBD) using the GLM procedure of SAS (statistical analysis system) version 9.0 (SAS, 2002). Comparison of treatment means was performed using the Least Significant Difference (LSD) at 5% probability.

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 salinity levels.

Two approaches were used: Separate ANOVA of data from each Salinity level; combined analysis of variance for data across the three salinity levels.

After testing the significance of the GxE interaction in the combined ANOVA, stability analysis was conducted for sugar yield using means of genotypes under each salinity level. The following methods were used for stability analysis.

Wricke's Ecovalence (Wi**):** This stability statistics measures the contribution of a genotype to the interaction sum of square (Wricke, 1962). The ecovalence (W_i) of an i^{th} genotype is its interaction with the environments, squared and summed across environments, and express as

$$W_i = \sum_j (Y_{ij} - \bar{Y}_{i.} - \bar{Y}_j + \bar{Y}_{...})^2$$

Where Y_{ij} is the mean performance of genotype i in the j^{th} environment and $\bar{Y}_i$ and $\bar{Y}_j$ are the genotype and environment mean deviation respectively, and $\bar{Y}.$ is the overall mean. For this reason genotypes with a low *Wi* have a smaller deviation from the overall mean across environment and are thus more stable.

Coefficient of Variability (CV_i): Use of Coefficient of variation as a stability parameter was proposed by Francis and Kannenberg (1978). The parameter was estimated as:

$$CV_i = \frac{SD_x}{x} \times 100$$

Where, SD_X is standard deviation of the means of a genotype over environments and X is the mean of the genotype over all environments.

According to CV_i, stable genotypes are the ones which have consistently lower CV with higher yield.

Genotypic Superiority Index (Pi): Linn and Binns (1988) defined the superiority measure (pi) of the i^{th} test cultivar as the mean square of the distance of the i^{th} test cultivar and the maximum response as:

$$P_i = [n (Yi - M...)^2 + (\sum_{j=1}^{n} (Yij - Y_{i.} - M_{j.} + M...)^2] / 2n$$

Where, Y_{ij} is the average response of the i^{th} genotype in j^{th} environment. Y_i is the mean deviation of the genotype i, M_j is the genotype with maximum response among all genotypes in j^{th} locations and n is the number of locations. The first term of the equation represents the genotype sum of squares and the second part represents the sum of squares for the genotype by environment interaction when two genotypes are compared. The smaller the value of pi, the less is the distance to the genotype with maximum yield and the better the genotype.

Results

Table 1 Results of soil salinity and sodicity parameters sampled during planting at Metahara Sugar Estate

Salinity level*	pH	Ece (dsm^{-1})	SAR	ESP	Exchangeable cations (cmol(+) kg-1				
					Na^+	K^+	Ca^{++}	Mg^{++}	CEC (meq/100)
A	7.9	1.3	1.2	13	5.2	1.5	31	2.5	40.2
B	7.4	4.4	1.25	13	5.55	2	32.5	2.6	42.65
C	7.1	6.5	1.3	12	5.85	4.8	34	4.1	48.75

*Ece= Electrical Conductivity of saturated paste extracts; SAR = Sodium absorption ratio; ESP= Exchangeable sodium percentage. CEC (meq100) = Cation exchange capacity, A= 1.3ds/m, B=4.4ds/m, C= 6.5ds/m.

Analysis of Variances

There were highly significant differences ($p\leq 0.001$) between genotypes at each of the salinity levels (1.3, 4.4 and 6.5ds/m) for all of the agronomic traits and juice quality traits considered in this experiment under all salinity levels except for brix% under 1.3ds/m and purity % which show no significant difference between genotypes for salinity level 1.3ds/m and 4.4ds/m This was similar with results obtained by Mebrathom *et al*. (2014) where the genotypes were very diverse; significant differences were observed in all agronomic traits at three salinity levels (1.6, 4.4 and 6.4ds/m).

Table 2 ANOVA of agronomic and juice quality traits across salinity levels at Metahara

	Source of variation	DF	1.3ds/m	4.4ds/m	6.5ds/m
Germination %	Replication	2	37	17.07	4.07
	Genotype	11	195***	84.23***	107.38***
	Error	22	15	10.88	5.65
	CV		5.04	5.28	4.40
No. Tillers	Replication	2	1051612	84180	149496
	Genotype	11	2529631***	3727571***	3607412***
	Error	22	1077450	362094	632443
	CV		14.32	12.38	19.75
Millable cane	Replication	2	9294	2392	4745
	Genotype	11	1429393***	1379916***	1167031***
	Error	22	43445	23164	8149
	CV		9.04	7.57	5.24
Plant height	Replication	2	0.0003	0.01	0.004
	Genotype	11	0.36***	0.14***	0.03***
	Error	22	0.01	0.01	0.01
	CV		4.31	4.90	4.37
Stalk diameter	Replication	2	0.01	0.05	0.004
	Genotype	11	0.18*	0.194***	0.21***
	Error	22	0.07	0.01	0.01
	CV		8.53	4.28	2.59
Stalk Weight	Replication	2	0.02	0.01	0.005
	Genotype	11	0.51***	0.23***	0.15***
	Error	22	0.01	0.007	0.01
	CV		5.68	4.92	10.54
Cane yield	Replication	2	761.15	138.09	21.60
	Genotype	11	2530.68***	3290.90***	1576.89***
	Error	22	137.19	155.87	46.15
	CV		7.73	11.57	9.58

Brix %	Replication	2	3.3	1.49	1.41
	Genotype	11	1.30^{ns}	2.00*	3.65*
	Error	22	1.10	0.71	1.16
	CV		5.03	4.99	7.28
pol%	Replication	2	1.59	1.05	0.25
	Genotype	11	3.56*	3.44**	3.17**
	Error	22	1.36	1.02	0.79
	CV		6.30	6.83	7.51
Purity %	Replication	2	1.36	3.61	20.90
	Genotype	11	24.17^{ns}	21.07^{ns}	34.04*
	Error	22	13.12	14.32	14.16
	CV		3.98	4.40	4.72
Recoverable Sugar recovery	Replication	2	0.51	0.53	0.02
	Genotype	11	3.97**	2.78**	2.16*
	Error	22	1.03	0.82	0.70
	CV		7.93	9.02	11.14
Sugar yield	Replication	2	6.44	0.28	0.18
	Genotype	11	48.62***	32.39***	14.16***
	Error	22	2.97	1.93	0.57
	CV		8.89	12.83	14.10

Where ns = non-significant,*, **, *** significant at 0.05, 0.01, 0.001 Probability level respectively.

Germination %

Germination % is the most essential physiological phase in the life cycle of a plant as without germination there is no plant. The ANOVA results (Table 2) depicted highly significant differences (p<0.01) among the 12 genotypes for germination % under each salinity levels. These results confirm the diversity among the genotypes. The highest germination percentage under 1.3ds/m salinity level was observed for the genotypes Moris (96.88 %) followed by Key Ageda1 (86.18 %), and Andegna Dereja Canada Shenkora (81.12 %) and the lowest germination percentage (67.7%) under this salinity level was recorded for Kay Ageda2 (Table 3). These results are in good agreement with findings of Nadeem et al., (2011). They reported significant differences for germination % among 16 sugarcane clones. For salinity level 4.4ds/m genotypes Holland (73.97%) had the highest germination percentage followed by Andegna Dereja Canada Shenkora (67.13 %) and Engda (66.50%).While the lowest germination percentage was observed for genotype Nech Ageda (55.41%). Whereas, under 6.5ds/m salinity level, the highest germination percentages were observed in Holland (64.99%) and Yemilat Nech Shenkora (60.48%) respectively where as minimum (32.17 %) was exhibited and by genotype Nech Shenkora (42.65%).

The result shows that as the salinity level increases from 1.3ds/m to 4.4ds/m and to 6.5ds/m, the germination percent of the genotypes also reduces accordingly as the salinity level increases. The reduction in germination percentage with increase in salinity level was observed in all genotypes. This result agrees with the work of Faraj *et al.* (2011) who also observed the reduction in germination percentage with increase in salinity levels (0, 3, 9 and 12ds/m).
Variability in percentage germination of sugarcane genotypes as a result of increased salinity has also been reported by Smith *et al*. (2004) and Muhammad *et al*. (2012) who found that at lower salinity levels (0 to 2 ds/m) the effect of salinity did not have large impact on germination percentage but increase in salinity to higher level had negative effect. In our investigation under 1.3ds/m salinity level all genotypes, except two (KayAgeda2 and Kay Ageda/Shenkora), showed germination percentage above 70%, under 4.4ds/m salinity level all genotypes except Nech Ageda, Kay Ageda1, and Kay Ageda2 and the check NCO 334 had germination percentage above 60%, while under 6.5ds/m salinity level only one genotype Holland had germination percent above 60%.

Number of tillers in thousands hectare^{-1}

Number of tillers is playing a pivotal role in enhancing the final yield of sugarcane. Highly significant differences (p<0.01) were recorded for number of tillers among the genotypes used in this study under each salinity levels (Table 2). Maximum numbers of tillers (378) were attained by genotype Moris (435.6) followed by Kay ageda1 (336.5); an increase in number of tiller in thousand/ha 202.3 and 232.5; 103.7 and 134 over the checks NCO 334 and B52-298, respectively (Table 3).whereas minimum numbers of tillers (124.5) were recorded for genotype Holland.

Under 4.4ds/m salinity level, the highest tiller number was obtained for genotype Nech Shenkora (211.1) followed by the checks NCO 334 (200.4) and B52-298 (193.9) respectively. On the other hand under 6.5ds/m salinity level due to less adaptability to the environment for this specific attribute all the genotypes could not exceed performance to checks NCO 334 (188.5) and B52-298 (184.6) (Table 3).

Table 1 Germination percent and tillering performances of genotypes across three salinity levels at Metahara

		Germination (%)			Tillers (thousands/ha)		
	Genotypes	1.3ds/m	4.4ds/m	6.5ds/m	1.3ds/m	4.4ds/m	6.5ds/m
1.	Nech Ageda	75.30[cde]	55.41[f]	46.80[g]	152.6[fgh]	173.8[bc]	143.8[bc]
2.	Kay Ageda1	86.18[b]	58.69[cdef]	55.77[cde]	336.5[b]	146.8[cd]	133.2[cd]
3.	Andegna Dereja Canada Shenkora	81.12[bc]	67.13[b]	56.08[cd]	293.8[bc]	145.1[cd]	111.0[cde]
4.	Engda	75.00[cde]	66.50[b]	56.91[bc]	230.6[de]	103.7[e]	94.2[de]
5.	Moris	96.88[a]	62.08[bcde]	54.87[cde]	435.6[a]	111.5[e]	107.8[cde]
6.	Holland	76.71[cd]	73.97[a]	64.99[a]	124.5[h]	123.5[de]	105.6[cde]
7.	Yemilat Nech Shenkora	72.18[def]	64.38[b]	60.48[b]	138.4[gh]	125.6[de]	112.8[cde]
8.	Kay Ageda2	67.70[f]	56.50[ef]	51.83[ef]	181.4[efg]	159.7[c]	142.9[bc]
9.	Nech Shenkora	75.31[cde]	62.18[bcd]	42.65[h]	261.9[cd]	211.1[a]	70.4[e]
10.	Kay Ageda/Shenkora	69.02[ef]	61.85[bcde]	49.21[fg]	158.0[fgh]	148.2[cd]	133.1[cd]
11.	B52-298	70.80[def]	63.27[bc]	55.58[cde]	202.5[ef]	193.9[ab]	184.6[ab]
12.	NCO 334	76.61[cd]	56.63[def]	52.15[def]	232.8[de]	200.4[ab]	188.1[a]
	Mean	76.90	62.38	53.94	229.0	153.6	127.3
	LSD	6.56	5.58	4.02	55.5	32.2	42.58
	CV	5.04	5.28	4.40	14.32	12.38	19.75

Number of millable canes

The magnitude of final cane yield is mainly determined by the millable cane count and it has a direct effect on cane yield. Highly significant differences (p<0.01) for number of millable canes were exhibited by the genotypes used in this study under each salinity levels (Table 2). Nech Ageda (109.4) followed by the check NCO 334 (108) had the highest number of millable stalks, while Kay Ageda/Shenkora (43.1) had the lowest number of millable stalks in thousand ha^{-1} under 1.3ds/m salinity level. Whereas highest number of millable canes under 4.4 and 6.5ds/m salinity levels were exhibited by the check NCO 334 (107.9) and (97.3) respectively. These results are in agreement with the findings of Wiegand *et al.* (1996) who found out that that as the Salinity level increases, millable stalk number, stalk length, and stalk weight decrease (Table 4).

Plant height (m)

Plant height is one of important parameters, influencing directly the final cane yield. Plant height data showed highly significant differences (p<0.01) (Table 2) among the genotypes under each salinity levels, the highest plant height 2.69m, 2.28m, and 1.67m being exhibited by the genotype Holland under 1.3, 4.4, and 6.5ds/m salinity levels respectively where as genotype Engida was the most retarded growth under 6.5ds/m salinity level (Table 4). Difference in plant height among genotypes grown under different same salinity level was observed. This could be happened due to the genetic makeup of the genotypes. The finding of this study is similar with Similarly, Arin *et al*. (2011), Khan *et al.* (2007), Feyissa *et al.* (2014) and Abiy *et al*. (2015) who reported significance differences in cane height among sugarcane genotypes

Table 4 Millable cane and Plant height performances of genotypes across three salinity levels at Metahara

		Millable Stalk Number (thousand/ha)			Plant height(m)		
	Genotypes	1.3ds/m	4.4ds/m	6.5ds/m	1.3ds/m	4.4ds/m	6.5ds/m
1.	Nech Ageda	109.4[a]	51.1[de]	44.9[e]	1.68[d]	1.52[gh]	1.39[de]
2.	Kay Ageda1	73.5[cd]	71.3[c]	56.3[d]	2.62[a]	1.90[bc]	1.45[cd]
3.	Andegna Dereja Canada Shenkora	66.4[de]	44.6[ef]	34.1[f]	2.38[b]	1.84[bcd]	1.52[bc]
4.	Engda	48.4[f]	44.6[ef]	35.4[f]	1.92[c]	1.47[h]	1.32[e]
5.	Moris	94.1[b]	93.1[b]	78.5[b]	2.43[b]	1.91[a]	1.53[bc]
6.	Holland	71.3[de]	70.4[c]	57.6[d]	2.69[a]	2.28[a]	1.67[a]
7.	Yemilat Nech Shenkora	45.9[f]	38.9[f]	36.6[f]	1.81[cd]	1.54[fgh]	1.36[de]
8.	Kay Ageda2	82.8[bc]	67.1[c]	65.4[c]	2.39[b]	1.69[de]	1.58[ab]
9.	Nech Shenkora	88.5[b]	57.0[d]	47.8[e]	2.37[b]	1.69[def]	1.40[de]
10.	Kay Ageda/Shenkora	43.1[f]	42.0[f]	34.5[f]	2.33[b]	1.72[de]	1.39[de]
11.	B52-298	76.5[cd]	73.6[c]	64.4[c]	1.90[c]	1.75[cde]	1.53[bc]
12.	NCO 334	108.0[a]	107.9[a]	97.3[a]	1.80[cd]	1.61[efgh]	1.45[cd]
	Mean	72.8	63.5	54.4	2.19	1.74	1.47
	LSD	11.11	8.14	4.8	0.16	0.14	0.10
	CV	9.04	7.57	5.24	4.31	4.90	4.37

Stalk diameter (cm)

Highly significant differences (p<0.01) for stalk diameter were exhibited by the genotypes used in this study across each salinity levels (Table 2). Under 1.3ds/m salinity level , the highest stalk diameter (girth) was found in Andegna Dereja Canada Shenkora (3.49cm), Engda (3.38cm), Holland (3.24cm), Kay Ageda/Shenkora (3.35cm) and Kay Ageda1 (3.22cm), respectively. These genotypes also manifested the highest stalk thickness under 4.4ds/m and 6.5ds/m salinity levels. The checks had the lowest stalk diameter under all salinity levels. Those genotypes which manifested higher stalk diameter were shortest in plant height relatively among the other genotypes. This agrees with the finding of Rafiq *et al.* (2006) who reported significant differences among genotypes in canethickness.

Table 2 Stalk diameter and stalk weight performances of genotypes across three salinity levels at Metahara

		Stalk diameter(cm)			Stalk weight (Kg)		
	Genotypes	1.3ds/m	4.4ds/m	6.5ds/m	1.3ds/m	4.4ds/m	6.5ds/m
1.	Nech Ageda	3.03^{bcd}	2.92^{cd}	2.78^{cd}	1.63^{f}	1.51^{d}	1.42^{bcd}
2.	Kay Ageda1	3.22^{abc}	3.05^{abc}	2.95^{abc}	2.34^{cd}	1.95^{b}	1.46^{bc}
3.	Andegna Dereja Canada Shenkora	3.49^{a}	3.23^{ab}	3.00^{bc}	2.38^{cd}	2.17^{a}	1.75^{a}
4.	Engda	3.38^{ab}	3.18^{ab}	3.01^{bc}	1.9^{e}	1.50^{d}	1.09^{ef}
5.	Moris	3.19^{abc}	3.01^{c}	2.96^{abc}	2.72^{a}	1.52^{d}	1.50^{b}
6.	Holland	3.35^{ab}	3.23^{a}	3.17^{a}	2.52^{abc}	2.23^{a}	1.47^{b}
7.	Yemilat Nech Shenkora	2.83^{cd}	2.64^{ef}	2.54^{e}	2.62^{ab}	1.79^{c}	1.23^{cde}
8.	Kay Ageda2	3.17^{abc}	3.12^{abc}	2.88^{c}	1.93^{e}	1.72^{c}	1.20^{edf}
9.	Nech Shenkora	2.95^{bcd}	2.78^{de}	2.6^{de}	1.62^{f}	1.51^{d}	1.48^{b}
10.	Kay Ageda/Shenkora	3.24^{abc}	3.18^{ab}	3.09^{ab}	2.51^{bc}	1.84^{bc}	1.26^{bcde}
11.	B52-298	2.89^{cd}	2.57^{ef}	2.36^{e}	2.17^{d}	1.53^{d}	1.07^{ef}
12.	NCO 334	2.65^{d}	2.52^{f}	2.45^{e}	1.59^{f}	1.39^{d}	0.97^{f}
	Mean	3.11	2.94	2.84	2.16	1.72	1.32
	LSD	0.45	0.21	0.12	0.20	0.14	0.23
	CV	8.53	4.28	2.59	5.68	4.92	10.54

Stalk weight (kg)

The leading genotypes under 1.3ds/m salinity level were Moris, Yemilat Nech Shenkora and Holland with stalk weight of 2.72kg, 2.62kg and 2.52kg, respectively. Under this salinity level the lowest stalk weight was recorded for genotypes Nech Ageda (1.63kg) and the check NCO 334 (1.59kg). These genotypes which manifested higher stalk weight for example Moris, Holland and Yemilat Nech Shenkora were thicker than the other genotypes when grown under same salinity level (1.3ds/m). For salinity level 4.4ds/m the highest performing genotypes were Holland and Andegna Dereja Canada Shenkora with stalk weight of 2.23kg and 2.17kg, respectively. Under this salinity level (4.4ds/m), the lowest stalk weight was recorded for the check NCO 334 with value of 1.39 kg respectively. On the other hand, under 6.5ds/m salinity level no genotypes other than Andegna Dereja Canada Shenkora (1.75kg) performed best in stalk weight (Table 5).

Cane Yield (t/ha)

Cane yield and its components are the most important traits in sugarcane production, where stalk weight and number of millable canes are the two primary components of cane yield. The ANOVA results (Table 2) depicted highly significant differences ($p<0.01$) among the 12 genotypes for germination % under each salinity levels. Genotype Holland (179.91) followed by Nech Shenkora (177.97), Kay Ageda1 (171.37), the check NCO 334 (170.37) and Moris (167.75) were the highest yielders under 1.3ds/m salinity level. Genotype Holland (158.27t/ha), NCO 334 (150.81 t/ha), Moris (141.05 t/ha) and Kay Ageda1 (138.86 t/ha) gave the highest cane yield (tons/ha) under 4.4ds/m salinity level but there were not statistically significant difference between them.

And under 6.5ds/m salinity level genotype Moris (118.05 t/ha) and the check NCO 334 (94.53) were the top yielders (Table 6). The result of this experiment also showed that most of the top yielding genotypes have the highest millable cane and better stalk weight.

The difference in these traits among sugarcane genotypes is due to their difference in genetic constitution and their response to soil salinity factors. These traits have been widely studied by Nsassar *et al.* (2005), El-Shefai and Ismail (2006), Manjunath *et al.* (2007), Abo El-Ghait (2000) and El-Sogheir and Ismail (2006), Manjunath *et al.* (2007.who found significant differences between the genotypes studied and their differential response to salinity levels.

Table 3 Cane Yield performances of genotypes across three salinity levels at Metahara

	Genotypes	Cane Yield (t/ha)			
		1.3ds/m	4.4ds/m	6.5ds/m	Mean
1.	Nech Ageda	177.97^{ab}	77.84^{cd}	64.10^{e}	106.64
2.	Kay Ageda1	171.37^{ab}	138.86^{a}	84.59^{c}	130.97
3.	Andegna Dereja Canada Shenkora	158.42^{bc}	97.14^{bc}	59.73^{e}	105.10
4.	Engda	91.99^{e}	67.06^{d}	38.85^{f}	65.97
5.	Moris	167.75^{ab}	141.05^{a}	118.05^{a}	142.29
6.	Holland	179.91^{a}	158.27^{a}	84.59^{c}	140.93
7.	Yemilat Nech Shenkora	120.62^{d}	69.70^{d}	45.05^{f}	78.46
8.	Kay Ageda2	160.30^{abc}	115.44^{b}	78.95^{cd}	118.23
9.	Nech Shenkora	143.55^{c}	86.51^{cd}	70.99^{de}	100.35
10.	Kay Ageda/Shenkora	108.53^{de}	77.41^{cd}	43.72^{f}	76.55
11.	B52298	166.54^{ab}	113.64^{b}	68.94^{de}	116.38
12.	NCO334	170.37^{ab}	150.89^{a}	94.53^{b}	138.60
	Mean	151.44	107.81	70.85	110.03
	LSD	19.83	21.14	11.50	
	CV	7.73	11.57	9.58	9.66

The results of this experiment also showed that locally collected genotypes were comparable with the standard checks in cane yield when evaluated across the salinity environments. The genotypes Holland and Moris remained on top with maximum average cane yield of 142.29 and 140.93 t ha^{-1} against the checks genotypes B52-298 (116.38 t ha^{-1}) and NCO 334 (138.60 t ha^{-1}). The genotypes Kay Ageda1 (130.97 t ha^{-1}) and Kay Ageda2 (118.23 t ha$^{-1)}$ also manifested good performance and outsmarted one of the checks B52-298 (116.38 t ha^{-1}) did not out outsmart NCO 334 (138.60 t ha^{-1}) checks. The genotypes Engda, Kay Ageda/Shenkora and Yemilat Nech Shenkora produced lowest average cane yield of 65.97, 76.55 and 78.46t ha^{-1}, respectively. Their yield under 6.5ds/m was reduced 57%, 58% and 62.7% as compared to the yield under 1.3ds/m. For the top yielding genotype the reduction between 1.3 and 4.4ds/m, between 4.4ds/m and 6.5ds/m and between 1.3 to 6.5ds/m were, for Moris (13, 16 and 29%), Holland (12.0, 46.6 and 53.0%) and Kay Ageda1 these were 18, 39 and 50% lower than yield under 1.3ds/m. Moris was more salt tolerant with less yield reduction under highest salinity level. For all 12 genotypes these reduction were 28.8, 34.3 and 53.2%. Salinity from 1.3 to 6.5ds/m reduced cane yield from 151.44 to 70.85 t ha^{-1}. Each ds/m increase in salinity decreased in cane yield by 15.5 t ha $^{-1.}$ This decline in cane yield is apparently related to the decline in millable stalk number, stalk weight and stalk diameter which is similar to the result of (Rozeff, 1995). Maas (1985) found 50% reduction in cane yield at an Ece of 5ds/m. Our result also agrees with that of Subbarao and Shaw (1985) who reported that sugarcane has stunted growth under saline conditions, thereby reducing the yield to about 50% or even more of its true potential. It also agrees with the result of Riet and Haynes (2002) who reported that salinity has a negative effect on sugarcane yield. Similarly Lingle and Weigand (1997) found that a significant impact on cane yield as a result of reduction in tiller number and retarded growth and this in turn affects the sugar yield.

Brix % and Pol %

Both are important qualitative parameters used for maturity judgment. The result of this study revealed that there was significant difference between genotypes in Brix% under two salinity levels but not under 1.3ds/m (Table 2). All genotypes gave the highest brix readings under 1.3ds/m. Under this salinity level genotypes Andegna Dereja Canada Shenkora and Engida had the highest brix of 21.57% while Moris had the lowest brix (19.02%).Under 4.4 dsm^{-1} salinity levels Yemilat Nech Shenkora (18.46%) gave the highest brix reading followed by Engda (17.99%) and the check B52-298 (17.77%). Under this salinity level the lowest brix reading was recorded for genotype Kay Ageda2 (15.72%) and the check NCO 334 (16.17%). The check B52-298 had the highest brix reading (16.16%) followed by Andegna Dereja Canada Shenkora (15.65%) and Moris (15.58%) under 6.5ds/m, while the lowest brix reading percentage was recorded on genotype Kay Ageda2 (12.25%) (Table7). The highest average brix percentage was recorded for genotype Engda (18.37%). An increase of salinity from 1.3 to 6.5ds/m decreased Brix from 20.82 to 14.79, a reduction of 29%. This finding is supported by the experiment of (LSU, 2010) where each ds/m increase in soil salinity reduced brix, pol and sugar purity. Under 1.3 ds/m, genotype Engda (19.92%) gave the highest pol percent cane followed by Key Ageda/Shenkora (19.44%). The lowest pol percent was recorded by genotype Moris (16.39%). Yemilat Nech Shenkora (16.55%) and Engda (16.24%) gave the highest pol percent under 4.4 ds/m. while, Nech Ageda, Key Ageda/Shenkora and Key Ageda 2 gave the lowest pol% with value of 13.51%, 13.48% and 3.47% .13.47% respectively

Table 4 Brix and Pol percent performances of genotypes across three salinity levels at Metahara

		Brix %			Pol %		
	Genotypes	1.3ds/m	4.4ds/m	6.5ds/m	1.3ds/m	4.4ds/m	6.5ds/m
1.	Nech Ageda	21.23^{a}	16.32^{de}	13.57^{cd}	19.32^{abc}	13.51^{e}	10.65^{de}
2.	Kay Ageda1	20.69^{ab}	17.02^{bcde}	14.91^{abc}	19.04^{abcd}	15.07^{abcde}	11.74^{bcd}
3.	Andegna Dereja Canada Shenkora	21.57^{a}	17.56^{abcd}	15.65^{a}	17.20^{de}	15.35^{abcd}	11.29^{cd}
4.	Engda	21.57^{a}	17.99^{ab}	15.54^{ab}	19.92^{a}	16.24^{ab}	12.12^{abcd}
5.	Moris	19.02^{b}	16.97^{bcde}	15.58^{ab}	16.39^{e}	15.29^{abcd}	13.24^{ab}
6.	Holland	21.39^{a}	16.36^{cde}	14.53^{abc}	19.16^{abcd}	13.89^{de}	12.11^{abcd}
7.	Yemilat Nech Shenkora	20.87^{a}	18.46^{a}	15.49^{ab}	17.36^{cde}	16.55^{a}	12.43^{abc}
8.	Kay Ageda2	20.53^{ab}	15.72^{e}	12.25^{d}	18.93^{abcd}	13.47^{e}	9.68^{e}
9.	Nech Shenkora	20.57^{ab}	16.74^{bcde}	15.15^{abc}	17.65^{bcde}	14.68^{bcde}	11.76^{bcd}
10.	Kay Ageda/Shenkora	20.62^{ab}	16.71^{bcde}	13.80^{bcd}	19.44^{ab}	13.48^{e}	11.24^{cd}
11.	B52-298	21.03^{a}	17.77^{abc}	16.16^{a}	1 8.97^{abcd}	15.60^{abc}	13.31^{a}
12.	NCO 334	21.02^{a}	16.17^{de}	1 4.86^{abc}	1 8.99^{abcd}	14.33^{cde}	12.36^{abc}
	Mean	20.82	16.98	14.79	18.53	14.79	11.83
	LSD	1.77	1.43	1.82	1.97	1.71	1.50
	CV	5.03	4.99	7.28	6.30	6.83	7.51

Purity %

Juice purity is the main factor that is used in maturity and quality judgment. Purity Percentage is the total percent of sucrose present in total solids content in juice, a higher purity indicates the presence of higher sucrose. The analysis of variance displayed significant variations among the genotypes for purity % under 1.3ds/m salinity level while under 4.4 and 6.5ds/m salinity levels no significant differences among genotypes (Table 2) Under 1.3 ds/m genotype Yemilat Nech Shenkora (94.34%) followed by Kay Ageda/Shenkora (94.29%) and Engda (983.75%) gave the highest purity percentage, respectively (Table 8). The lowest purity percentage was recorded for the genotype Moris (86.25%) under 1.3 ds/m. For salinity level 4.4 ds/m, genotype Nech ageda (90.08%) followed by the check NCO 334 (88.71) and Engda (88.92%) gave the highest purity percent, respectively, While, Yemilat Nech Shenkora (80.85%) gave the lowest purity percent. Under 6.5 ds/m salinity level genotype Nech Ageda (84.94%) gave the highest purity percent followed by Holland (83.33%), the checks NCO 334 (83.25%) and B52-298 (82.34%), respectively. The highest and lowest mean of purity percent from the candidates were recorded for genotype Nech Ageda (88.67%) and Andegna Dereja Canada Shenkora (81.09%), respectively (Table 8).

Table 5 Purity and Recovery sucrose percent performances of genotypes across three salinity levels at Metahara

		Purity%			Recovery Sucrose %		
	Genotypes	1.3ds/m	4.4ds/m	6.5ds/m	1.3ds/m	4.4ds/m	6.5ds/m
1.	Nech Ageda	91.01^{abc}	90.08^{a}	84.94^{a}	13.61^{ab}	8.85^{e}	6.65^{cde}
2.	Kay Ageda1	93.42^{ab}	85.19^{abc}	83.33^{ab}	13.53^{ab}	10.42^{abcd}	7.36^{bcde}
3.	Andegna Dereja Canada Shenkora	87.40^{bc}	83.54^{bc}	72.32^{c}	11.05^{c}	10.50^{abcd}	6.47^{de}
4.	Engda	93.73^{a}	88.92^{ab}	78.06^{bc}	14.18^{a}	11.38^{ab}	7.53^{abcd}
5.	Moris	86.25^{c}	85.79^{abc}	78.52^{bc}	11.09^{c}	10.69^{abc}	8.85^{a}
6.	Holland	89.60^{abc}	85.12^{abc}	78.88^{ab}	13.35^{ab}	9.28^{cde}	7.97^{abc}
7.	Yemilat Nech Shenkora	94.34^{a}	80.85^{c}	79.36^{ab}	11.54^{c}	11.54^{a}	7.92^{abc}
8.	Kay Ageda2	92.13^{abc}	85.61^{abc}	78.95^{ab}	13.47^{ab}	9.07^{de}	6.08^{e}
9.	Nech Shenkora	87.30^{bc}	85.80^{abc}	77.87^{bc}	11.9^{bc}	10.07^{abcde}	7.27^{bcde}
10.	Kay Ageda/Shenkora	94.29^{a}	83.30^{bc}	78.53^{bc}	14.04^{a}	8.62^{e}	7.26^{bcde}
11.	B52-298	90.13^{abc}	87.84^{ab}	$82. 34^{ab}$	13.29^{ab}	10.71^{abc}	8.68^{ab}
12.	NCO 334	90.25^{abc}	88.71^{ab}	$83. 25^{ab}$	13.31^{ab}	9.90^{bcde}	8.13^{ab}
	Mean	90.82	85.89	79.69	12.85	10.09	7.51
	LSD	6.13	6.40	6.37	1.72	1.54	1.41
	CV	3.98	4.40	4.72	7.93	9.02	11.14

Recoverable sugar percent

Significant differences were recorded among all the genotypes across three salinity levels for sugar recovery (Table 2). The highest recovery (14.18%) under 1.3 ds/m salinity level was exhibited by the genotype Engda whereas the lowest was Andegna Dereja Canada Shenkora (11.05%) followed by Moris (11.04%) and Yemilat Nech Shenkora (11.54%), respectively (Table 8). For salinity level 4.4ds/m genotype Yemilat Nech Shenkora (11.54%), followed by the Engda (11.38%) gave the highest recoverable sucrose percentage. Nech Ageda (8.85%) and Key Ageda/Shenkora (8.62%) gave the lowest recoverable sucrose percentage under 4.4 ds/m. Under 6.5 ds/m salinity level genotype Moris (8.85%) and the checks B52-298 (8.68%) and NCO 334 (8.13%) gave the highest recoverable sucrose percentage respectively (Table 8).

The highest and lowest reduction sugar recovery percent was recorded in Key Ageda2 and Moris with reduction of 54% and 20% respectively under 6.5ds/m salinity level (Table 8). These results are in agreement with the finding of Mebrathom *et al.*, 2014 who studied ten sugarcane genotypes and two commercial varieties and found different levels of reducing sugar percent. The average recoverable sucrose percentages attained when grown at 1.3,4.4 and 6.5ds/m was 12.85%, 10.09% and 7.51%, respectively with reduction of 22% under 4.4ds/m and 41% under 6.5ds/m

Sugar Yield (t/ha)

The ANOVA results (Table 2) depicted highly significant differences ($p<0.01$) among the 12 genotypes for sugar yield under each salinity levels). Under 1.3ds/m salinity level the highest sugar yield was recorded for genotype Nech Ageda (24.23 t ha^{-1}) and the lowest sugar yield was recorded by genotype Engda (13.04 t ha^{-1}). Under 4.4ds/m salinity level genotype Moris (15.09 t ha^{-1}) gave the highest sugar yield followed by the check NCO 334 (14.90 t ha^{-1}), Holland (14.58 t ha^{-1}) and Kay Ageda1 (14.46 t ha^{-1}) respectively while genotypes Kay Ageda/Shenkora (6.67 t ha^{-1}), Nech Ageda (6.97 t ha^{-1}) and Engda (7.62 t ha^{-1}), recorded the lowest sugar yield respectively (Table 9).

Table 6 Sugar Yield performances of genotypes across three salinity levels at Metahara

	Genotypes	Sugar Yield (t/ha)		
		1.3ds/m	4.4ds/m	6.5ds/m
1	Nech Ageda	24.23^{a}	6.97^{f}	4.26^{efg}
2	Kay Ageda1	23.03^{a}	14.46^{ab}	5.89^{cd}
3	Andegna Dereja Canada Shenkora	17.48^{bc}	10.20^{cde}	3.89^{efgh}
4	Engda	13.04^{d}	7.62^{f}	2.92^{h}
5	Moris	18.61^{b}	15.09^{a}	10.44^{a}
6	Holland	24.01^{a}	14.58^{a}	.76.72$^{bc\ bc}$
7	Yemilat Nech Shenkora	13.76^{d}	8.05^{ef}	3.57^{fgh}
8	Kay Ageda2	21.58^{a}	10.45^{cd}	4.80^{def}
9	Nech Shenkora	17.08^{bc}	8.77^{def}	5.15^{de}
10	Kay Ageda/Shenkora	15.26^{cd}	6.67^{f}	3.14^{gh}
11	B52-298	21.87^{a}	12.16^{bc}	5.98^{cd}
12	NCO 334	22.65^{a}	14.90^{a}	7.72^{b}
	Mean	19.38	10.83	5.39
	LSD	2.92	2.35	1.28
	CV	8.89	12.83	14.10

Under 6.5ds/m salinity level the highest sugar yield was recorded for genotype Moris (10.44 t ha^{-1}) and the lowest was recorded for Engida (2.92 t ha^{-1}). Under this salinity level all genotypes gave very lowest sugar yield relative to yield under 1.3ds/m and 4.4ds/m salinity level.

The highest mean sugar yield was recorded for genotypes Holland (15.10 t ha^{-1}) and the check B52-298 (15.09 t ha^{-1}). The lowest was recorded for genotype Engda (7.86 t ha^{-1}). The average sugar yield attained when grown at 1.3ds/m 19.38 t ha^{-1} while, under 4.4ds/m and 6.5ds/m salinity levels the means were 10.83 t ha^{-1} and 5.39 t ha^{-1} respectively with a reduction of 44.1 and 72.2%, respectively (Table 9). This result also agrees with the results of Nasir *et al.* (2000) and Nadioo *et al.* (2004) revealed that the effect of soil salinity was significant on sugar yield and the reason given physiologically for the reduction in sugar yield was attributed to the reduction of stalk population, sucrose % and cane yield or stalk mass as these are negatively affected by salinity and sugar yield by nature it is directly affected by these parameters. Although sugarcane is prone to salinity stress, but varietal differences exist in terms of salinity tolerance (Rozeff, 1995).

Results of Combined Analysis of Variance

The genotype by salinity interaction was statistically highly significant for all traits except for stalk diameter, Brix% and purity percentage (Table 2). The tested genotypes did not perform persistently over the three salinity levels. Some genotypes performed best under certain salinity level, while others performed best under other salinity levels indicating that some genotypes have specific adaptation to a certain salinity level. This result agrees with that of Mebrathom *et al*. (2014) who found significant difference between 12 sugarcane genotypes and significant Salinity and Genotype x Salinity interaction at Metahara Sugar Estate. Due to the significant Genotype x Salinity interaction, direct comparison of the means of the 12 sugarcane genotypes and the three salinity levels cannot be made

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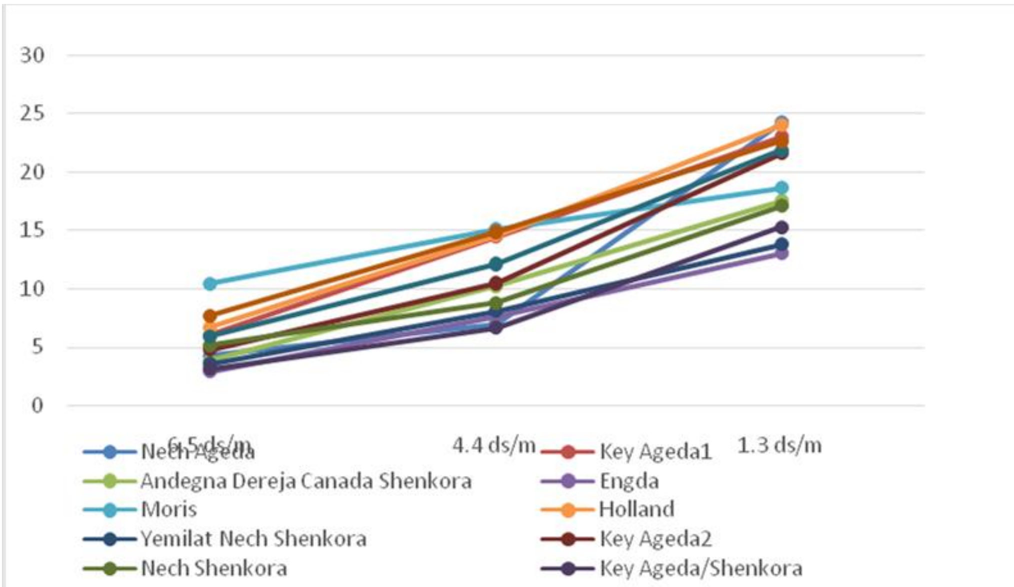


Figure 1 Mean Sugar yield Performances of 12 sugarcane genotypes across three salinity levels.

The inconsistency in performance of the sugarcane genotypes across the three salinity levels is reflected in the changes of ranks of the genotypes in the three salinity levels(Fig 1).There was an increase in sugar yield with decrease in salinity level (from 6.5 to 4.4 and to 1.3ds/m). For some genotypes rank change is observed over the three salinity levels. For example, considering sugar yield (ton/ha) the genotype Nech Ageda ranked 1st, 11th and 8th, Kay Ageda1 ranked 3rd, 4th and 5th while Andegna Dereja Canada Shenkora ranked 8th, 7th and 9th under 1.3d/s, 4.4ds/m and 6.5ds/m salinity levels respectively and this showed that there was cross over interaction.

In practice, GxE complicates the identification of superior varieties (Allard and Bradshaw, 1964).Generally, the more significant differences of interaction components and the more complex problem of identifying broad adapted genotypes. Highly significant yield difference between genotypes and salinity levels, and the significant G x Salinity interaction indicated the need to develop genotypes that are exceptional in their stability across salinity levels.

Correlations of Cane and Sugar Yield with other Traits

Phenotypic correlations have been computed between pairs of quantitative traits including agronomic traits, and juice quality of sugarcane.

Cane yield was positively correlated with all the traits except with stalk diameter and brix% which had a negative correlation (Table 10). Number of Millable stalks ($r = 0.84^{***}$) and plant height ($r= 0.58^*$) had positive and significant correlation with cane yield and seem to be determining cane yield in our experiment. A positive and highly significant correlation between cane yield and its components, cane height and number of millable canes number was also reported by Punia *et al.* (1983).

This indicates that high values of these traits contribute to high cane yield and this result coincide with that of Raman *et al*. (1985) who reported that number of stalks per stool was a major yield contributing factor followed by height and cane girth. Cane girth did not contribute to cane yield in our experiment (r=-0.07). Singh & Sharma (198) concluded that cane yield exhibited phenotypic association with stalks per stool.

Sugar yield had a positive and significant correlation with Millable stalk (r = 0.83***), cane yield (r = 0.96***), purity percentage (r = 0.75 **) and recovery sugar percentage (0.62*). The major contributing factors for high sugar yield are cane yield and recoverable sugar percentage (Terzi *et al*., 2009).

This study revealed that higher number of millable stalks, plant height, cane yield endowed with better purity and recovery sucrose % are the important characters which should be considered while selecting for higher sugar yield in the tested sugarcane genotypes. Similarly Dosado *et al*. (1980) reported that high sugar yield was mainly due to high number of millable stalks and high cane yield.

Table 7 Pearson correlation coefficients for 12 genotypes across the three salinity levels

Traits	Ger	Till	MS	PH	SD	SW	CY	POL	BR	PUR	RSP	SY
Ger		-0.01	-0.00	0.39	0.09	-0.01	0.03	0.38	0.32	0.25	0.37	0.12
Till			0.55	0.16	-0.47	-0.57	0.19	0.05	-0.14	0.33	0.16	0.19
MS				0.42	-0.40	-0.35	0.84***	0.29	-0.03	0.74**	0.46	0.83***
PH					0.18	0.25	0.58*	-0.06	-0.21	-0.31	0.03	0.48
SD						0.52	-0.07	-0.50	-0.45	-0.28	-0.47	-0.18
SW							0.16	-0.19	0.05	-0.43	-0.31	0.06
CY								0.26	-0.01	0.64*	0.38	0.96***
POL									0.86***	0.56	0.95***	0.51
BR										0.07	0.66*	0.19
PUR											0.78**	0.76**
RSP												0.62*

Where Ger=Germination, Till= Number of tillers, MS= Number of millable stalk, PH=Plant height, SD= Stalk diameter, SW= stalk weight, CY=Cane yield, POL= Pol%, BR= Brix%, PUR= Purity percentage, RSP= Recoverable sugar percentage and SY= Sugar yield.

Stability Analysis

Genotypes that provide high average yields with minimum G x E interaction in varying environments, have been gaining importance over those with highest mean yields (Ceccarelli, 1989; Gauch and Zobel, 1997; Kang, 1998). The definition of a stable cultivar varies with the type of stability analysis used, but generally breeders want cultivars with high mean yield and those which at the same time, respond to improved environments (Hallauer and Miranda, 1988).

Stability by Wricke's Ecovalence (Wi)

According to Wricke's (1962) ecovalence, Andegna Dereja Canada Shenkora, the checks NCO 334 and B52-298, Kay Agada/ Shenkora and Nech Shenkora, were the most stable genotypes as they had relatively low ecovalence values and among these genotypes only the two checks, NCO 334 and B52-298, gave sugar yields higher than the grand mean. Therefore, the checks NCO 334 and B52-298 were the most stable based on this model (Table 11).

Genotypes Nech Agada, KayAgada1, Engda, Moris, Holland, Kay Ageda2 and Yemilat Nech Shenkora, were the most unstable genotype according to this model. Among these genotypes Kay Agada1, Moris, Holland and Kay Agada2 gave high sugar yield, but the rest were low yielders. From the most unstable genotypes, Moris, Kay Ageda1, Kay Ageda2 and Holland have high mean sugar yield and can be recommended to specific area of adaptation.

Therefore accordingly genotype Moris, Holland, Kay Ageda1 and Kay Agada2 were best performer in sugar yield under 4.4ds/m salinity level; in addition to this Moris also performed best under 6.5ds/m salinity level. Thus, they could be recommended for these specific salinity environments.

Regression Coefficient (bi)

According to Regression Coefficient, Andegna Dereja Canada Shenkora, NCO 334, Kay Agada/Shenkora, B52-298, Nech Shenkora and Kay Agada1 were the most stable genotypes, as they had relatively less differences from unity. Among these genotypes only the checks NCO 334 and B52-298 and Kay Agada1 gave above average sugar yield and therefore they were the most stable genotypes (Table 11).

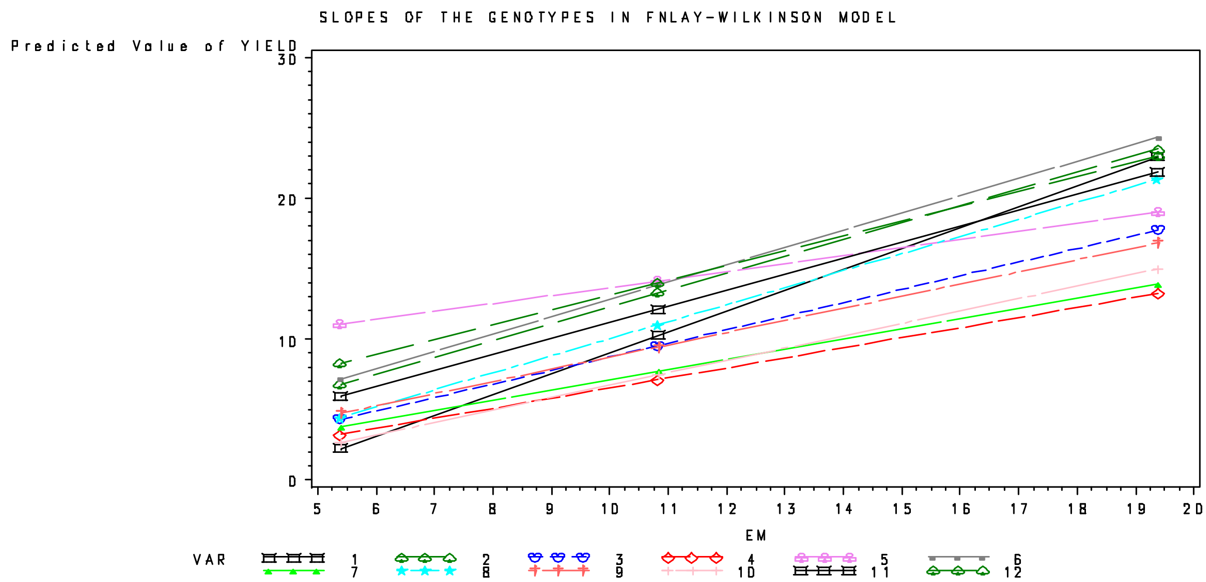


Figure 2 Slopes of the 12 sugarcane genotypes for sugar yield trait

Figure 2 Shows that the highest and lowest yielding environments were 1.3ds/m and 6.5 ds/m, respectively, with the mean yield of 19.38t/ha and 5.39 t/ha. Nech Ageda, Kay Ageda1, Holland, Kay Ageda2 and B52-298 had regression slope far greater than 1 which indicates the adaptation of these genotypes to the low salinity levels (most favorable environment). The slope of NCO 334 was also greater than 1 but the deviation from one was small. This indicates that this genotype is also sensitive to the change in salinity levels, but to lesser extent than the previous genotypes.

The slope of Engda, Andegna Dereja Canada Shenkora, Kay Agada/Shenkora, Nech Shenkora, and Yemilat Nech Shenkora was less than 1 which shows that these genotypes were high yielding in high salinity levels (low yielding environments) but they had low mean sugar yield. Also the significant change in the rank of the genotypes in the three salinity levels (Figure 2) reveals the significant genotype by environment interaction. Andegna Dereja Canada Shenkora, Kay Agada/Shenkora, Nech Shenkora, had slope close to 1 (flatter slope) (Figure 2). This shows the general adaptability of these genotypes is good but all these genotypes had very low mean yield which reveals the poor adaptability (Susceptibility) of these genotypes

Mean Square deviation from Regression (S^2d)

According to Eberhart and Russell (1966), a regression deviation (S^2d) near to zero indicates average stability. Based on mean square deviation from regression the check B52-298, Yemilat Nech Shenkora, Engda, Key Ageda2, Nech Shenkora and Andegna Dereja Canada Shenkora were the most stable genotypes, respectively as they had relatively less differences from zero. Among these genotypes the check B52-298 and Kay Ageda2 gave higher overall average sugar yield than the others. Therefore, according to coefficient and mean square deviation from regression the two checks (B52-298 and NCO 334), Kay Ageda1 and Kay Ageda2 were the most stable genotypes (Table11).In addition to this, the check B52-298 had a regression deviation (S^2d) of zero which is the most stable.

Stability by Coefficient of variation (CVi)

In Figure 2 the mean yield is plotted against the CV. The stable genotype is the one that provides a high yield performance and consistent low CV. Based on this definition, Moris, NCO 334, Holland, Kay Ageda1 and B52-298 fall into the high yield and low variation group and can be considered the most stable (Table 11). Nech Ageda, Andegna Dereja Canada Shenkora, Engda, Yemilat Nech Shenkora and Kay Agada/Shenkora were the most undesirable ones having high CV and low yield.

According to Coefficient of variation genotypes which were found in quadrant IV are the most desirable and stable (Figure 3).

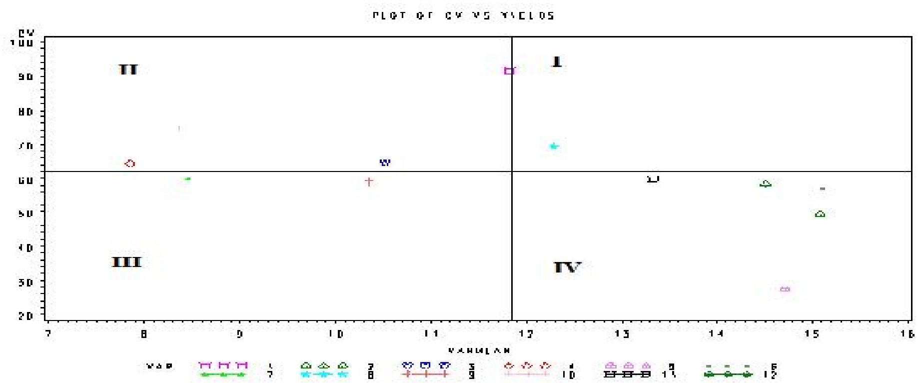


Figure 3 Graph of Francis and Kannenberg's for twelve sugarcane genotypes across the three salinity levels. Where, 1=Nech Agada, 2= key ageda1, 3= Andegna Dereja Canada Shenkora, 4= Engda. 5= Moris, 6= Holland 7= Yemilat Nech Shenkora, 8= Key Ageda2, 9= Nech Shenkora, 10= Key Agada/Shenkora, 11= B52298 and 12= NCO334.

Stability by Genotypic Superiority Index (Pi)

The genotypes with the lowest (P_i) values are considered the most stable. Accordingly, among twelve sugarcane genotypes under the study, genotypes NCO 334, Holland, Kay Ageda1, Moris, B52-298 and Kay Ageda2 received the lowest values and all of these had above average sugar yield and were the most stable according to genotypic superiority index (Pi).

The ranks of genotypes that had above average sugar yield by the above five stability parameters (Wricke's ecovalence, regression coefficient, mean square deviation from regression, coefficient of variation and genotypic superiority index,) were the following. Kay Agada1 (8^{th}, 6^{th}, 11^{th}, 4^{th} and 3^{rd}), Moris (11^{th}, 11^{th}, 10^{th}, 1^{st} and 4^{th}), Holland (7^{th}, 8^{th}, 7^{th}, 3^{rd} and 2^{nd}), Kay Agada2 (6th, 7^{th}, $4^{th,}$ 10^{th} and 6^{th}), B52-298 ($3^{rd,}$ 4^{th}, 1^{st}, 6^{th} and 5^{th}) and NCO 334 (2^{nd}, 2^{nd}, 9^{th}, $2^{nd\ and}$ 1^{st}), respectively. Thus the two checks NCO 334 and B52-298 followed by Holland were relatively the most stable genotypes according to the stability parameters computed.

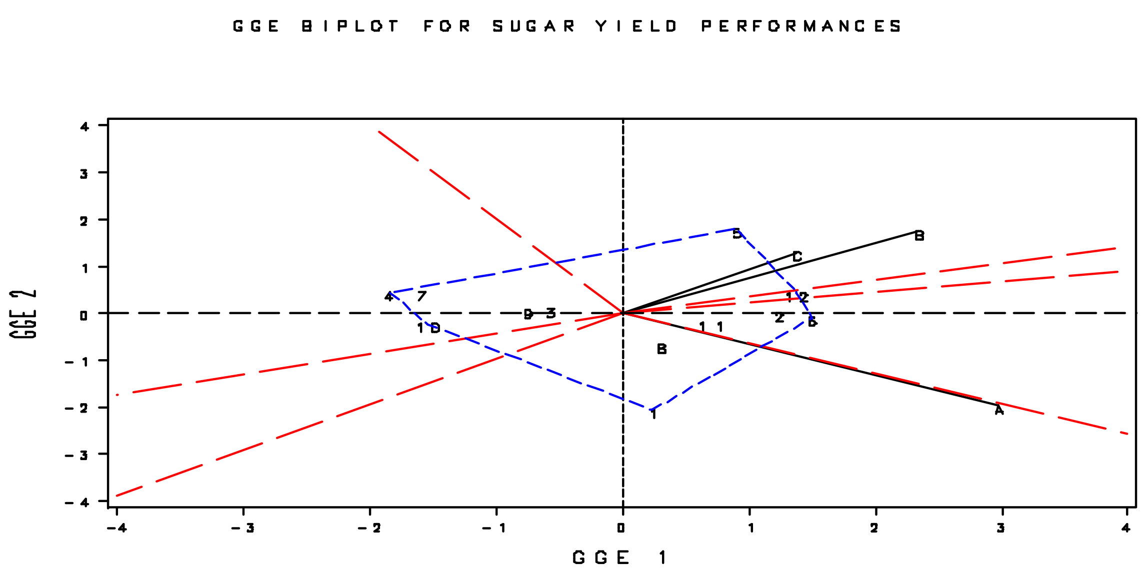
Table 81 Stability by five parameters of twelve sugarcane genotypes tested under the three salinity levels at Metahara sugar estate

No	Genotypes	Means	R of mean	Wi	R of wi	bi	R of bi	S^2d	R of S^2d	CV	R of CV	Pi	R of Pi
1	Nech Ageda	11.82	7	39.60	12	1.48	12	16.77	12	91.59	12	17.35	7
2	Kay Ageda1	14.53	4	5.81	8	1.19	6	2.13	11	58.34	4	3.49	3
3	Andegna Dereja Canada	10.53	8	0.84	1	0.96	1	0.69	6	64.65	9	18.73	8
4	Engda	7.86	12	8.47	10	0.71	10	0.39	3	64.43	8	39.62	12
5	Moris	14.72	3	20.03	11	0.57	11	1.41	10	27.81	1	5.26	4
6	Holland	15.10	1	5.85	7	1.22	8	0.85	7	57.34	3	2.37	2
7	Yemilat Nech Shenkora	8.46	10	7.84	9	0.72	9	0.18	2	60.37	7	34.42	11
8	Kay Ageda2	12.28	6	4.82	6	1.21	7	0.49	4	69.54	10	10.05	6
9	Nech Shenkora	10.34	9	2.53	5	0.86	5	0.68	5	59.23	5	19.83	9
10	Kay Ageda/Shenkora	8.36	11	2.36	4	0.88	3	0.90	8	74.58	11	34.07	10
11	B52-298	13.34	5	1.82	3	1.13	4	0.00	1	60.04	6	5.6	5
12	NCO-334	15.09	2	1.52	2	1.05	2	1.24	9	49.48	2	1.66	1
	Grand mean	11.87											

Genotype plus genotype by environment bi plot analysis (GGE)

GGE bi plot for sugar yield of 12 sugarcane genotypes tested over three salinity levels is presented on Fig. 4. If environments fall into different sectors, it means that different genotypes win in different sectors (Yan *et al*., 2007). The GGE biplot grouped the three salinity environments in two sectors; sector one containing 4.4ds/m and 6.5ds/m and sector 2 contains the 1.3ds/m Salinity level. Salinity levels 4.4 and 6.5 ds/m were positively correlated with each other as the angle between them was less than 90° (i.e., acute angle).The correlation of salinity level 1.3ds/m with the other two salinity levels was also positive; the angle between them was also less than 90^0 (i.e., acute angle) but it is more distantly correlated to the two than the two with each other. The two salinity levels (4.4 and 6.5ds/m) are more correlated and are found in the same polygon. Thus, Moris (#5) and NCO 334 (#12) were the winning genotypes in this polygon. Moris ranked 1st while NCO 334 ranked 2nd under both salinity levels. Moris ranked 7th under salinity level of 1.3 ds/m, and is specifically adapted to saline soils, while NCO 334 ranked 4th under 1.3 ds/m. Indeed these genotypes were the highest yielding genotypes under these salinity levels giving sugar yield of 15.09 and 10.44 t ha^{-1}; 14.90 and 7.72 t ha^{-1} respectively. Nech Ageda (#1) Holland (#6) and Kay Agada1 (#2) had higher sugar yields and they were the winning genotypes under 1.3ds/m salinity level and ranked 1st, 2nd, and 3rd. Nech Ageda ranked 11th and 8th under salinity levels 4.4 and 6.5 ds/m, and manifested specific adaptation to non-saline conditions. Holland ranked 3rd under both 4.4 and 6.5 ds/m while Kay Agada1 ranked 4th under these salinity levels. Holland, therefore, can also be considered as widely adapted genotype, while NCO 334 and Kay Agada1 can also, to some extent, be considered for wider adaptation. Engda (#4) (12th,10th and 12th), Yemilat Nech Shenkora (#7) (11th,9th and 10th), Nech Shenkora (#9) (9th, 8th and 6th) and Kay Agada/Shenkora (#10) (10th,12th and 11th), with respective ranks in brackets at the 1.3, 4.4 and 6.5 ds/m, were found to be not adapted to any of the salinity levels, as they were far from all of the salinity levels (Figure 4).

Andegna Dereja Canada Shenkora (#3), Kay Agada2 (#8), Nech Shenkora (#9) and B52-298 (#11) lie near the center of the polygon and can be considered stable. Out of these only Kay Agada2 (#8) (6th, 6th and 7th) and B52-298 (#11) (5th, 5th and 5th) had above average mean sugar yield and can be recommended for wide adaptation, although their ranks under the three salinity levels were not among the highest. According to Abay and Bjornstand (2009) genotypes close to the origin of the bi-plot axes have wider adaptation.



Where A, B and C are 1.3ds/m, a.4ds/m and 6.5ds/m salinity levels respectively, and the number represent the 12 genotypes, 1= Nech Ageda, 2= Key Agada1, 3=Andegna Dereja Canada Shenkora, 4= Engda, 5= Moris, 6= Holland, 7= Yemilat Nech Shenkora, 8= Key Agada2, 9= Nech Shenkora, 10= Key Ageda/Shenkora, 11= B52-298 and 12= NCO334.

Figure 4 Genotype main effect plus Genotype by Environment interaction biplot analysis of sugar yield performances.

Summary and Conclusion

Nech Ageda (24.23), Holland (24.01) and KayAgeda1 (23.03) gave the highest sugar yield under 1.3ds/m salinity level. Under 4.4ds/m salinity level genotypes Moris (15.09), the check NCO-334 (14.9), Holland (14.58) and Kay Ageda1 (14.46) gave the highest sugar yield. While At 6.5ds/m salinity level genotypes Moris (10.44), NCO 334 (7.71) and Holland (6.72) were the best. Therefore, those genotypes which performed best in cane and sugar yield under the salinity level where they grown and achieved the highest value were found to be promising genotypes in cane and sugar yield with its respective salinity levels at Metahara Sugar Estate.

The overall result of Pearson correlation analysis implied that yield and most of yield components (traits) positively correlated to the yield and to each other , and were used as salinity indices in this experiment hence, they can be serve as a basis to predict the final yield (white sugar) of the genotypes evaluated. Sugar yield was positively and significantly correlated with cane yield and Recovery sugar % which implies that these traits are more important in determining sugar yield.

In conclusion, genotypes such as Nech Ageda, Holland and key Ageda1 were found tolerant at lower salinity level (1.3ds/m). At 4.4ds/m and 6.5ds/m Moris, the check NCO 334 and Holland were performed better. So these genotypes can be recommended for similar salinity problematic areas in Metahara sugar estates and also for the others sugar projects especially for Tendaho and Kessem and they should be evaluated for their ratoon crops and also verified further on large commercial plots.

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