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Genotype by Environment Interaction and Stability Analysis of Cane and Sugar Yields and Their Components, of 30 advanced Sugarcane Genotypes at Three Areas of Cone Production Schemes, Sudan

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ABSTRACT

The success of improving the sugarcane crop and its production activities of sugar and cane can only be achieved with the scientific information that results from the study of genotypes, environments and genotype by environmental interactions (GEI). In this study, 30 genotypes include three check genotypes were evaluated in the seasons 2018/19 and 2019/20 at three locations, *viz* Kenana, White Nile and Guneid, Sudan, with the aim of assessing Genotype by environment interaction and stability of yield components of sugarcane. Genotypes were tested using a randomized complete block design with four replications at each location. The components of cane yield measured, were the number of stalks (1000/ha), stalk thickness (cm), number of internodes, stalk height (cm), stalk weight (kg) and cane and sugar yield (ton cane/hectare, ton sugar/hectare), respectively. The study also included genotype by environment interaction and stability of the cane and sugar yield. The mean squares due to environment were significant while genotype and genotype by environment interaction were highly significant for cane and sugar yield. The results of the study showed significant differences among the genotypes, seasons and location for all of the traits studied and, therefore, expected to respond to selection. The genotype by environment interaction analysis over locations showed that the interaction of genotype with locations was significant for the traits of cane and sugar yield, except for Kenana 2018/19, the interaction of genotype with location was not significant. This finding indicated that genotypes responded differently to different environments. Stability statistical analysis by Eberhart and Russell (1966) model and the additive main effect and multiplicative interaction (AMMI) model, showed that genotypes VMC 95-37 (108, 13.2 t/h), KnB 03- 5261(105.2, 12.7 t/h), KnB 05- 1022 (104.7, 12.8 t/h), KnB 05- 0086 (104.6, 12.3 t/h), KnB 04-1123 (104.3, 12.5 t/h), R 570 (100.4, 12.1 t/h) and KnB 03- 4181 (100.2, 13.2 t/h), respectively, revealed good stability and high yielding of cane and sugar in all environments. It is recommended to test these genotypes under field conditions for several seasons in the three locations to confirm the results, to benefit from them in recommending the release of these genotypes to be grown commercially in the three projects and sugarcane production areas with similar environments in Sudan.

INTRODUCTION

Sugarcane *(Saccharum officinarum L*) is a high biomass perennial crop originated in New Guinea. Sugarcane is the main sugar-producing crop in the world contributing more than 80% of the total sugar produced and has recently become a primary crop for biofuel production (Garsmeur et al., 2018). In Sudan, as in other tropical countries, sugarcane is the main source of sugar and sugar industry plays a significant role in the socioeconomy of the country.

One of the main goals of sugarcane breeding programs is to obtain high-yielding cultivars adapted to different agro ecological regions (Rea et al., 2014). Therefore, it is essential to establish selection indices that simultaneously combine yield and stability. However, Genotype by Environment Interaction (GEI) reduces the association between genotypic and phenotypic values and affects the selection progress (Rea et al., 2014). The importance of GEI in genotype evaluations and breeding programs has been demonstrated in many crops, including sugarcane. Genotype x environment (G x E) interaction are a serious concern in breeding programs as they affect selection decision. When the rank of a genotype changes across environments it necessitates evaluation of genotypes across the environments to determine their real value (Kimbeng et al., 2002). Sugarcane yield is a polygenic character that highly affected by environmental condition, it is essential to know that the improvement of any character depends on the interaction between genes controlling this character and proper environmental condition. Several statistical methods (parametric and non-parametric) have been proposed to study the GEI (Lin et al., 1986, Mohammadi and Amri, 2008). The regression of Eberhart and Russell analysis and The additive main effects and multiplicative interactions (AMMI) Stability model and Biplot Analysis are effective and most appropriate tools to describe and identify stable and superior genotypes for most crops. The objective of this study was to determine the magnitude of GXE interaction of advanced sugarcane genotypes and the stability and yield performance of advanced sugarcane genotypes in multiple locations in order to identify stable high yielding candidate cultivar (s) for possible release using regression of Eberhart and Russell (1966) and AMMI stability model.

MATERIALS AND METHODS

Experimental site

The experiment was conducted for two seasons 2018/2019 and 201/2020 at three sites, *viz*, Kenana, White Nile and Guneid sugar schemes.

Kenana is located at the intersection of latitude 13º N and 13º 16/ N and 33º 49/ E and 33º 10/ E, about 410 meter above sea level. The climate is tropical aridic with summer rainy season of five months (June to October) with a peak of rainfall in August. The average rainfall fluctuates greatly from year to year. The average rainfall for the two seasons was 379 mm; the mean maximum temperature was 42º C (May) and minimum was 13.7º C (January), while the relative humidity was between 20.5% and 79.8%.

White Nile Sugar Company (WNSC) extends along the Khartoum – Rabak highway from kilometer 102 to kilometer 180. It is located at the latitudes 14º20/ and 13º 45/ N and longitudes 32º15/ and 32º40/ E. The climate is arid climatic zone with summer rainy season. The average rainfall was 232 mm; in 2017 the average fluctuates greatly from year to year. The mean maximum temperature was 41.2ºC (May) and minimum temperature is 16.6ºC (January) while the average relative humidity was 36%.

Guneid sugar scheme lies on eastern bank of the Blue Nile River. It is enclosed within latitudes 14º48/ and 15º00/ N, and longitudes 33º16/ and 33º22/ E. The mean maximum temperature was 41.5ºC (May) and mean minimum temperature 14.5º C (January). The rainy season extends from July to October with an average of 212 mm; the average fluctuates greatly from year to year. The average relative humidity was 43%. The soil classification of the three sites, generally the types of the soil is Vertisols and the series disparately from Kenana (Dinder), White Nile (Sharrafat) and Guneid (Remaytab).

Genetic materials

material used in this study consisted of 27 clones of sugarcane genotypes, local bred in Kenana Sugar Company and introduced from CIRAD, France plus three commercial check varieties (R579, TUC 75- 3 and Co 6806). (Table1)

Table 1. Genetic materials used in the study

Entry no	Genotype name	Parentage		Source
		Female	**Male**	
1	KnB 02- 0554	BT 88133	Poly cross	Kenana
2	Kn 02- 1839	Co 421	Poly cross	Kenana
3	KnB 03- 5209	BT 88133	Poly cross	Kenana
4	KnB 03- 5261	WI 96907	Poly cross	Kenana
5	KnB 03- 4181	BBZ 8257	Poly cross	Kenana
6	Kn 03- 1500	Kn 9128	Poly cross	Kenana
7	KnB 03- 4229	Co 6846	Poly cross	Kenana
8	KnB 03- 1184	BT 87220	Poly cross	Kenana
9	KnB 04- 1050	CP 811254	Poly cross	Kenana
10	KnB 04- 1092	PINDAR	Poly cross	Kenana
11	Kn 04- 1138	Kn 9128	Poly cross	Kenana
12	KnB 04- 2121	BR 9433	Poly cross	Kenana
13	KnB 04- 1008	D 8928	Poly cross	Kenana
14	KnB 04- 1127	C 32368	Poly cross	Kenana
15	KnB 04- 1123	D 9083	Poly cross	Kenana
16	KnB 04- 4154	D 9338	Poly cross	Kenana
17	Kn 04- 2001	Kn 92101	Poly cross	Kenana
18	KnB 04- 2008	D 8928	Poly cross	Kenana
19	KnB 05- 0065	B 85342	D 8415	Kenana
20	KnB 05- 1079	DB 7869	D 848415	Kenana
21	KnB 05- 1022	R 831592	Poly cross	Kenana
22	KnB 05- 0086	D 9338	Poly cross	Kenana
23	VMC 9537	VMC 67- 273	Poly cross	Ciradca – France
24	BT 7714	B 73378	Poly cross	Barbados – India
25	R 570	H 32/8560	R 445	Ciradca – France
26	FG 03- 333	N 22	BJ 6902	Ciradca – France
27	FG 04- 296	B 7784	D 172	Ciradca – France
28	R 579	PR 1028	N 8	Ciradca – France
29	TUC 75-3	L 60-25	CP 44- 155	Ciradca – France
30	Co 6806	Co 775	Co 798	Kenya

Cultural practices

The experiments were laid out in a randomized complete block design (RCBD) with four replications. Plot size was 2 rows x 10 meters' length x 1.5 meters' width, total plot area (30 m^2). The two rows (plot) were used for assessing the cane yield and its components. The observations recorded were number of stalks (1000/ha), stalk thickness (cm), number of internodes, stalk height (cm), stalk weight (kg) and cane and sugar yield (ton cane/hectare, ton sugar/hectare) respectively. All other cultural practices were performed as recommended by cane production of the schemes.

Stability Analysis

Combined analysis of data generated from different environments were used for estimation of stability parameters. two different approaches, Regression approach of Eberhart and Russel (1966) model was performed. In addition, AMMI model was carried out to show the stability and pattern of adaptation of sugarcane genotypes in six environments (2 seasons x 3 locations).

RESULTS AND DISCUSSION

The genotypes showed significant character variation in each location, in each season and across seasons and location (Table 2). Seasonal variations were very highly significant for all characters studied, while that of location were also significant. Though the main effects of genotype, season and location on almost characters were significant, but their second degree interaction effects (S x L x G) were significant only for internodes number. Combined analysis of variance showed highly significant differences among environments for cane yield and sugar yield. Further differences in cane yield and sugar yield among genotypes were highly significant. The interaction effects of genotypes x environments were highly significant for cane yield and sugar yield at E2 (location 2), E3 (location 3) and not significant at E1 (location 1), (Table 3).

Table 2. Mean squares of different cane yield parameters of 30 genotypes grown at Kenana, White Nile and Guneid for seasons 2018/19 and 2019/20.

SOV	STPH	STW	STH	STTH	INENO
Season (S)	9517**	6.43**	7354**	6.18**	1566.45**
Location (L)	101054**	13.24**	558238**	4.56**	1464.18**
Genotype (G)	2098**	0.68**	3076**	0.71**	59.49**
S x L	2637**	0.19	1968	3.56**	36.01**
S x L x G	309	0.09	793	0.06	9.92**
Error	284	0.09	944	0.05	6.81

STH= Stalk height, STTH= Stalk thickness, INENO= Internode number, STW= Stalk weight and STPH = Stalk population. *, ** Significant ate the 0.05 and 0.01 probability levels, respectively.

Table 3. genotype x environment interaction of cane yield (TCH) and sugar yield (TSH) of 30 sugarcane genotypes grown at three environments.

Environment	Characters	Environment	Genotype	Genotype x Environment
E1	TCH	18665.2**	1012.0**	441.4^{ns}
	TSH	260.5**	27.6**	10.4^{ns}
E2	TCH	19981.4**	766.6**	526.1**
	TSH	164.4**	9.8**	9.9**
E3	TCH	8972.2**	906.8**	468.9*
	TSH	92.1**	14.1**	8.2**

E1= Kenana 2018/19 and 2019/20, E2= White Nile 2018/19 and 2019/20, E3= Guneid 2018/19 and 2019/20. TCH= Tone cane per hectare. TSH= Tone sugar per hectare. *, ** Significant at 0.05 and 0.01 probability levels, respectively ns= Not significant at 0.05 and 0.01 probability levels, Degree of freedom for season=1, genotype= 29 and season x genotype= 29

Cane and sugar yield stability

Evaluation of varieties and hybrids of any breeding program aims at identifying genotypes that consistently produce stable yield over a range of diverse environments. The high cane and sugar yields of the tested genotypes over environments showed, high cane yield by genotype KnB 03-5209 (113.3 t/h), and low cane yield by KnB 04- 1050 (77.5 t/h), while high and low sugar yield were reported by genotypes KnB 03- 5209 (14.3 t/h) and KnB 04- 1050 (9.8 t/h), respectively, (Table 4).

The genotype x environment (G x E) was significant for cane and sugar yield which justifies cane and sugar yield stability analysis to identify the most stable and adapted genotype(s) to the test environments.

Eberhart and Russel model is an example of a parametric and univariate analysis approach, used in stability analysis, it was defined the stable genotype as one with $b_i = 1$, $S^2d = 0$ and higher than the grand mean of cane and sugar yield. (Table 4) showed clear differences in slopes of the regression lines between tested genotypes. Some regression coefficient (bi) exceeded unity while others were less than one. The values of regression coefficient (slope), for cane yield ranged from (0.63 to 1.31), and sugar yield ranged from (0.68 to 1.32).

From this study, the regression coefficient close to one (b_i =1) and high performance of cane yield (above grand mean) were shown by genotypes, G29 (TUC 75-3), G25 (KnB 05- 1079), G1 (VMC 95- 37), G3 (KnB 03- 5261), G28 (R 579), G26 (KnB 05- 1022), G27 (KnB 05- 0086), G16 (KnB 04- 1123) and G10 (Kn 04- 1138). These results, indicated that those genotypes had average stability for cane yield and are good adapted to all environments. Similar results have been reported earlier by Tahir *et al.* (2013) an Guddadamath *et al.*, (2014) for cane yield. However, considering the three parameters of stability together i.e. mean yield, regression coefficient and deviation regression, genotypes, G29 (TUC 75-3), G25 (KnB 05- 1079), G1 (VMC 95- 37), G28 (R 579) and G16 (KnB 04- 1123) were the stable for cane yield. Genotypes G29 (TUC 75-3), G28 (R 579) check varieties visible had most stable and good performance to all environments. The stability parameters for sugar yield are presented in the last three columns in (Table 4). Genotypes, G8 (Kn 02- 1839), G1 (VMC 95- 37), G5 (KnB 04- 4181), G7 (KnB 03- 1184), G26 (KnB 05- 1022), G28 (R 579), G3 (KnB 03- 5261) and G18 (KnB 04- 2001), were had regression coefficient value close to one (b_i=1) and the sugar yield of these genotypes were higher than the grand mean. These genotype can be well adapted to all environments.

The outcome from Eberhart and Russel (1966) model, suggested that the four genotypes G1 (VMC 95- 37), G3 (KnB 03 5261), G26 (KnB 05- 1022), and G28 (R 579), are the most promising due to higher yield and stability for both the traits: cane and sugar yields.

Table 4. regression coefficient (bi) and variance due to deviation for cane and sugar traits of 30 sugarcane genotypes grown at 3 locations for 2 years.

Genotype	GN	CY t/ha	Slope (bi)	MS-DEV	SY t/ha	Slope (bi)	MS-DEV
VMC 95-37	G1	108.0	1.01	57.50	13.2	1.06	0.02
KnB 03- 5209	G2	113.3	1.10	266.10	14.3	1.27	2.05
KnB 03- 5261	G3	105.2	1.09	-114.63	12.7	0.98	-1.52
Kn 03- 1500	G4	95.4	0.83	-64.92	11.3	0.76	-1.78
KnB 03- 4181	G5	100.2	1.00	-48.33	13.2	1.05	-1.19
KnB 03- 4229	G6	107.1	0.77	129.95	13.1	0.73	-1.59
KnB 03- 1184	G7	107.8	1.14	66.17	13.1	1.05	-0.79
Kn 02- 1839	G8	107.1	1.16	65.46	13.9	1.06	1.51
KnB 02- 0554	G9	106.2	1.16	-121.71	13.5	1.19	-1.36
Kn 04- 1138	G10	103.9	0.92	-127.23	11.7	0.74	-1.53
KnB 04- 1050	G11	77.5	1.00	-49.35	9.8	0.99	0.25
Kn 04- 1092	G12	90.1	0.68	-124.85	10.8	0.68	-2.24
KnB 04- 2121	G13	96.7	0.67	-132.71	12.1	0.78	-1.30
KnB 04- 1008	G14	109.6	1.31	-142.71	13.4	1.27	-2.36
KnB 04- 1127	G15	92.5	0.99	-34.05	11.1	0.97	-0.62
KnB 04- 1123	G16	104.3	1.02	6.09	12.5	0.89	-1.00
KnB 04- 4154	G17	101.2	1.04	-47.51	13.2	1.17	-2.23
Kn 04- 2001	G18	98.1	0.94	-53.31	12.7	0.97	-1.15
FG 04- 296	G19	106.8	0.63	188.04	13.0	0.74	3.94
FG 03- 333	G20	95.6	1.00	-65.56	12.7	1.13	-1.04
KnB 04- 2008	G21	104.3	0.79	-98.06	12.8	0.85	-1.33
BT 7714	G22	100.4	1.26	-22.07	12.7	1.32	-0.54
R 570	G23	100.4	1.07	-68.17	12.1	1.02	-1.58
KnB 05- 0065	G24	90.6	1.18	-140.22	11.3	1.23	-2.44

KnB 05- 1079	G25	111.4	1.09	-81.43	13.9	1.17	-2.05
KnB 05- 1022	G26	104.7	0.96	-113.89	12.8	0.95	-2.33
KnB 05- 0086	G27	104.6	0.96	-114.92	12.3	0.94	-2.25
R 579	G28	104.7	1.03	64.89	12.8	1.00	-0.47
TUC 75- 3	G29	112.5	1.01	27.40	13.7	1.10	-0.17
CO 6806	G30	97.4	1.08	50.76	11.9	0.93	0.20
Grand mean		**101.9**			**12.6**		

GN= Genotype number, CY= Cane yield (t/h), MS- DEV= Means square deviation, SY= Sugar yield (t/h).

AMMI cross site analysis

AMMI is widely used in GEI studies for different crops (Crossa *et al.* 1990, Queme *et al.* 2001) to separate the additive portion from the interaction by way of an analysis of variance. The results of AMMI analysis are useful in supporting the decision in a breeding program for selection of stable genotypes and selection of environment for location-specific genotypes in sugarcane. AMMI analysis involves the clustering analysis to classify genotypes under the most adapted sites for them depending on the AMMI principle components scores (Gaush and Zobel, 1988; Nachit *et al*., 1992).

The combined analysis of variance of cane and sugar yield according to the AMMI model is presented in Tables 5 and 6, respectively. The AMMI analysis of variance for cane and sugar yield revealed that the effect of genotype, environment and genotype x environment interaction GEI were significant for cane yield, whereas the effect of genotype and environment were significant, with non-significant genotype x environment interaction (GEI) effects. Significant interactions resulted from the changes in the relative ranking of the genotypes or changes in the magnitudes of differences between genotypes from one environment to another. Significant differences between two years suggest the different reactions of genotypes from a year to another. The same interpretation can be expressed for locations. The significant G×L effect demonstrated different responses of genotypes to the variation in environmental conditions of location indicating the necessity of testing sugarcane genotypes at multiple locations.

The analysis of variance of cane and sugar yield across the six environments showed that (67.9%-71.4%), respectively, of the total sum squares was attributable to environmental effects, (3.0% - 2.6%), respectively, to genotypic effects and (6.0% - 5.2%), respectively, to genotype x environment interaction GEI effects. A large value of SS sum of squares for environments indicated that the environments were diverse with large differences in their mean causing most of the variation in cane yield. The significant GEI indicated differential and inconsistent responses of the genotypes across environments (Gauch and Zobel 1996, Kumar *et al*., 2009, Rea *et al*., 2011). Also AMMI analysis revealed that the two multiplicative terms interactive principal component analysis (IPCA1, and IPCA2) were significant for cane yield, IPCA2 not significant for sugar yield (Tables 5 and 6), and the first PC axis (IPCA1) of the interaction computed (32.9%, 43.5%), respectively, of the genotype environment interaction GEI sum of squares, also the second PC axis (IPCA2) explained a further (25.6%, 25.0%) respectively, of the GEI sum of squares. Together they accounted for 58.5% for cane yield and 68.5% for sugar yield of genotype x environment interaction GEI sum of squares. However most of the variation was explained by the first principle component (PCA1). The AMMI model with only two PCA interactions was the best predictive model, which is in agreement with Zobel *et al*. (1988) and Annicchiarico (1997). Similarly, in the present study, the AMMI analysis of sugar yield further revealed that the first interaction principle component axes (PCA1 and PCA2) explained 68.5% of genotype x environment interaction GEI sum of squares. This was in agreement with that of Sneller et al. (1997), who suggested that GEI pattern is collected in the first principle components of analysis.

Table 5. ANOVA Table for AMMI model analysis of variance for cane yield (t/ha) across six environments.

Source	**D.F**	**S.S**	**M.S**	**F. Ratio**	**% explained**
Treatments	179	1068493	5969**	12.86	76.9
Genotypes	29	41055	1416**	3.05	3.0
Environments	5	943857	188771**	43	67.9
Block	18	79015	4390**	9.45	5.7
Interactions	145	83582	576*	1.24	6.0
IPCA 1	33	27492	833**	1.79	32.9
IPCA 2	31	21377	690*	1.49	25.6
Residuals	81	34712	429	0.92	
Error	522	242352	464		
Total	719	1389860	1933		

** Significant at 0.05, 0.01 probability levels, respectively.

Table 6. ANOVA Table for AMMI model analysis of variance for sugar yield (t/ha) across six environments.

Source	**D.F**	**S.S**	**M.S**	**F. Ratio**	**% explained**
Treatments	179	21399	119.5**	14.06	79.2

Genotypes	29	703	24.2**	2.85	2.6
Environments	5	19297	3859.5**	58.53	71.4
Block	18	1187	65.9**	7.75	4.4
Interactions	145	1398	9.6ns	1.13	5.2
IPCA 1	33	608	18.4**	2.17	43.5
IPCA 2	31	349	11.3ns	1.32	25.0
Residuals	81	441	5.4	0.64	
Error	522	4439	8.5		
Total	719	27024	37.6		

** Significant at 0.01 probability level, ns = not significant.

The high IPCA scores, negative or positive, are more specific or adaptive genotype to certain environments. The IPCA scores, close to zero is more stable genotype over all environments. Accordingly, the AMMI genotype means cane and sugar yield, scores of IPCA1and IPCA2 analysis presented in (Table7 and 8), respectively, showed the high and low cane and sugar yield means by genotypes KnB 03-5209 (113.3 t/h), and low cane yield by KnB 04- 1050 (77.5 t/h), with grand mean (101.9 t/ha), while high and low sugar yield were reported by genotypes KnB 03- 5209 (14.3 t/h) and KnB 04- 1050 (9.8 t/h), respectively, and grand mean (101.9 t/ha). Also AMMI genotype means analysis, revealed that genotypes G29 (TUC 75-3), G3 (KnB 03- 5261), G28 (R 579), G26 (KnB 05- 1022), G27 (KnB 05- 0086), G16 (KnB 04- 1123) and G10 (Kn 04- 1138) scored high cane yielding over grand mean (101.9 t/h) and good stability over all environments. Whereas high sugar yield more than grand mean (12.6 t/h) and more stability over all tested environments revealed by genotypes G29 (TUC 75- 3), G1 (VMC 95- 37), G5 (KnB 04- 4181), G7 (KnB 03- 1184), G26 (KnB 05- 1022), G28 (R 579), G18 (Kn 04- 2001) and G3 (KnB 03- 5261).

Table.7. Means and scores of IPCA1 and IPCA2 of 30 genotypes for cane yield (TCH) trait of 30 sugarcane genotypes grown at 3 locations for 2 years

Genotype	**GN**	**GM (t/h)**	**IPCAg1**	**IPCAg2**
VMC 95-37	G1	13.2	-0.31258	-0.97489
KnB 03- 5209	G2	14.3	-0.87783	1.36509
KnB 03- 5261	G3	12.7	0.03527	-0.31453
Kn 03- 1500	G4	11.3	0.87671	0.45244
KnB 03- 4181	G5	13.2	-0.14426	-0.19208
KnB 03- 4229	G6	13.1	0.89814	-0.17683
KnB 03- 1184	G7	13.1	-0.2554	0.52796
Kn 02- 1839	G8	13.9	-0.33359	-1.17651
KnB 02- 0554	G9	13.5	-0.72103	-0.70416
Kn 04- 1138	G10	11.7	0.85178	0.49614
KnB 04- 1050	G11	9.8	0.14426	-0.89401
Kn 04- 1092	G12	10.8	1.16233	-0.2284
KnB 04- 2121	G13	12.1	0.86514	0.11972
KnB 04- 1008	G14	13.4	-0.96426	0.04017
KnB 04- 1127	G15	11.1	-0.00765	0.76028
KnB 04- 1123	G16	12.5	0.31203	0.36176
KnB 04- 4154	G17	13.2	-0.57479	-0.13728
Kn 04- 2001	G18	12.7	0.06287	-0.65345
FG 04- 296	G19	13.0	1.2843	0.30585
FG 03- 333	G20	12.7	-0.59263	0.15939
KnB 04- 2008	G21	12.8	0.51383	0.49569
BT 7714	G22	12.7	-1.25853	0.59906
R 570	G23	12.1	0.00018	-0.30707
KnB 05- 0065	G24	11.3	-0.79851	0.01323
KnB 05- 1079	G25	13.9	-0.5479	0.17228
KnB 05- 1022	G26	12.8	0.15741	0.21369
KnB 05- 0086	G27	12.3	0.19988	0.09285
R 579	G28	12.8	0.00865	0.52549
TUC 75- 3	G29	13.7	-0.22335	-0.23914
CO 6806	G30	11.9	0.23954	-0.70276

Grand Mean		**12.6**		

Table.8. Means and scores of IPCA1 and IPCA2 of 30 genotypes for sugar yield (TSH) trait of 30 sugarcane genotypes grown at 3 locations for 2 years

Genotype	**GN**	**GM (t/h)**	**IPCAg1**	**IPCAg2**
VMC 95-37	G1	108.0	1.28196	-3.2076
KnB 03- 5209	G2	113.3	1.5067	4.37871
KnB 03- 5261	G3	105.2	0.78008	-1.037
Kn 03- 1500	G4	95.4	-2.1179	0.40513
KnB 03- 4181	G5	100.2	-0.3886	1.17529
KnB 03- 4229	G6	107.1	-1.44	-2.7985
KnB 03- 1184	G7	107.8	1.28079	-0.9876
Kn 02- 1839	G8	107.1	1.55563	-2.7511
KnB 02- 0554	G9	106.2	1.36875	-0.9036
Kn 04- 1138	G10	103.9	-0.5744	0.33581
KnB 04- 1050	G11	77.5	-0.6601	-0.267
Kn 04- 1092	G12	90.1	-3.1414	-0.606
KnB 04- 2121	G13	96.7	-3.0065	0.43305
KnB 04- 1008	G14	109.6	2.55829	0.09599
KnB 04- 1127	G15	92.5	0.58223	1.42385
KnB 04- 1123	G16	104.3	-0.3079	-0.5569
KnB 04- 4154	G17	101.2	0.31019	1.41651
Kn 04- 2001	G18	98.1	-0.0783	-0.7512
FG 04- 296	G19	106.8	-4.6904	1.42144
FG 03- 333	G20	95.6	0.81152	-0.0231
KnB 04- 2008	G21	104.3	-1.3591	1.1401
BT 7714	G22	100.4	3.05889	1.74016
R 570	G23	100.4	0.43364	-0.0055
KnB 05- 0065	G24	90.6	1.7285	0.48832
KnB 05- 1079	G25	111.4	1.23332	1.47241
KnB 05- 1022	G26	104.7	-0.5594	-1.1236
KnB 05- 0086	G27	104.6	-0.0338	-0.1971
R 579	G28	104.7	-0.3092	0.56661
TUC 75- 3	G29	112.5	0.07958	1.22916
CO 6806	G30	97.4	0.09685	-2.5069
Grand Mean		**101.9**		

AMMI biplot analysis

The biplot from AMMI analysis is a useful tool in explaining the specific pattern of main effects and G×E interaction, of genotypes and environments simultaneously (Crossa et al. 1990, Kempton 1984). The graphical visualization of GGE biplot helps to visualize the identification of stable genotypes and environments (Yan, 2002). On this AMMI bi-plot graphic, genotypes and environment having IPCA values close to zero (near the origin) have small interaction effects, whereas those having large positive or negative IPCA values (distant from biplot origin) largely contribute to genotype x environment interaction GEI (Yau. 1995). Accordingly, in this study, (Fig. 1) showed genotypes G29 (TUC 75- 3), G3(KnB 03- 5261), G28 (R 579), G26 (KnB 05- 1022), G27 (KnB 05- 0086), G16 (KnB 04- 1123), G10 (Kn 04- 1138), G17(KnB 04- 4154), G23(R 570), G5 (KnB 03- 4181), G18 (Kn 04- 2001), G30 (Co 6806), G20 (FG 03- 333), G15 (KnB 04- 1127) and G11 (KnB 04- 1050), were the least interactive, more stable over all environment with higher and lower cane yielding. (Fig. 2) for sugar yield showed , genotypes G29 (TUC 75- 3), G1 (VMC 95- 37), G5 (KnB 03- 4181), G7 (KnB 03- 1184), G26 (KnB 05- 1022), G28 (R 579), G18 (Kn 04- 2001), G3 (KnB 03- 5261), G16 (KnB 04- 1123), G27 (KnB 05- 0086), G23 (R 570), G30 (Co 6806), G15 (KnB 04- 1127) and G11 (KnB 04- 1050), were the nearest located with the origin of biplot, indicated most stable genotypes over all environments, with higher and lower sugar yielding and it did not influence by genotype x environment interaction GEI.

In deduction both parametric and nonparametric approaches of sugarcane, cane and sugar yield stability analysis (Eberhart and Russell as well as AMMI) agreed in identifying the genotypes G1 (VMC 95- 37), G3 (KnB 03- 5261), G26 (KnB 05- 1022), G27 (KnB 05- 0086), G16 (KnB 04- 1123), G23 (R 570) and G5 (KnB 03- 4181) as the higher cane and sugar yielding, stable genotypes over all testing environments.

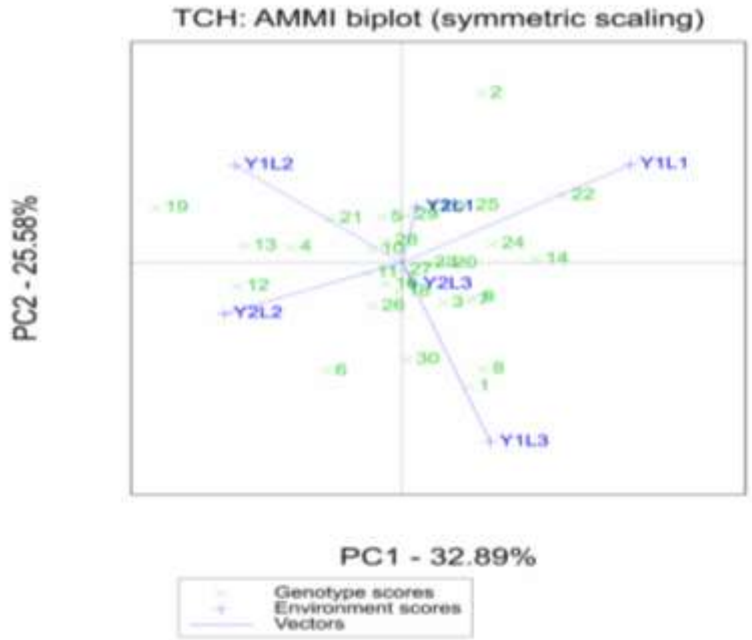

Fig. 1. The AMMI biplot of the IPCA1 and IPCA2 axes for cane yield of 30 sugarcane genotypes grown in six environments visualize the stabile genotypes and environment interaction and effect on the performance of genotypes.

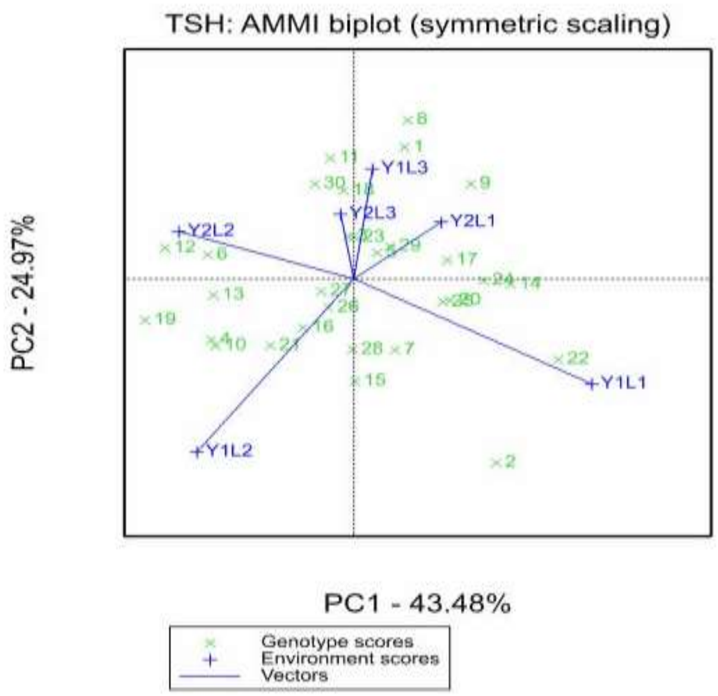

Fig.2. The AMMI biplot of the IPCA1 and IPCA2 axes for sugar yield of 30 sugarcane genotypes grown in six environments visualize the stabile genotypes and environment interaction and effect on the performance of genotypes.

CONCLUSIONS AND RECOMMENDATION

In this study based on the Eberhart and Russell (1966) regression model and AMMI analysis parameters, genotypes, VMC 95- 37, KnB 03- 5261, KnB 05- 1022, KnB 05- 0086, KnB 04- 1123, R 570 and KnB 03- 4181 gave comparable high cane and sugar yield in all the six different environments. This genotype can be considered as stable in terms of cane and sugar yield performance to the tested environments. However, these genotypes are recommended for further evaluation under commercial field test in that three locations and are then can be released to be used as commercial varieties in the three locations (Schemes) and also for similar agroecological regions of the Sudan.

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التراكيب الوراثية وتفاعلها مع البيئة وتحليل ثبات إنتاجية القصب والسكر و مكوناتـهـما ل 30 تراكيباً وراثياً متقدماً من قصب السكر في ثلاثة مشاريع لانتاج السكر، السودان

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ملخــص

لا يمكن تحقيق نجاح تحسين محصول قصب السكر وأنشطة إنتاجه من السكر والقصب إلا بالمعلومات العلمية الناتجة عن دراسة التراكيب الوراثية، تفاعلات البيئة و التفاعل بين التراكيب الوراثية والبيئة. في هذه الدراسة ، تم تقييم 30 نمطًا وراثيا تشمل ثلاثة طرز وراثية قياسية، في موسمي 19/2018 و 20/2019 في ثلاثة مواقع ، وهي كنانة والنيل الأبيض والجنيد، السودان، بهدف دراسة تقييم التركيب الوراثي عن طريق التفاعل بين التراكيب الوراثية والبيئة والثبات لصفات إنتاجية القصب والسكر. تم اختبار الطرز الوراثية باستخدام تصميم القطاعات العشوائية الكاملة بأربعة مكررات في كل موقع. قيست صفات إنتاجية القصب والتي تضمنت عدد السيقان (1000 / هكتار) ، سمك الساق (سم) ، عدد السيلاميات، طول الساق (سم) ، وزن الساق (كجم) وإنتاجية القصب والسكر (طن قصب / هكتار ، طن سكر / هكتار) على التوالي. كما اشتملت الدراسة على التفاعل الوراثي والبيئ وثبات درجة إنتاجية القصب والسكر. . أظهرت الوراثى وجود فروقات معنــويه بين الاصـناف و الموسم والموقع لكل الصفات التي درسة، هذا يشير الي امكانية ألاختيار بين هذه التراكيب نتائج التحليل الوراثية، كما أن تحليل التفاعل بين التراكيب الوراثية مع البيئة، أظهر أن تفاعل التركيب الوراثى مع الموقع معنوى لصفات إنتاجية القصب والسكر عدا كنانة كان تفاعل التركيب الوراثى مع الموقع غير معنوى. هذا يشير الي تباين إنتاجية القصب والسكر لهذه التراكيب الوراثية في بيئات الإختبار المختلفة.

أوضح التحليل الإحصائي ل Eberhart and Russell (1966) و(AMMI)، أن الطرز الوراثية، VMC 95-37 (12.7 ، 105.2 ط/ه)، KnB 03- (13.2، 10.8 ط/ه) و R 570 (100.2، 100.4، 12.1 ط/ه)، KnB 04-1123 (12.5، 104.3 ط/ه) KnB 05- 0086 (104.6، 12.3 ط/ه) KnB 05 1022، (12.8، 104.7 ط/ه) 5261 1KnB 03- 418 (13.2 ط/ه) أظهرة درجة ثبات وإنتاجية عالية من القصب والسكر في كل البيئات، علية يوصي بإختبار هذه الطرز تحت ظروف الحقل لعدة مواسم في الثلاثة مناطق للتأكد من نتائج هذه الدراسة والإستفادة منها في توصية بإجازة هذه الطرز ليتم زراعتها تجارياً في الثلاثة مشاريع و مناطق إنتاج قصب السكر ذات البيئات المشابهة في السودان.