Genotype and Environment Effects on Agronomic and Technological Traits of Some Sweet Sorghum (Sorghum bicolor L. Moench) Varieties

Marwa. M. A. Ghallab [1] and S.A.M. Helmy [2]

ABSTRACT

The objective of this study was to investigate the influence of the interaction of genotype and environment on the agronomic and technological traits of sweet sorghum. Fifteen sweet sorghum (Sorghum bicolor L. Moench) varieties were grown in two locations El Giza (30.01 N latitude) and Alexandria (31°, 12N latitude) over two consecutive years (2020 and 2021). Variability in climatic growing conditions between environments affects the studied traits. As a result, genetic (G), environmental (E), year (Y) and their interactions significantly affected the majority of studied traits. Within the studied variety, 'Brands' had significantly greater mean values than other varieties in seven of the measured traits (stalk diameter, ethanol yield, syrup yield, sucrose%, reducing sugar%, fermentable sugar%, and syrup%) and 'Umbrella' had the highest stalk yield, juice yield, ethanol yield, juice extraction%, Brix % and purity% mean values in El Giza while in Alexandria 'M N8311' had significantly higher mean value in seven of thirteen traits (plant height, juice yield, ethanol yield, Brix%, reducing sugar%, juice extraction and syrup%) and 'GK Ahron' had greater stalk diameter, stalk yield, juice yield, syrup yield and syrup% than those observed in other varieties. MN83-11 and SS301-1 had significantly higher mean values than other varieties in plant height at El Giza and Alexandria. Also, SS301-1 and Tracy recorded higher stalk diameters as compared to other varieties.In addition MN1500, MN83-11 and Umbrella recorded higher mean values of Brix% in both environments. As a result, we identified eight strong positive pairwise correlations and fifteen moderately positive correlated traits.

Keywords: Sorghum bicolor L. Moench- genotype-environment.

INTRODUCTION

Sweet sorghum (Sorghum bicolor (L.) Moench) is a C4 crop in the grass family and is characterized by high photosynthetic efficiency. It is a multipurpose crop, yielding food in the form of grain and golden syrup , as well as fuel in the form of ethanol from its stem juice. Sweet sorghum is a high biomass and sugar-yielding crop. Sweet sorghum is an energy crop cultivated in many countries across different continents, mainly due to its high total soluble solid content (Appiah-Nkansah *et al*., 2019). In Egypt, grain sorghum is an important cereal crop; it is ranked 4th in use and production after wheat, maize, and rice.

The genotype x environment interaction greatly influences the success of any breeding strategy, as the significant interaction of location (environment) with the cultivars has been demonstrated (Wortmann *et al*., 2010). To foster the commercial release of new cultivars, plant breeding programs constantly perform multi-environment trials(MET) to evaluate the productivity of genotypes across distinct environments (Gauch *et al*., 2008; Malosetti *et al*., 2013; Smith *et al*., 2015).

There is season specificity in sweet sorghum, which necessitates the breeding of separate cultivars for different seasons. The genotype–environment interaction greatly influences the success of any breeding strategy, as the significant interaction of location (environment) with the cultivars has been demonstrated (Wortmann *et al*., 2010).

The genetic improvement of sweet sorghum crops has mainly focused on developing new genotypes that have high sugar yields to provide raw materials for the biofuels industry Different studies have reported ~~a~~ high positive correlation between sugar yields and Brix values, sugar content, stem production, and stem moisture; and between stem production and plant height, stem diameter, and juice yield (Shinde *et al*., 2012; Gutjhar *et al.*, 2013).

Food security initiatives in Senegal include introducing new sorghum genotypes adapted to different soil and climate environments. However, when genotypes are evaluated for the recommendation, a common problem arises: the high variability of their productivity from year to year and from environment to environment. Such variability creates difficulty in determining which genotypes can be recommended, so it deserves careful consideration. The different responses of a genotype in different environments are known as genotype × environment interaction (G × E) (Cruz,1997).

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[1]Department of Breed. and Genetic, sugar Crops Research Institut, ARC, El-Sabhieya, Alex., Egypt
[2]Department of Physiology and Biochemistry, sugar Crops Research Institut, ARC, Giza, Egypt
*Corresponding author's email: ghallab.marwa@yahoo.com

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This study aimed to estimate the effect of genotype-environment interaction on agronomic and technological traits in improved sweet sorghum varieties, identify varieties with broad or specific adaptation to environmental conditions, and assess the correlation between agronomic and technological traits.

MATERIALS AND METHODS

Sorghum varieties and experimental locations

The study was carried out during the 2020 and 2021 seasons at El Giza Research Station (latitude: 30.01N) and El Sabahia Research Station, Alexandria (latitude: 31.12N). Sugar Crops Research Institute, Agricultural Research Center, Egypt.

The mean values of minimum and maximum temperatures and humidity percent during the May, June, July, and August 2020 and 2021 seasons at El Giza and El Sabahia Research Stations are presented in Table (1).

Fifteen varieties of sweet sorghum (Table2) had been grown. Seeds of Sorghum are sown in May in El Giza and El Sabahia stations of each growing season (2020 and 2021). In each location, the varieties are sown in a completely randomized block design with three replicates. Each experimental plot had 4x 5.0 m-long rows, with 0.60 m spacing between the rows and 0.20 m spacing between the plants. The blocks had been separated by 1.5m alleys. The agronomic management practices were carried out by considering each location environmental conditions and crop requirements (El-Safy, 2018). Traditional cultural practices had been executed following the hints of ARC Egypt. Harvesting occurred approximately sixteen weeks after sowing in the two studied sites for the first and second seasons.

Table 1. Summary of meteorological data recorded at El Giza and El Sabahia Stations of Sugar Crops Research, Egypt during the 2020 and 2021 seasons

Months	2020				2021			
	El-Giza		El-Sabahia		El-Giza		El-Sabahia	
	Means Temperature(C°)							
	Max	Min	Max	Min	Max	Min	Max	Min
May	32.22	19.67	27.74	18.55	35.32	21.04	29.30	16.61
June	34.22	22.07	29.44	20.79	34.04	21.94	29.15	21.43
July	34.69	24.14	30.43	20.22	36.59	24.08	31.99	22.31
August	35.31	24.84	31.65	25.48	39.27	27.82	34.44	25.86
	Means Humidity(%)							
	Max	Min	Max	Min	Max	Min	Max	Min
May	71.13	18.9	80.81	36.32	67.61	18.81	84.23	36.74
June	71.17	21.23	84.23	45.83	77.43	25.07	84.13	49.17
July	78.77	30.16	83.87	49.77	79.71	26.32	82.19	48.03
August	81.74	25.87	82.45	54.48	78.26	26	83.71	49.81

Table 2. List of 15 sweet sorghum varieties tested and their origin

No	Varieties	Origin	No	Varieties	Origin
1	MN1500	Mississippi	9	GK Ahron	unknown
2	MN4080	Mississippi	10	GK Gaba	unknown
3	MN4508	Mississippi	11	Sugar drib	Oklahoma
4	MN4416	Mississippi	12	SS301-1	Nigeria
5	MN83-11	Mississippi	13	Umbrella	Mississippi
6	Brands	Mississippi	14	Rex	Mississippi
7	Honey	Mississippi	15	Tracy	Texas
8	EM2014-15	Egypt			

Data collection Observations had been recorded as mean values from 10 randomly selected plants to form the 2 central rows from each plot, for plant height (cm), stalk diameter (cm), and clean stalk weight (kg). Stalk yield (Ton/fed) was calculated based on the stalk weight/ kg and converted to ton/fed.

Quality parameters: Brix (total soluble solids) percentage was measured in the juice with a hand refractometer. Juice yield Ton/fed and ethanol yield L/fed were calculated according to the method described by Wortmann *et al*. (2010). The juice extraction percentage of each plant was calculated as the ratio of juice weight to fresh stalk weight, and expressed as a percentage (Sun and Yamana, 2012).

According to A. O. C. (2005), the sucrose percentage of clarified juice was determined by using an automated saccharimeter. Purity was calculated as: [(Sucrose / Brix) x 100]. Reducing sugar in juice: Determined by using Fehling solution according to the method described by Meade and Chen (1977). Syrup extraction percentage (SEP) was calculated from the following equations: SEP = Syrup weight × 100 / Juice weight, Fermentable sugars% FSP = Sucrose % + Reducing sugars % according to the method described by Meade and Chen (1977).

Statistical analysis

The data were subjected to a three-way ANOVA followed by a Least Significant Difference. Statistical analysis of the data was done using a Co-STATIC software (2004) computer and Duncan's New Multiple Range Test (DNMRT) was used for testing the mean difference at a 5% probability level (Steel *et al*., 1997). A correlation test was used to determine the relationship between variables.

RESULTS AND DISCUSSION

RESULTS

Variance across Environments and Years

The results of the combined ANOVA are presented in table (3), making it clear that environment (E), and years (Y), E×Y and Y×G, were significant at ($p<0.05$) for plant height, sucrose%, reducing sugar% and ethanol yield, while E×Y×G was significant at ($p<0.05$) for all studied traits except brix% and G ,and E×G was significant at ($p<0.05$) for all studied traits.

The environment significantly influenced the majority of the evaluated traits. The sweet sorghum plants had significantly higher plant height, brix%, sucrose%, fermentable sugar%, purity% and ethanol yield mean values at the El Giza site, while the plants grown at Alexandria had a higher reducing sugar%. Meanwhile the mean values of stalk diameter, juice extraction %, syrup %, stalk yield, juice yield, and syrup yield, were not significantly affected under the environmental conditions of the two locations i.e. El Giza, and Alexandria Governorate, as shown in (Table 4).

The effects of years were significant for all studied traits except fermentable sugar%, syrup%, and syrup yield. The first-year mean values of brix, sucrose, and purity percentages exceeded those of the second year. While in the second year, the mean values of plant height, stalk diameter, reducing sugar percentage, juice extraction percentage, stalk yield, juice yield, and ethanol yield exceeded those of the first year, as shown in Table (4).

The difference between varieties was significant for all measured traits these may be due to the genetic makeup of these varieties, For example, 'SS301-1' had the lowest sucrose, reducing sugar, fermentable sugar and purity percentages but the highest, plant height, stalk diameter and stalk yield (Table 4). On the other hand, GK Ahron, EM 2014-15 and GK Coba 'had the lowest Brix% values, while 'umbrella, MN1500 and MN83-11' had the highest Brix% values of the evaluated varieties. Umbrella had the lowest syrup%. Conversely, 'MN4080' had the highest measured syrup% (Table 4).

Brands had the highest percentages of sucrose, reducing sugar, fermentable sugar, syrup% and syrup yield while MN83-11 had the highest percentage of Brix, juice extraction and the yields of juice and ethanol.

Genotypic Means within Environment and Years

Statistical analysis within genotype analysis between environments indicated that. In El Giza and Alexandria MN83-11 and SS301-1 had significantly greater mean values than other varieties in terms of plant height, while Honey had a lower plant height (Figure 1 A). In El Giza MN83-11, Brands, GK Ahron, SS301-1 and Tracy had greater stalk diameters than those observed in other varieties. While in Alexandria all the above varieties had significantly higher values except for Brands and MN83-11. (Figure 1 A).

Stalk yield, juice Yield, ethanol yield and syrup yield had variability traits across environment locations, so Sugar drib and Umbrella had significantly greater values than other varieties in juice yield in El Giza, whereas Sugar drib had significantly lower values for the above trait in Alexandria (figure 1B).

Table 3. Summary of the combined analysis of variance (ANOVA) mean square of thirteen traits with fifteen sweet sorghum varieties under two environments in 2020 and 2021 seasons

Source of Variation	Environment (E)	Years (Y)	Genotype (G)	E×Y	E×G	Y×G	E×Y×G
Plant height /cm	41678.45**	333.4722**	20482.89**	638.45**	2283.05**	192.03**	373.31**
Stalk diameter/cm	0.005556^{ns}	0.10952**	1.29777**	0.056888^{ns}	0.1685**	0.02477^{ns}	0.03416*
Brix%	15.5879**	28.2348**	11.8823**	0.049005^{ns}	1.3777**	1.05724**	0.65049^{ns}
Sucrose%	21.7569**	0.09067**	2.0254**	0.05408**	6.8723**	0.038516**	0.02771**
Reducing sugar%	1.32098**	0.1705**	1.4069**	0.11858*	3.04972**	0.080067**	0.10078**
Purity%	90.7864**	4.9137**	91.6299**	0.1323^{ns}	162.9568**	3.3254**	1.82217**
Juice extraction%	1.3904^{ns}	41.7797**	127.463**	0.0125^{ns}	174.498**	10.2393**	9.8722**
Fermentable sugar%	12.482**	0.02222^{ns}	4.9002**	0.30422**	17.05414**	0.12603**	0.09946**
Syrup%	0.01942^{ns}	0.8255^{ns}	8.5899**	4.8576**	6.8561**	1.08417*	1.31816**
Stalk yield Ton/fed	0.01760^{ns}	1.0857**	21.8088**	0.27848*	7.0597**	2.2356**	1.002619**
Juice yield Ton/fed	0.04608^{ns}	0.8597**	6.8627**	0.2645*	11.2971**	0.3292**	0.3936**
Ethanol yield L/fed	14833.815**	6606.1278**	60196.305**	6597.407**	166820.93**	2515.0986**	3107.4424**
Syrup yield Ton/fed	0.01386^{ns}	0.07854^{ns}	0.60477**	0.1196*	0.057612**	0.04242^{ns}	0.051926*

**,* = significant at 0.1% and 0.5% respectively

In El Giza, Umbrella had significantly higher stalk yield and ethanol yield values than the other varieties, while MN4080 had significantly lower values in the above traits. In Alexandria, SS301-1 had a significantly greater value in stalk yield, while Honey had the lowest stalk yield. In addition, MN83-11 had a greater value in ethanol yield, followed by MN4080, EM 2014-15, and GK Ahron, while Sugar Drib, SS301-1, and Tracy had the lowest value in ethanol yield (Figures 1B and C).

In Alexandria Brands, Honey, EM2014-15 and GK Ahron had significantly greater syrup yields. otherwise, at El Giza site Honey and EM2014-15 had significantly lower mean values in syrup yields (Figure1C).

MN1500, MN83-11 and Umbrella had greater Brix% at both locations while EM 2014-15, and GK Coba at El Giza and MN4080 and GK Ahron at Alexandria had the lowest Brix% (Figure 2B).

Brands had better average sucrose%, reducing Sugar%, and fermentable sugar% in El Giza than the other varieties. In contrast, Alexandria, MN4508, and MN4080 had significantly greater mean values than other varieties in all the above mentioned traits except for reducing sugar percentage (Figures 2A, C, and D).

MN4080 and MN4508 had significantly lower fermentable sugar%, purity% and reducing sugar mean values than those observed in other varieties in El Giza, while SS301-1 had lower mean values in all the above traits with the statistical comparison between varieties at the Alexandria location (Figures 2C, D, and F).

MN4080, Brands, and GK Ahron performed better with Syrup% and MN83-11, Honey and SS301-1 had low Syrup% values at El Giza, whereas Sugar Drib, Umbrella, Rex, and Tracy had significantly lower Syrup% values when compared to another genotype in Alexandria (Figure 2 G).

El Giza and Alexandria had significant variation among varieties across years, stalk diameter, plant height, and stalk yield average were consistent across years at El Giza while these traits increased from first year to second one at Alexandria, and in Alexandria juice yield, ethanol yield, and syrup yield were consistent across years, whereas in Giza, juice yield, and ethanol yield were highest in year2. In addition, El Giza decreased in purity% and syrup% from year 1 to year2 while the above mentioned traits were consistent across the years at Alexandria. Overall the brix% decreased. While the juice extraction% increased from year1 to year 2 in El Giza, and Alexandria environments (Figure 3).

Table 4. Means values of thirteen traits across environments, years and genotypes

	Plant height(cm)	Stalk diameter (cm)	Brix%	Sucrose %	Reducing sugar%	Fermentable sugar%	Purity%	Juice extraction %	Syrup%	Stalk yield (Ton/Fed)	Juice yield (Ton/fed)	Ethanol yield (L/Fed)	Syrup yield (Ton/fed)
							Environment						
El-Giza	243.77a	2.154 a	15.14 a	9.59a	6.8433 b	16.43 a	47.56 a	44.05 a	12.07 a	17.77a	7.85 a	691.38 a	2.16 a
Alexandria	213b	2.146a	14.55 b	8.89 b	7.0146 a	15.90 b	46.14 b	43.87 a	12.09 a	17.75 a	7.89 a	673.22 b	2.18 a
							Year						
year1	227.19 b	2.124 b	15.24 a	9.27 a	6.89 b	16.15 a	47.02a	43.47b	12.15 a	17.69 b	7.80b	676.24 b	2.19 a
year2	229.91a	2.177 a	14.45 b	9.22 b	6.96 a	16.17 a	46.69 b	44.44 a	12.01 a	17.84 a	7.94 a	688.36 a	2.15 a
							Genotype						
MN1500	221 f	2.01 de	16.46 a	9.41 b	6.95 ef	16.35 de	49.81 c	44.12 de	12.26 c	16.27g	7.17 h	624.42ef	1 2.01gh
MN4080	204.33hi	1.84 f	14.05 fgh	9.76 a	6.56 jk	16.32 e	45.07 h	41.48 i	13.66 a	15.94 h	6.87 ij	611.01 ef	2.23cd
MN4508	245.33d	2.13 c	15.27 bc	9.78 a	6.78 gh	16.54 c	48.27 e	42.94 fg	12.09 cd	16.32 g	7.02 hi	627.64 e	1.96 gh
MN4416	214.08	2.05 cd	14.65 de	9.26 c	6.59 ij	15.84 h	45.95 g	39.61 j	11.80cde	17.72e	7.18 h	606.08 f	2.14def
MN83-11	309.5 b	2.49 b	16.26 a	9.37 b	7.36 b	16.73 b	46.74 f	49.75 a	11.29 ef	18.36 d	9.13 a	814.41 a	2.09 efg
Brands	203.83hi	2.43 b	14.28efg	9.78 a	7.71 a	17.49 a	46.02 g	42.56 gh	13.16 ab	18.47cd	8.12 de	762.38 b	2.53 ab
Honey	173.92 k	2.04cde	14.85 cd	9.25 c	6.68 hi	15.94 gh	43.68 i	43.67 ef	11.36 ef	16.31 g	8.24 cd	699.77 c	2.17 def
EM2014-15	208.17 gh	1.81 f	13.90fgh	9.40 b	7.18 c	16.58 c	46.95 f	46.16 c	11.68cde	16.58 f	8.03 e	709.52 c	2.04 fgh
GK Ahron	239.92d	2.62 a	13.75 gh	9.42 b	7.06 de	16.46 cd	43.73 i	41.92hi	13.25 ab	19.64a	8.34c	718.93 c	2.61a
G-K-Coba	213.5 g	1.95 e	13.53 h	9.17 d	7.08 cd	16.27 e	49.06 d	47.36 b	13.04 b	18.49cd	8.99a	771.19b	2.46 b
Sugar drib	200.58 i	1.70 g	15.25 bc	8.53 g	6.58 ij	15.11 i	47.03 f	42.27 ghi	12.01 cd	18.61 c	8.12 de	661.72 d	2.3 c
SS301-1	320.08 a	2.62 a	15.52 b	8.40 h	6.45 k	14.83 j	41.49 j	44.84 d	11.56 de	19.69 a	7.53 g	618.12ef	1.95 h
Umbrella	229.75 e	2.13 c	16.52 a	9.13 d	6.94 f	16.08 f	51.78 a	47.16 b	10.80 f	18.43cd	8.72 b	752.87 b	2.01 gh
Rex	186.08 j	1.79 fg	14.11efg	8.86 f	7.13 cd	16 fg	50.54 b	47.78 b	11.34 ef	16.29 g	7.79 f	669.87d	1.83 i
Tracy	258.17 c	2.64 a	14.31 def	9.06 e	6.86 fg	15.93 gh	46.68 f	37.8k	12.04 cd	19.31 b	6.80 j	586.55 g	2.19 cde

Means followed by the same letter(s) within a column under the subheading of environment, year and genotype are not significantly different using the least squares means ($p < 0.05$).

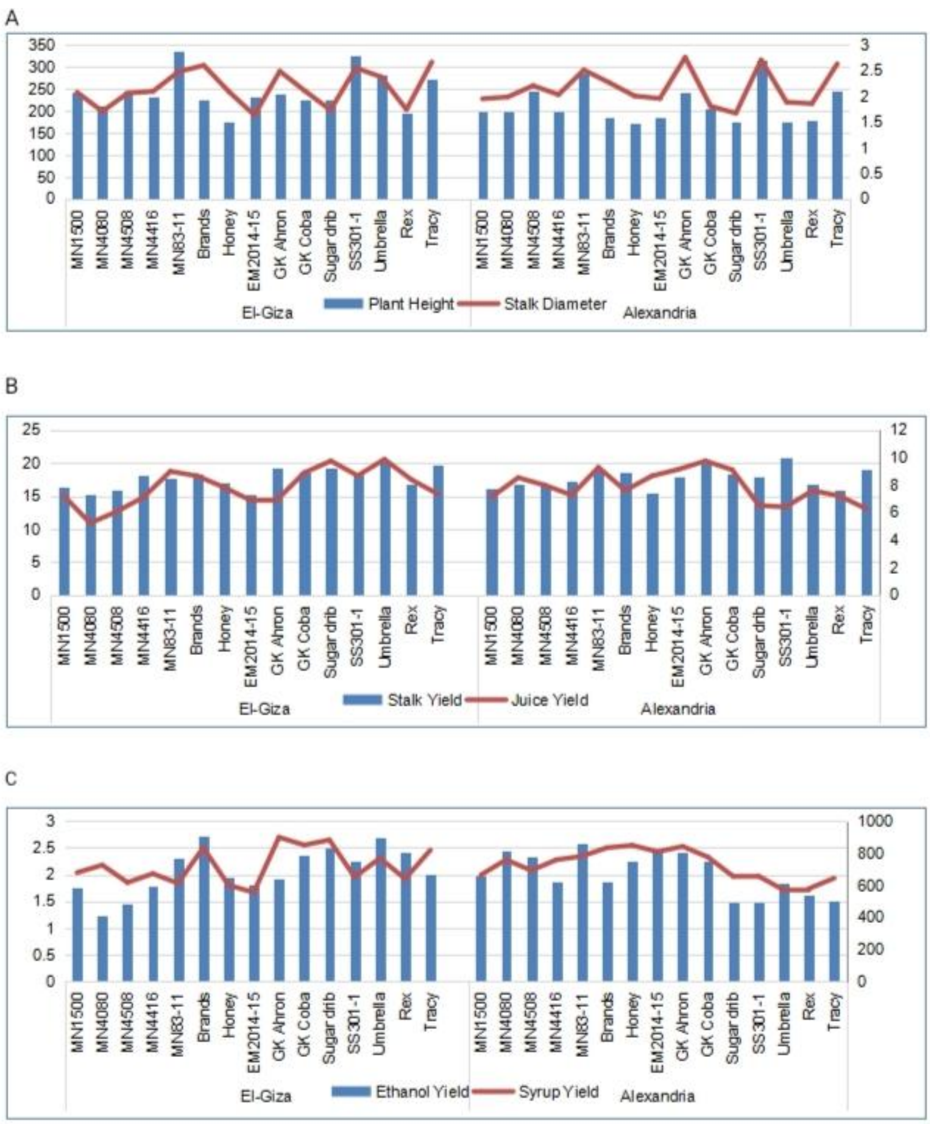


Fig. 1. Genotype means of plant height, stalk diameter (A), stalk yield, juice yield (B), ethanol yield and syrup yield (C) evaluated within year 2020 , 2021 at El Giza and Alexandria environments

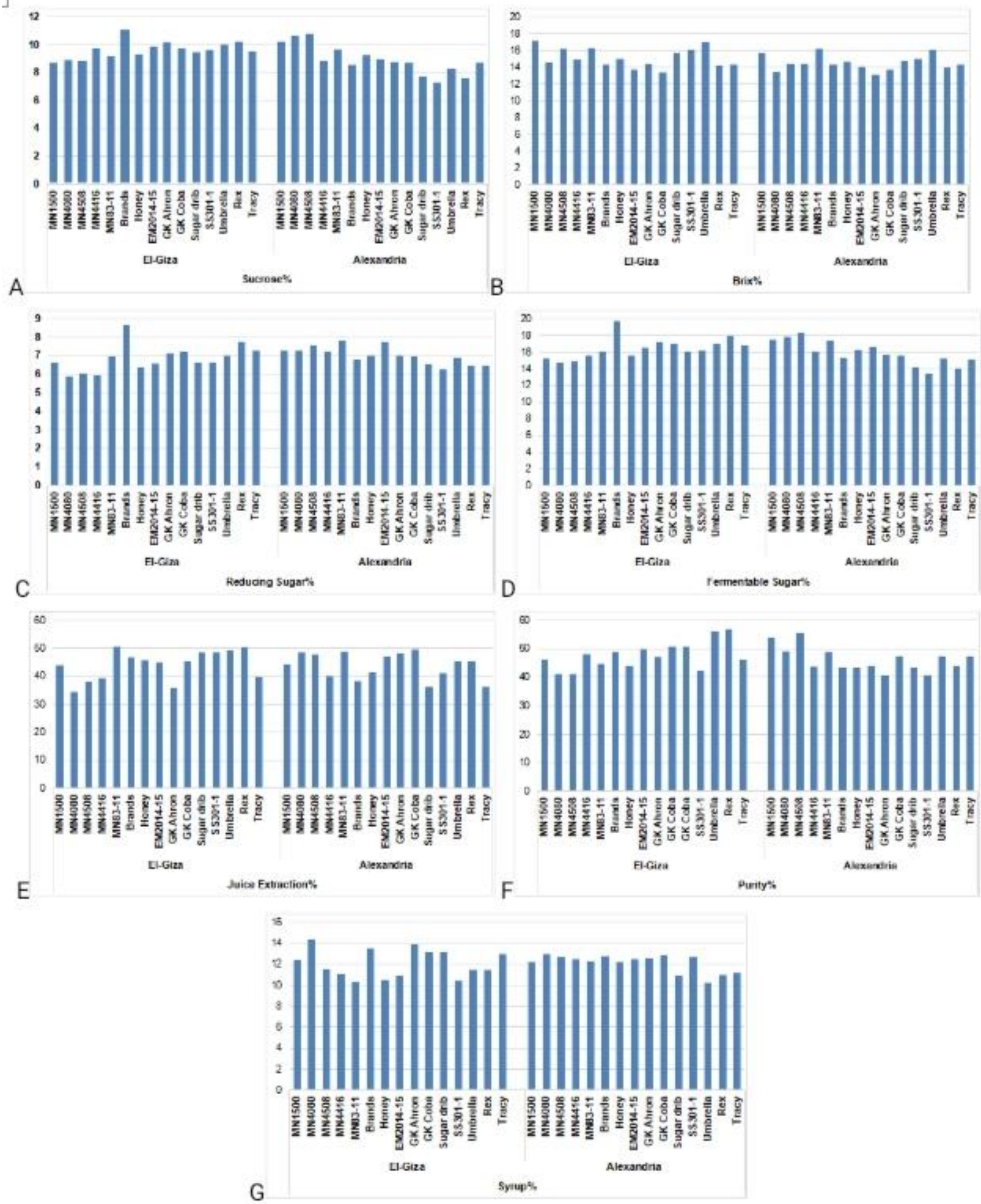
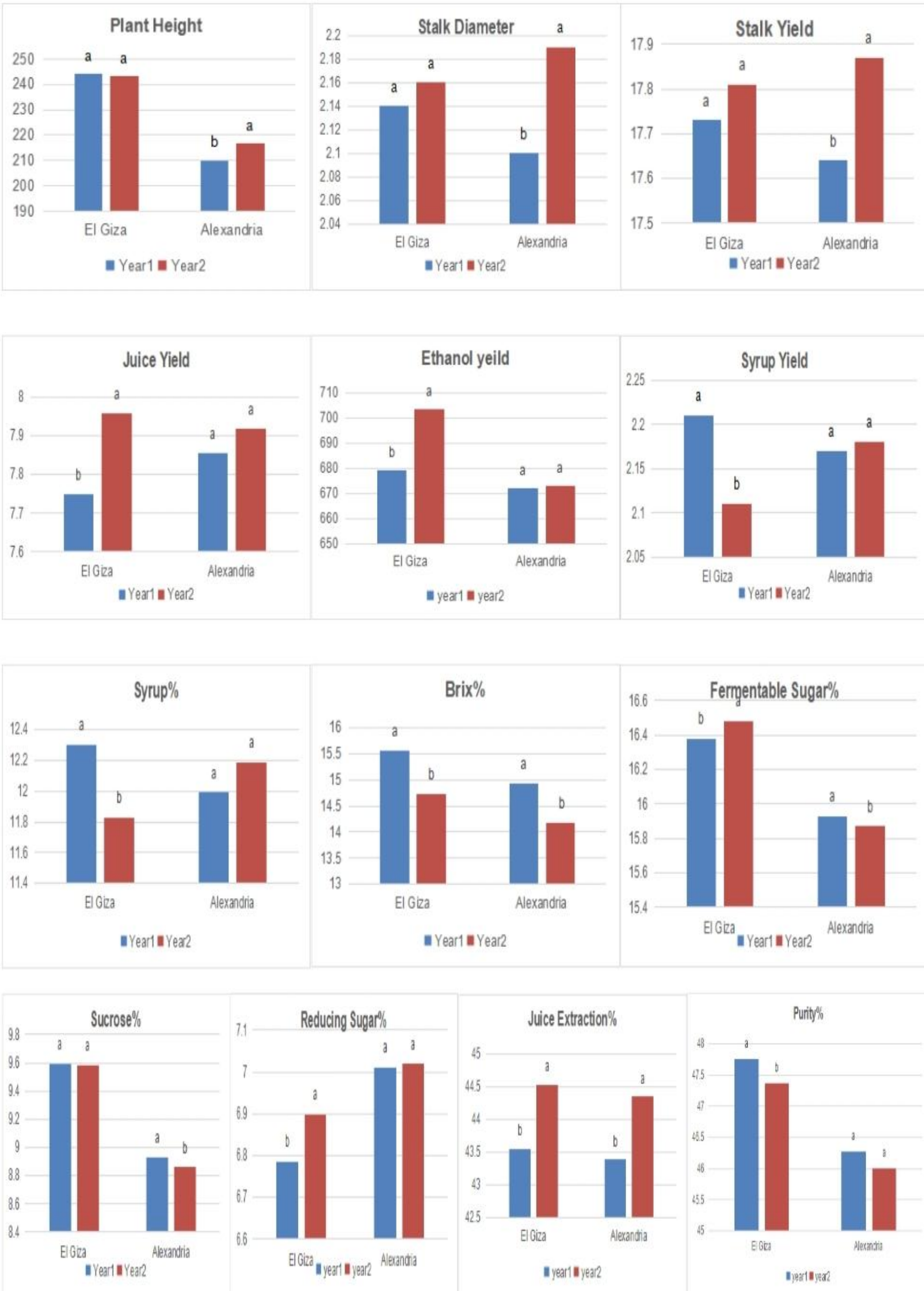


Fig. 2. Genotypic means of sucrose % (A),Brix% (B), reducing sugar% (C), fermentable Sugar% (D), juice extraction% (E), purity% (F) and syrup% (G) evaluated within environments El Giza and Alexandria



The same letter within years are not significantly $p<0.05$

Fig. 3. Genotype means of plant height, stalk diameter, stalk yield, juice yield, ethanol yield, syrup yield, Brix%, sucrose%, reducing sugar%, fermentable sugar%, juice extraction%, purity% and syrup% evaluated within year 2020 and 2021 at environments El Giza and Alexandria

Correlation between studied traits

Individual measures were averaged within each clonal replicate (per genotype, location, and year) for each studied trait that utilized individual (plant height/cm, stalk diameter/cm, stalk yield ton/fed, juice yield ton/fed ethanol yield L/fed syrup yield ton/fed, brix%, sucrose%, reducing sugar%, fermentable sugar%, juice extraction%, purity%, and syrup%). Pairwise Pearson's correlation between each of the thirteen studied traits was performed. We identified eight strong positive (>0.70) pairwise correlations. Strongly correlated traits included Sucrose%-Fermentable Sugar% (*r*=0.919), reducing Sugar%-Fermentable Sugar% (*r*=0.821), Reducing Sugar%-Ethanol Yield (*r*=0.716), Juice Extraction%-Juice yield (*r*=0.819), Juice Extraction%-Ethanol Yield (*r*=0.785), Fermentable Sugar%-Ethanol yield (*r*=0.741), Syrup%-Syrup yield (*r*=0.811) and Juice Yield- Ethanol Yield (*r* =0.924) .

Further, we identified fifteen moderately positively correlated traits (|0.70|> |*r*| >|0.40|). including Plant Height-Stalk Diameter (*r*=0.617), Plant Height-Stalk yield (*r*=0.477), Stalk Diameter-Stalk yield (*r*=0.634), Sucrose%-Reducing Sugar% (*r*=0.532), Sucrose%-Purity% (*r*=0.659), Sucrose%-Ethanol yield (*r* = 0.609), Reducing Sugar%-Purity% (*r*=0.429), Reducing Sugar%-Juice extraction% (*r*=0.439), Reducing Sugar%-Juice Yield (*r*=0.506), Purity%- Juice Extraction% (*r*=0.419), Purity%-Fermentable Sugar% (*r*=0.645), Purity%-Ethanol yield (*r*=0.501), Juice extraction%-Fermentable Sugar% (*r*=0.424), Fermentable Sugar%-Juice yield (*r*=0.458), Ethanol yield-Syrup yield (*r*=0.425). (Table5)

DISCUSSION

Yearly variation in some studied traits is likely a result of the differential humidity and temperature between years of analysis as observed within each environment. Within the El Giza environment, maximum temperatures increased by 8.8%, 5.2% and 10% at May, July and August respectively and humidity% increased in June by 8.1% and July by 1.2% in 2021 compared to 2020. Resulted in increases in reducing sugar%, fermentable sugar%, juice extraction%, juice yield and Ethanol yield by 1.6%,0.6%,2.2%,2.6% and 3.4% respectively and deceased brix%, purity%, syrup% and syrup yield by 5%,0.8%, 4% and 4.5% respectively.

Climate data reported that maximum temperatures increased in May, July, and August 2021 compared to 2020 by 5.3%. 4.9% and 8.1%, respectively, and humidity% increased by 5% and 1.5% in May and August, respectively, at Alexandria, resulting in increased plant height, stalk diameter, stalk yield, and juice extraction percent, while brix%, sucrose%, and fermentable sugar percent all decreased by 5%, 0.7%, and 0.3% in 2021.Global warming, and heat could become major limiting factors for restricting growth, development, and productivity in sorghum (Prasad *et al*., 2006, 2015; Lobell *et al*., 2013; Singh *et al*., 2014).

Brix% increased in 2020 at El Giza and Alexandria locations compared to 2021.These agree with Cole *et a*l. (2017), who reported a 21% difference in Brix values between the two consecutive years, presumably due to environmental differences between those two years. Brix values are known to be highly dependent on temperature, environment, and agronomic practices, and thus are highly variable among different locations and planting years (Daniel *et a*l., 2017).

Further, stalk height, stalk diameter, sucrose% and stalk yield were not significantly different at El Giza in both years of study while reducing sugar%, purity%, syrup% juice yield, ethanol yield, and syrup yield were non significantly between the two studied years at Alexandria; however, they varied in accordance with annual humidity % and temperatures within the location.

Brands had significantly greater values in seven of the measured traits (stalk diameter, sucrose%, reducing sugar%, syrup%, ethanol yield, syrup yield, fermentable sugar%) than other varieties in El Giza. While, in Alexandria, 'M N8311' had a significantly higher values in seven of the thirteen traits (plant height, juice yield, ethanol yield, Brix%, reducing sugar%, juice extraction and syrup%). Different measures of traits within varieties signify differences in humidity and temperature events between the two environments. These results are in agreement with previous findings on sorghum (Showimimo *et al*., 2000; Almeida *et al.*, 2014). In different agro-ecologies, locales, and seasons, genotypes will respond differently (Werkissa, 2022).

MN83-11 and SS301-1 had a significantly higher value in stalk height than other varieties at El Giza and Alexandria. Also, SS301-1 and Tracy had higher stalk diameters compared to other varieties, and MN1500, MN83-11, and Umbrella had higher Brix% in both environments; however, these two environments varied in humidity percentage and temperatures.

Our results found wide genetic variability among the 15 varieties for plant height/cm, stalk diameter/cm, stalk yield ton/fed, juice yield ton/fed ethanol yield L/fed syrup yield ton/fed ,brix%,, sucrose%, reducing sugar%, fermentable sugar%, juice extraction%, purity% , and syrup%. There was a significant positive correlation between ethanol yield and juice yield, mainly due to direct effect.

Table 5. Correlation coefficients for thirteen traits in 15 sweet sorghum varieties grown in two environments over two sequential years. Traits includes stalk height(cm), stalk diameter(cm), Brix%, sucrose%, reducing sugar%, purity%, juice extraction%, fermentable sugar%, syrup%, stalk yield (Ton/fed), juice yield (Ton/fed),ethanol yield(L/fed) and syrup yield(Ton/fed)

	Syrup yield	Ethanol yeild	Juice yield d	Stalk yield	Syrup %	Fermentable sugar%	Juice extaction%	Purity %	Reducing suger%	Sucrose %	Brix%	Stalk diameter	Plant height/
Plant height	-0.048^{ns}	0.133^{ns}	0.126^{ns}	0.477**	-0.063^{ns}	0.029^{ns}	0.174*	-0.033^{ns}	-0.054^{ns}	0.084^{ns}	0.339**	0.617**	1
Stalk diameter	0.231**	0.189*	0.152*	0.634**	0.102^{ns}	0.141^{ns}	0.006^{ns}	-0.179*	0.206**	0.071^{ns}	-0.010^{ns}	1	
Brix%	-0.162*	-0.032^{ns}	-0.007^{ns}	-0.014^{ns}	-0.197**	-0.107^{ns}	0.042^{ns}	0.071^{ns}	-0.168*	-0.042^{ns}	1		
Sucrose%	0.243**	0.609**	0.333**	-0.084^{ns}	0.195**	0.919**	0.328**	0.659**	0.532**	1			
Reducing suger%	0.362**	0.716**	0.506**	0.129^{ns}	0.223**	0.821**	0.439**	0.429**	1				
Purity%	0.023^{ns}	0.501**	0.326**	-0.032^{ns}	-0.009^{ns}	0.645**	0.419**	1					
Juice extaction%	-0.030^{ns}	0.785**	0.819**	0.055^{ns}	-0.162*	0.424**	1						
Fermentable sugar%	0.329**	0.741**	0.458**	0.002^{ns}	0.232**	1							
Syrup%	0.811**	0.102^{ns}	-0.009^{ns}	0.14^{ns}	1								
Stalk yield	0.395**	0.273**	0.332**	1									
Juice yield	0.385**	0.924**	1										
Ethanol yeild	0.425**	1											
Syrup yield	1												

**,* = significant at 0.1% and 0.5% respectively

Generally, correlation analyses indicated a greater contribution of juice yield to higher ethanol yield, and syrup yield than brix alone, suggesting that improvements in high ethanol yield, and syrup yield could be achieved through selecting genotypes with high juice yield. These results agree with Rani and Umakanth (2012); Prasad *et al.* (2013); Rono *et al.* (2018).Who found that, the genotype that had the greatest ethanol yield also had the greatest juice yield. Juice composition affects the amount of ethanol produced (Widianto *et al*., 2010) and composition is affected by genotype, environment (Almodares and Hadi, 2009).

In this study, there was a strong positive correlation between ethanol yield and reducing sugars, which these results agree with Rani and Umakanth (2012).

CONCLUSION

Our results indicated the presence of significant interactions among varieties, years, and environments for most measured traits. This research established twenty-three moderate-to-strong correlations between multiple traits, yield, and quality components, which were significantly correlated in these studies, and are suggested to receive due attention during sweet sorghum varietal selection. Genotype is a significant source of variation for the majority of studied traits. MN83-11 and SS301-1 had a significantly higher value in stalk height than other varieties at El Giza and Alexandria. Also, SS301-1 and Tracy had higher stalk diameters compared to other varieties, and MN1500, MN83-11, and Umbrella had higher Brix% in both environments. Air temperature and humidity varied between years in the two environments studied, implying an influence on measured traits. Overall, these findings provide a solid foundation for breeding sweet sorghum in various target locations and elucidating the effects of climate on the studied characteristics.

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الملخص العربي

تاثيرات التركيب الوراثي والبيئة علي الصفات المحصولية والتكنولوجية لبعض أصناف الذرة السكرية

مروي مهدي أحمد غلاب وسمر عبد العاطي محمد حلمي

هدفت هذه الدراسة إلى معرفة تفاعل التركيب الوراثي والبيئة على الصفات المحصولية والتكنولوجية للذرة السكرية(Sorghum bicolor L.) تمت زراعة خمسة عشر صنف من الذرة السكرية في موقعين هما الجيزة (خط عرض ٣٠,٠١ شمالًا) والإسكندرية (خط عرض ٣١ درجة و ١٢ شمالًا)على مدار عامين متتاليين (٢٠٢٠ و ٢٠٢١). أثرت العوامل الوراثية (G) والبيئية (E) وسنوات الدراسة (Y)وتفاعلاتهم على غالبية الصفات تحت الدراسة. سجل الصنف Brands اعلي متوسطات في سبع صفات (سمك الساق، محصول الإيثانول، محصول الشراب، السكروز٪ ، نسبة السكر المختزلة، السكر القابل للتخمير٪ ، الشراب٪) و الصنف"Umbrella" كان أعلى محصول ساق ، محصول عصير، محصول إيثانول، نسبة استخلاص العصير، نسبة البركس ونسبة النقاء وذلك في الجيزة بينما وجد في الاسكندرية أن الصنف MN٨٣-١١ اعلي معنويا في سبعة صفات هما (طول النبات، محصول العصير، محصول الايثانول، نسبة السكروز، نسبة السكر المختزل، السكر القابل للتخمر%، الشراب%) و ايضا الصنف GK Ahronكان أكبرسمك ساق، محصول ساق، محصول عصير، محصول ايثانول، محصول شراب و نسبة شراب. كما وجد بعض الأصناف تفوقت في كلا الموقعين في بعض الصفات مثل الصنفين SS301-1, MN83-11 اعلي متوسط طول النبات و Tracy,SS301-1 اكبر سمك ساق وايضا Umbrella , MN83-11,MN1500 سجلوا اعلي نسبة بركس. لقد وجد ثمانية ارتباطات زوجية موجبة قوية وخمسة عشر ارتباطات زوجية موجبة متوسطة.