

Evaluation of some promising sugarcane genotypes for different levels of nitrogen fertilization by multivariate analysis

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ABSTRACT: The present experiment was conducted at El-Mattana Agriculture Research Station in Luxor Governorate, Egypt (latitude and longitude of 25.25°N and 32.31°E, respectively) to evaluate seven promising sugarcane genotypes compared with the commercial G.T.54-9 variety based on GGE biplot and to study the association among characters using the Biplot-Principal component analysis (PCA) under different levels of nitrogen fertilizer. Two plant cane crops were planted in 2021/2022 and 2022/2023 seasons. The results showed that increasing nitrogen levels had a significant effect on the number of millable canes/fed in both seasons. Among the tested genotypes, G.2004-27 and G.2005-47 consistently outperformed the other ones in terms of stalk weight, cane and sugar yields when they were fertilized with 250 kg N/fed in both seasons. Furthermore, G.2003-47 genotype recorded higher values of brix, sucrose, and sugar recovery percentages compared to other genotypes, indicating its genetic potential for high-quality sugarcane. The GGE-biplot technique indicated that the PC1, PC2 could explain 96.6% of total genotype × environment interactions (GEI) variation for cane yield, and explains 93.98% of total GEI variation for sugar yield. The analysis also identified two mega-environments for cane yield and three mega-environments for sugar yield. Correlation analysis showed a positive relationship between cane yield and millable cane weight, as well as between cane yield and sugar yield. Additionally, sugar yield exhibited a strong positive correlation with juice purity, sugar recovery, sucrose, and brix percentages. Conversely, the number of millable canes and the percentages of brix and sucrose were negatively correlated. These findings suggest that increasing cane yield and millable cane weight can contribute to higher sugar yield. Moreover, improving juice purity percentage can enhance sugar production efficiency. Based on the principal component analysis, it was found that planting G.2004-27 and G.2005-47 genotypes, fertilized with 250 kg N/fed produced the highest cane yield and millable cane weight. Supplying G.2004-27, G.2005-47, and G.T. 54-9 with 250 kg N/fed showed the highest performance., Growing G.2003-47 applied with 210 kg N/fed recorded the best values of brix%, sucrose%, and sugar recovery%. Additionally, G.99-80, G.2009-11 and G.2003-47 given 250 kg N/fed recorded the highest number of millable canes/fed. These results provide valuable insights for optimizing crop management practices and improving sugar production.

Keyword: Sugarcane, PCA, GGE-Biplot, genotype, correlation, nitrogen fertilization, quality, yield

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INTRODUCTION

In Egypt, sugarcane crop is the second source for sugar production after sugar beet. The domestic consumption of sugar has been drastically increased from 501.00 thousand tons in 1972 to 3.37 million tons in 2022 due to the continuous increase of population (Sugar Crops Council, 2022). The strategy of the Egyptian government is to increase the productivity of sugarcane per unit area, along with widening area of sugar beet in the newly

reclaimed soils. Extracting sugar from cane crop, is one of the oldest industries in Egypt. In respect to raising the productivity of sugarcane crop, it has high nitrogen requirements due to its high biomass as a robust tillering C4 plant. Nitrogen is considered most essential and limiting element for growth, yield and quality of such crop. Yet, its optimum management of nitrogen requirement remains somewhat elusive goal. Excessive nitrogen

application may suppress sucrose content, delay its maturity and cause lodging, while the primary effect of insufficient nitrogen is to lower yield biomass, in respect to decreasing its stalk length, diameter and weight, as well as decreasing number of millable canes per unit area. Several investigators reported that cane yield was increased with increasing nitrogen level. Ismail and El-Sogheir (2008), Ahmed et al. (2008), Abdel-Kader et al. (2019) and Yousif et al. (2021).

Sugarcane variety is regarded as the foundation of the sugar business. The commercial variety G.T.54-9 occupies the majority of Egypt's sugarcane planting area. The Sugar Crops Research Institute has recently generated a number of promising sugarcane genotypes, among them G.2003-47 and G.2004-27 (Mehareb et al. 2022a). Sugarcane varieties must have desired characteristics such as stalk length, diameter, fresh weight, number of millable canes/fed, along with high sucrose content and sugar recovery percentages, etc. Soil, meteorological conditions, and agronomic techniques all have an impact on the genotypes of cane, which in turn has an impact on all of the qualities that constitute extractable sugar. Numerous investigations recorded a wide variability among sugarcane genotypes in yield, its components, and the characteristics that determine juice quality. Yousif et al., 2015; Mehareb et al., 2015; Mehareb et al., 2017; Abazied 2018; Abo Elenen et al., 2018 Abo El-hamd et al., 2019, Ahmed et al., 2020, Yousif et al., (2021) and Yousif et al. (2023).

Breeders frequently employ the principal component analysis (PCA) biplot, a clever breeding tool, to identify traits that may be used to select elite genotypes. Identifying the variability among the traits that contribute to high yielding would be essential for establishing an effective breeding programme (Johnson, 2012; Abo Elenen et al., 2019 and Mehareb et al. 2021). A multivariate approach called Principal Component Analysis (PCA) classifies observations based on a variety of inter-correlated quantitative variables (Mehareb and El-Mansoub 2020; Fahmy et al. 2021 and El-manhaly et al. 2023). Variety identification with both particular and broad adaptation can be supported by the GGE-biplot model, which also serves as superiority indices (Mehareb et al. 2022b).

The aim of this study was to evaluate and define the promising sugarcane genotypes based on GGE-biplot and to study the association among characters using the Biplot-Principal component analysis (PCA) under different levels of nitrogen fertilization conditions.

MATERIALS AND METHODS

This work was carried out at El-Mattana Agriculture Research Station (latitude of 25.25°N and longitude of

32.31°E), Agricultural Research Center, Luxor Governorate, Egypt on two plant cane crops in 2021/2022 and 2022/2023 seasons to study the effect of four nitrogen fertilization levels (190, 210, 230 and 250 kg N/fed) on yield and quality of seven promising genotypes of sugarcane: G.99-80, G.2004-27, K.81113, G.2009-11, G.2005-47, G.2000-5 and G.2003-47 in addition to G.T.54-9 commercial variety. The randomized complete block design was used, in a split plot arrangement, with three replications as outlined by Gomez and Gomez (1984). The four nitrogen fertilization levels were distributed in the main plots, while the eight sugarcane genotypes were planted at random in the sub plots. The area of each sub plot was 42 m², which included six rows of 7-m in length and 1-m in width. Sugarcane genotypes were planted in the mid-March using two rows of three-budded/setts and harvested at age of 12 months. Nitrogen was applied as urea (46 % N) in three equal doses, (after the 1st and 2nd hoeing and 30 days later, i.e. 45, 75 and 105 days from planting). Phosphorus fertilizer was added during land preparation at 60 kg P₂O₅/fed (4200 m²) as calcium super phosphate (15% P₂O₅), meanwhile, potassium fertilizer was added at 48 kg K₂O/ fed as potassium sulphate (48% K₂O) once, with the second N-dose. The other agronomic practices for growing sugarcane were done as recommended by the Sugar Crops Research Institute. Physical and chemical properties of the experimental soil are presented in (Table 1).

Recorded data

At harvest, the following traits were determined:

1. Number of millable canes/fed, which was counted in one square meter then converted into number per fed.
2. Millable cane weight (kg) was determined as an average of cane weight of the 20 millable canes sample. A representative sample of 20 millable canes from each plot was taken at random, stripped, cleaned and squeezed by an electric mill. The extracted juice was screened to determine the following traits:
3. Total soluble solids (brix percentage), which was determined using "Brix Hydrometer" standardized at 20° C.
4. Sucrose percentage, which was determined using "Sacharemeter" according to A.O.A.C. (1995).
5. Sugar recovery percentage was calculated as described by Yadav and Sharma (1980):

$$\text{Sugar recovery \%} = [\text{sucrose \%} - 0.4 (\text{brix \%} - \text{sucrose \%}) \times 0.73].$$
6. Cane yield/fed (ton), which was determined from the weight of the four middle guarded rows of each plot converted into value per fed.
7. Sugar yield/fed (ton) was estimated as follows:

Table 1: Physical and chemical properties of experimental soil.

Season		2018	2019
Mechanical analysis	Sand %	70.12	67.32
	Silt %	19.00	21.00
	Clay %	10.88	11.68
Soil texture		Sand loam	Sand loam
pH		8	7.8
Concentration of N (ppm)		20	30
Concentration of P (ppm)		11.00	10.4
Concentration of K (ppm)		31.2	28.2
		Cations meq/100g	
Chemical analysis	Na ⁺ Meq/100g	0.51	0.60
	K ⁺ Meq/100g	0.09	0.08
	Ca ⁺⁺ Meq/100g	0.31	0.50
	Mg ⁺⁺ Meq/100g	0.19	0.30
		Anions meq/100g	
Cl ⁻ Meq/100g		0.23	0.42
So ₄ ⁼ Meq/100g		0.27	0.37
HCO ₃ Meq/100g		0.59	0.69

Sugar yield/fed (ton) = cane yield/fed (ton) x sugar recovery %.

Table 2: Number of millable canes (thousand /fed) of the tested sugarcane genotypes as affected by nitrogen fertilization levels and their interactions, in 2021/2022 and 2022/2023 seasons

N level (kg/fed)	2021/2022 season								
	G.T.54-9	G.99-80	G.2004-27	K.81113	G.2009-11	G.2005-47	G.2000-5	G.2003-47	Mean
190	48.0	44.5	47.5	48.1	50.8	46.3	50.7	50.7	48.3
210	50.4	51.1	51.7	49.0	53.3	50.7	53.0	52.2	51.4
230	53.3	56.1	56.8	50.0	57.0	51.7	57.0	56.1	54.8
250	58.0	59.0	58.0	57.7	59.7	56.3	58.7	58.7	58.3
Mean	52.4	52.7	53.5	51.2	55.2	51.3	54.8	54.4	53.2
LSD	F	0.64		G	1.39		FxG	2.78	
2022/2023 season									
190	48.3	43.3	50.0	50.0	51.0	50.0	50.0	50.7	49.2
210	49.0	50.0	53.3	53.3	55.1	53.3	53.3	53.3	52.6
230	52.6	53.3	55.7	53.3	58.5	56.7	56.7	56.7	55.4
250	56.7	60.0	58.7	54.7	61.5	56.7	58.7	60.0	58.4
Mean	51.6	51.7	54.4	52.8	56.5	54.2	54.7	55.2	53.9
LSD	F	1.10		G	1.22		FxG	2.45	

F (nitrogen fertilizer level), G (sugarcane genotype) and FxG (interaction between them)

Statistical analysis

The collected data were statistically analyzed according to the procedures outlined by Snedecor and Cochran (1981). Means of significant variance were separated using LSD test at 5% probability level. The GEI was visualized using the GGE-biplot (genotype main effect plus G x E interaction) as shown by Tollo et al. (2020). The components were extracted using the principal component analysis (PCA) method as outlined by Harman (1976).

RESULTS AND DISCUSSION

Number of millable canes

Data in (Table 2) showed that increasing nitrogen levels up to 250 kg N/fad increased number of millable canes by (9.9, 6.8 and 3.5 thousand /fed) in the first season and (9.2, 5.8 and 2.9 thousand /fed) in the second season compared to 190, 210 and 230 kg N/fed, respectively. This outcome could be explained by nitrogen's ability to

Table 3: stalk weight (kg) of the tested sugarcane genotypes as affected by nitrogen fertilization levels and their interactions, in 2021/2022 and 2022/2023 seasons

N level kg/fed	2021/2022 season								
	G.T.54-9	G.99-80	G.2004-27	K.81113	G.2009-11	G.2005-47	G.2000-5	G.2003-47	Mean
190	1.03	0.76	1.39	1.06	0.85	1.32	0.94	0.97	1.04
210	1.26	1.05	1.51	1.14	1.05	1.45	0.94	1.06	1.18
230	1.44	1.16	1.58	1.14	1.14	1.57	1.04	1.14	1.28
250	1.44	1.34	1.67	1.24	1.25	1.67	1.05	1.24	1.36
Mean	1.29	1.08	1.54	1.15	1.07	1.50	0.99	1.10	1.22
LSD	F	0.05		G	0.04		FxG	0.08	
2022/2023 season									
190	1.11	0.99	1.18	0.89	0.95	1.25	0.72	0.87	0.99
210	1.33	1.06	1.39	0.90	0.97	1.32	0.82	1.05	1.10
230	1.38	1.07	1.54	1.01	1.19	1.55	1.05	1.05	1.23
250	1.41	1.15	1.66	1.03	1.21	1.63	1.21	1.38	1.34
Mean	1.31	1.06	1.44	0.95	1.08	1.44	0.95	1.09	1.17
LSD	F	0.07		G	0.02		FxG	0.04	

F (nitrogen fertilizer level), G (sugarcane genotype) and Fx G (interaction between them)

stimulate plant metabolism, which raises metabolites needed to build up plant organs like new tillers, as well as its role in improving the meristemic activity of plant tissues, which aids in the development of new organs. Ismail and El-Sogheir (2008), and Ahmed et al. (2008) also reported that the maximum values of the number of millable canes/m² were obtained with increasing nitrogen fertilization levels. In the same table sugarcane genotypes differed significantly in number of millable cans in both seasons. Sugarcane genotype G.2009-11 gave the highest number of millable cans (55.2 and 56.5 thousand/fed) compared with the other genotypes in the first and second seasons, successively. Moreover, the variance in number of millable cans between the three genotypes i.e. G.2009-11, G.2003-47 and G.2000-5 was insignificant in the first season only. In addition, insignificant difference in this trait was observed between the commercial variety G.T.54-9 and each of promising genotypes i.e. G.2004-27 and G.2005-47 in the first season. Genetic variations in a variety's ability to generate more millable cane tillers at harvest and higher survival may be the cause of variance in the number of millable canes. This has been shown by Abo El-hamd *et al.*, 2019, Mehareb *et al.*, 2015 and Yousif *et al.*, (2021) that there are variations in the number of millable canes amongst sugarcane genotypes.

Number of millable canes was significantly influenced by the interaction between the tested cane genotypes and nitrogen fertilization levels in both seasons. In general, all genotypes increased significantly in number of millable canes when fertilized at 250 kg N/fed. Also, the differences between the commercial variety G.T.54-9 and the other tested genotypes were insignificant when fertilized at 250 kg N/fed in 1st season only. The highest number of millable canes/fed (59.7 and 61.5 thousand/fed) was obtained from promising genotype G.2009-11 when it was fertilized with 250 kg N/fed.

Stalk weight

Results in (Table 3) cleared that increasing nitrogen fertilization levels up to 250 kg/fed significantly increased stalk weight by (0.32, 0.18 and 0.08kg), respectively compared to that obtained at 190, 210 and 230 kg N/fed, in the 1st season, corresponding to (0.34, 0.23 and 0.11 kg), respectively in the 2nd one (Abdel-Kader et al., 2019; Yousif et al., 2021). The promising cane genotypes viz. G.2004-27 and G.2005-47 significantly surpassed the other genotypes in stalk weight in both seasons. While, the promising genotype G.2000-5 recorded the lightest stalk weight (0.99 and 0.95 kg) in both seasons, respectively. This outcome might be the result of genetic variations among types having an impact on the components of stalk weight—stalk diameter and height. The current study's findings are consistent with those of (Yousif et al., 2015; Abazied 2018; Abo El-hamd et al., 2019 and Ahmed *et al.*, 2020), who discovered that there are notable differences across cane genotypes in terms of millable cane weight.

Stalk weight was significantly influenced by the interaction between the tested cane genotypes and nitrogen fertilization levels in both seasons. The two promising genotypes viz. G.2004-27 and G.2005-47 gave the highest stalk weight when they were fertilized with 250 kg/fed in both seasons.

Cane and sugar yields/fed

Data in Table 4 cleared that cane yield ton/fed was significantly affected by increasing nitrogen levels in both seasons. Increasing nitrogen levels up to 250 kg N/fed increased cane yield by (13.7, 9.5 and 4.6 ton /fed) and sugar yield by (2.7, 1.9 and 1.0 ton/fed) compared to 190, 210 and 230 kg N/fed in the first season, respectively, corresponding to (11.3, 7.3 and 4.2 ton /fed) and (1.9, 1.3

Table 4: Cane yield (ton/fed) of the tested sugarcane genotypes as affected by nitrogen fertilization levels and their interactions, in 2021/2022 and 2022/2023 seasons

N level (kg/fed)	2021/2022 season								
	G.T.54-9	G.99-80	G.2004-27	K.81113	G.2009-11	G.2005-47	G.2000-5	G.2003-47	Mean
190	43.3	25.4	44.2	34.0	32.1	41.1	31.7	41.4	36.6
210	47.2	28.9	47.5	42.9	36.4	47.2	34.4	42.3	40.9
230	51.4	37.1	55.7	47.4	42.9	51.4	36.0	44.2	45.8
250	54.2	42.7	58.2	54.0	47.9	56.0	42.7	47.0	50.3
Mean	49.0	33.5	51.4	44.6	39.8	48.9	36.2	43.7	43.4
LSD	F	0.93		G	1.09		FxG	2.19	
2022/2023 season									
190	46.9	26.5	49.4	38.0	36.0	45.9	32.3	39.5	39.3
210	49.7	29.6	51.9	47.7	40.3	49.5	36.6	41.3	43.3
230	52.5	41.0	54.5	45.2	44.0	49.6	37.3	47.4	46.4
250	54.1	43.0	60.0	51.4	46.5	58.5	40.4	51.1	50.6
Mean	50.8	35.0	54.0	45.6	41.7	50.8	36.6	44.8	44.9
LSD	F	1.14		G	1.06		FxG	2.12	

F (nitrogen fertilizer level), G (sugarcane genotype) and FxG (interaction between them)

and 0.8 ton/fed) in the second season. The application of nitrogen fertilization increased cane yield because nitrogen is essential for the development of metabolites, the activation of enzymes, and the accumulation of carbohydrates that go from leaves to the declining stalk. These processes increased the number of millable canes, the weight of the stalk, and ultimately the amount of cane yield per unit area. These results are consistent with those of (Ahmed et al., 2008; Abdel-Kader et al., 2019; Yousif et al., 2021).

An increase in sugar yield relative to nitrogen fertilizer was primarily due to increase in cane yield and sugar recovery. These results are in agreement with Sugarcane variety G.2004-27 gave the highest cane yield (51.4 and 60.0 ton/fed) and sugar yield (5.8 and 6.3 ton/fed) compared with the other genotypes in the first and second seasons, successively. Moreover, insignificant difference in cane and sugar yields was observed between the commercial variety G.T.54-9 and G.2005-47 in both seasons. This superiority of G.2004-27 variety in cane yield mainly attributed to its superiority in millable cane weight (Table). These results are in agreement with those obtained by Yousif et al., 2015, Mehareb et al., 2015, Mehareb and Galal., 2017 and Yousif et al., (2023) discovered significant differences in cane yield/fad among types. In both seasons, the interaction between the tested cane genotypes and nitrogen fertilization levels had a considerable impact on cane and sugar yields. When fertilized with 250 kg N/fed in both seasons, the two promising types, G.2004-27 and G.2005-47, produced the highest cane and sugar yields.

Quality

Quality traits of sugarcane such as brix, sucrose and sugar recovery percent (Table) were significantly by difference levels of nitrogen fertilizers. Increasing

nitrogen levels from 190 up to 250 kg N/fed increased brix by (15.4 and 11%), sucrose by (22.3 and 11.8%) and sugar recovery by (26 and 12.1%) in the first and second seasons, respectively (Ismail and El-Sogheir, 2008 and Yousif et al., 2021).

Sugarcane variety G.2003-47 gave significantly higher brix% (20.8 and 21.5%), sucrose (18.3 and 18.7%) and sugar recovery (12.6 and 12.8%) over the other genotypes in the first and second seasons, respectively. However, the variance in quality traits between sugarcane variety G.2003-47 and G.99-80 were insignificant during the first season only. In addition, insignificant difference in brix%, sucrose% and sugar recovery% was observed between the commercial variety G.T.54-9 and each of promising genotypes i.e. G.2004-27 and G.2005-47 in the first season. Improvement in brix%, sucrose% and sugar recovery% in sugarcane variety G.2003-47 may be due to its genetic potential compared to other genotypes. Mehareb et al., 2015; Abazied 2018; Abo El-hamd et al., 2019, and Yousif et al., (2023).

In both seasons, the interaction between nitrogen fertilizer levels and tested sugarcane genotypes was significant of brix, sucrose and sugar recovery percent (Tables 4, 5, 6, 7 and 8). Sugarcane variety G.2003-47 recorded the highest brix (21.9 and 21.9%), sucrose (19.5 and 19.1%) and sugar recovery (13.6 and 13.1%) when it was fertilized with 250 kg N/fed in the first and second seasons, respectively.

Furthermore, there was no difference in brix%, sucrose%, or sugar recovery% when sugarcane variety G.2003-47 was fertilized with 230 and/or 250 kg N/fed in both seasons.

Furthermore, the differences in brix% and sucrose% in the first season and sugar recovery% in both seasons between the commercial variety G.T.54-9 and each of the promising genotypes, namely G.2003-47, G.2004-27, and G.2005-47, were minor.

Table 5: sugar yield (ton/fed) of the tested sugarcane genotypes as affected by nitrogen fertilization levels and their interactions, in 2021/2022 and 2022/2023 seasons

N level (kg/fed)	2021/2022 season								
	G.T.54-9	G.99-80	G.2004-27	K.81113	G.2009-11	G.2005-47	G.2000-5	G.2003-47	Mean
190	4.6	2.8	3.5	3.3	3.3	4.2	3.3	4.7	3.7
210	4.9	3.5	5.2	4.3	3.9	5.3	4.1	5.1	4.5
230	5.4	4.7	7.0	4.7	4.7	6.3	4.6	6.0	5.4
250	7.3	5.8	7.5	5.8	6.2	7.2	5.4	6.4	6.4
Mean	5.5	4.2	5.8	4.5	4.5	5.7	4.4	5.5	5.0
LSD	F	0.11		G	0.33		FxG	0.65	
N level (kg/fed)	2022/2023 season								
	G.T.54-9	G.99-80	G.2004-27	K.81113	G.2009-11	G.2005-47	G.2000-5	G.2003-47	Mean
190	5.4	2.7	5.6	3.9	3.7	5.8	3.5	4.8	4.4
210	5.8	3.4	5.9	5.2	4.3	5.8	4.2	5.4	5.0
230	6.5	4.8	6.3	5.0	5.2	5.9	4.4	6.1	5.5
250	6.9	5.4	7.7	5.8	5.7	7.5	5.0	6.7	6.3
Mean	6.2	4.1	6.3	5.0	4.7	6.3	4.3	5.7	5.3
LSD	F	0.12		G	0.11		FxG	0.23	

F (nitrogen fertilizer level), G (sugarcane genotype) and FxG (interaction between them)

Table 6: Brix% of the tested sugarcane genotypes as affected by nitrogen fertilization levels and their interactions, in 2021/2022 and 2022/2023 seasons

N level (kg/fed)	2021/2022 season								
	G.T.54-9	G.99-80	G.2004-27	K.81113	G.2009-11	G.2005-47	G.2000-5	G.2003-47	Mean
190	18.6	18.9	19.0	16.5	18.8	19.4	16.9	19.2	18.4
210	19.3	20.9	20.7	17.1	18.9	19.5	21.3	20.8	19.8
230	21.8	21.1	21.2	19.0	18.9	19.9	21.1	21.3	20.5
250	21.8	21.9	21.3	19.4	20.9	21.4	21.4	21.9	21.3
Mean	20.4	20.7	20.5	18.0	19.4	20.1	20.2	20.8	20.0
LSD	F	0.19		G	0.41		FxG	0.81	
N level (kg/fed)	2022/2023 season								
	G.T.54-9	G.99-80	G.2004-27	K.81113	G.2009-11	G.2005-47	G.2000-5	G.2003-47	Mean
190	19.8	18.9	19.9	16.5	17.7	16.4	18.4	21.1	18.6
210	19.9	20.2	20.4	17.9	18.9	19.4	19.9	21.2	19.7
230	20.0	20.9	20.9	18.8	19.8	20.4	19.9	21.9	20.3
250	20.4	20.9	21.8	18.9	19.9	20.4	21.0	21.9	20.7
Mean	20.0	20.2	20.8	18.0	19.1	19.2	19.8	21.5	19.8
LSD	F	0.38		G	0.17		FxG	0.35	

F (nitrogen fertilizer level), G (sugarcane genotype) and FxG (interaction between them)

Table 7: Sucrose% of the tested sugarcane genotypes as affected by nitrogen fertilization levels and their interactions, in 2021/2022 and 2022/2023 seasons

N level (kg/fed)	2021/2022 season								
	G.T.54-9	G.99-80	G.2004-27	K.81113	G.2009-11	G.2005-47	G.2000-5	G.2003-47	Mean
190	15.6	16.0	13.1	14.3	15.6	15.5	15.1	16.5	15.2
210	15.6	17.7	16.5	14.6	16.0	16.6	17.7	17.7	16.5
230	16.5	18.3	18.3	15.1	16.1	17.6	18.5	19.4	17.5
250	19.3	19.5	18.7	16.1	18.6	18.7	18.6	19.5	18.6
Mean	16.8	17.9	16.7	15.0	16.6	17.1	17.4	18.3	17.0
LSD	F	0.18		G	0.66		FxG	1.32	
N level (kg/fed)	2022/2023 season								
	G.T.54-9	G.99-80	G.2004-27	K.81113	G.2009-11	G.2005-47	G.2000-5	G.2003-47	Mean
190	17.0	15.4	16.7	14.8	15.2	17.0	15.8	17.8	16.2
210	17.2	16.9	16.9	15.8	15.8	17.1	16.9	18.8	16.9
230	17.8	17.5	17.2	16.2	17.2	17.6	17.2	18.9	17.5
250	18.4	18.2	18.8	16.4	17.6	18.3	18.2	19.1	18.1
Mean	17.6	17.0	17.4	15.8	16.4	17.5	17.0	18.7	17.2
LSD	F	0.21		G	0.12		FxG	0.25	

F (nitrogen fertilizer level), G (sugarcane genotype) and FxG (interaction between them)

GGE biplot: genotypic discriminating ability and representativeness of the studied environments

The GGE-biplot technique presented that the PC1, PC2 could explain 96.6% of total genotype × environment

interactions (GEI) variation for cane yield, and explain 93.98% of total GEI variation for sugar yield, respectively (Figures 1, 2). The GGE biplot graph's genesis is near stable genotypes and settings with low IPCA-1 and IPCA-2 scores (Yan and Tinker 2005 and Mehareb et al., 2022b).

Table 8: Sugar recovery% of the tested sugarcane genotypes as affected by nitrogen fertilization levels and their interactions, in 2021/2022 and 2022/2023 seasons

N level (kg/fed)	2021/2022 season								
	G.T.54-9	G.99-80	G.2004-27	K.81113	G.2009-11	G.2005-47	G.2000-5	G.2003-47	Mean
190	10.5	10.8	7.9	9.8	10.4	10.2	10.5	11.3	10.2
210	10.3	11.9	10.9	9.9	10.8	11.2	11.8	12.0	11.1
230	10.5	12.5	12.6	9.9	10.9	12.2	12.7	13.6	11.9
250	13.4	13.6	12.9	10.7	12.9	12.8	12.7	13.6	12.8
Mean	11.2	12.2	11.0	10.1	11.3	11.6	11.9	12.6	11.5
LSD	F	0.17		G	0.68		FxG	1.36	
2022/2023 season									
190	11.6	10.2	11.2	10.3	10.3	12.6	10.8	12.0	11.1
210	11.7	11.4	11.4	10.9	10.6	11.8	11.5	13.1	11.5
230	12.4	11.8	11.5	11.0	11.8	12.0	11.8	12.9	11.9
250	12.8	12.5	12.8	11.2	12.2	12.8	12.4	13.1	12.5
Mean	12.1	11.5	11.7	10.9	11.2	12.3	11.6	12.8	11.8
LSD	F	0.15		G	0.14		FxG	0.29	

F (nitrogen fertilizer level), G (sugarcane genotype) and FxG (interaction between them)

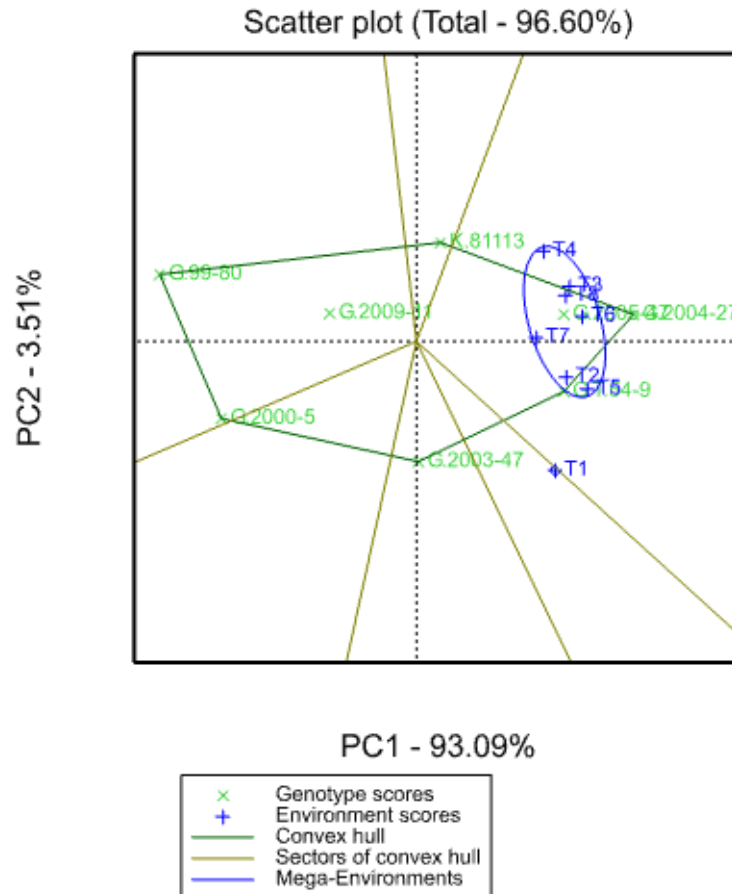


Figure 1 Which-won-where polygon view of the GGE biplot for cane yield of 8 sugarcane genotypes (G) in 8 different treatments (T) to show that sugarcane genotype performed superlative in which environment and significant mega environment

2022b). An equality line divides which-won-where GGE-biplot charts into sectors where different mega environments are discernible (Yan and Tinker 2006). In this trial, the equality line divided the tested treatments

into two and three mega- environments for cane and sugar yield (Figures 1 and 2). For cane yield, the first mega environment consisted of all treatments except first treatment (190 Kg N/fed), however, T1 and T6 (190 and

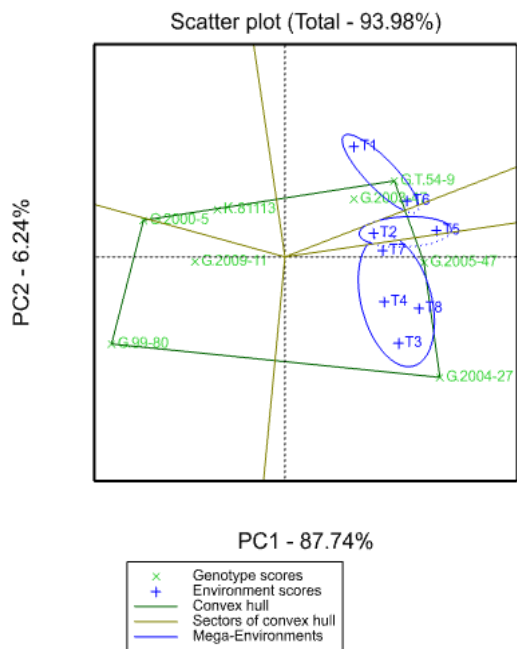


Figure 2: Which-won-where polygon view of the GGE biplot for sugar yield of 8 sugarcane genotypes (G) in 8 different treatments (T) to show that genotype performed superlative in which environment and significant mega environment Cane

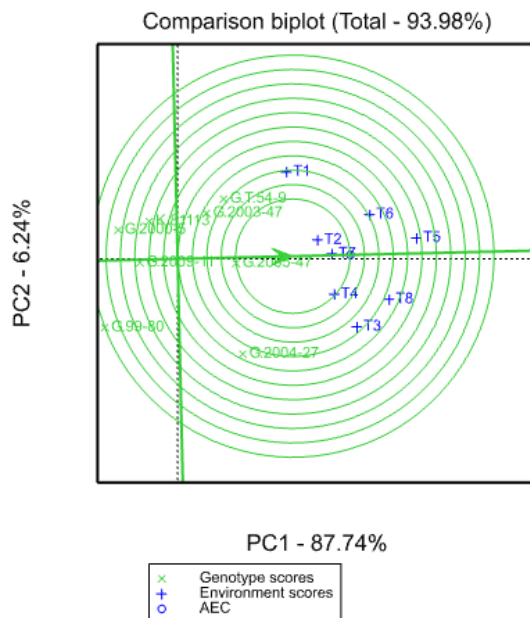


Figure 4: GGE Biplot of the discrimination and representative among the environments of 8 sugarcane genotypes for the sugar yield with applying nitrogen fertilization levels

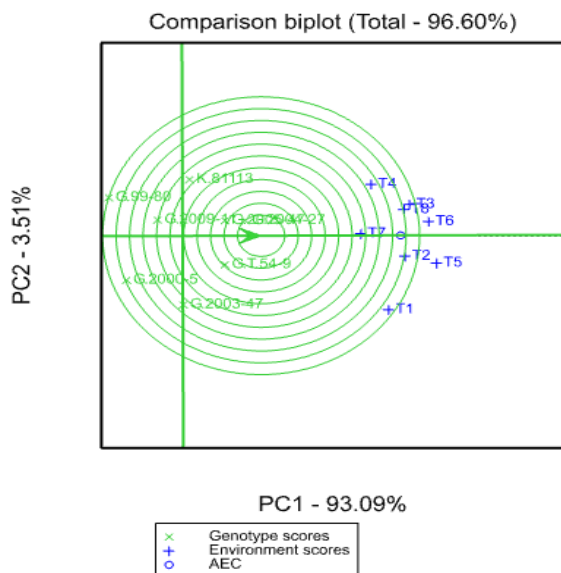


Figure 3: GGE Biplot of the discrimination and representative among the environments of 8 sugarcane genotypes for the cane yield with applying nitrogen fertilization levels

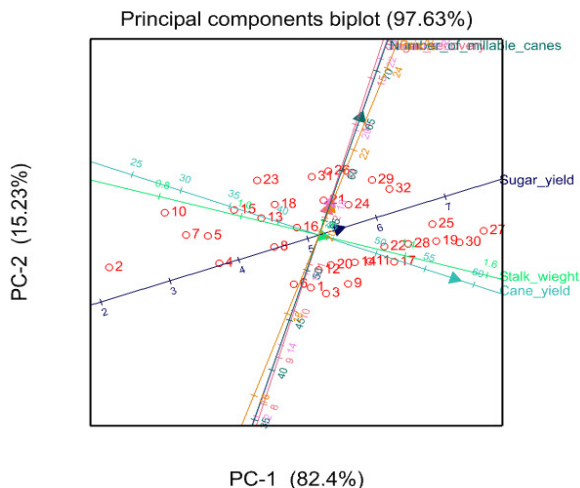


Figure 5: Biplot based on principal component analysis for cane and quality traits in sugarcane genotypes (G1= GT 54-9, G2= G.99-80 G3=G2004-27,G4= K 81113, G5=G.2009-11, G6=G 2005-47, G7=G.2000-5 and G8=G.2003-47) under four nitrogen fertilization levels (T1=190, T2= 210, T3= 230 and T4= 250 Kg N/fed)) with 32 combinations; Q1=(G1,N1), Q2= (G2,N1), Q3=(G3,N1), Q4=(G4, N1), Q5=(G5,N1), Q6= (G6,N1), Q7=(G7,N1), Q8=(G8, N1), Q9=(G1,N2), Q10= (G2,N2), Q11=(G3,N2), Q12=(G4, N2), Q13=(G5,N2), Q14=(G6,N2), Q15=(G7,N2), Q16=(G8, N2), Q17=(G1,N3), Q18= (G2,N3), Q19=(G3,N3), Q20=(G4, N3), Q21=(G5,N3), Q22= (G6,N3), Q23=(G7,N3), Q24=(G8, N3), Q25=(G1,N4), Q26= (G2,N4), and the percentage of sucrose.

210 Kg N/fed), were part of the first mega environment for sugar yield. The distances between each environment and the ideal environment, the "model studied environment," which is located in the center of the concentric circles (Mehareb et al 2022b), Consequently, from T2 to T8 for cane yield (Figure 1) and T1 and T6 for sugar yield (Figure 2), respectively were the highest representative treatment and had the maximum ability for discriminating genotypes with respect to cane and sugar yield. The vertex genotype connected by the polygon in (Figures 3 and 4) were G 2004-27, GT 54-9 and G 2005-47 for cane yield (Figure 4). Furthermore, G 2004-27 and G2005-47 were the vertex genotype for sugar yield (Figure 4). Based on their direction from origin, the vertex genotypes were the extremes from the GGE biplot's origin, indicating that they were either the best at producing sugar in all or some of the environments (Tollo et al. 2020 and Mehareb et al 2022b). Figure 5 display highly significant and positive correlation between cane yield and millable cane weight, then cane yield and sugar yield followed by cane yield and number of millable canes. Gadallah and Mehareb (2020) found genotypic correlation among Millable cane weight, number of millable canes and cane yield. Furthermore, the number of millable canes showed a positive and highly directed effect on cane yield, according to Kumar and Kumar (2014). On the other hand, a strong positive link was also found between the weight of millable cane and number of millable canes, according to (Jamoza et al. 2014 and Mehareb et al 2023). Sugar yield had a strong positive correlation with juice purity percentage, followed by sugar recovery percentage, sucrose percentage, and brix percentage. The number of millable cane and the percentages of brix and sucrose were shown to be negatively correlated. These results are agreement with Tadesse and Dilnesaw (2014), who found a negative and significant correlation between the millable cane number. On the other hand, results in Figure 5 presented that Q27=(G.2004-27,N4) and Q30=(G 2005-47,N4) = were the highest genotypes in cane yield and millable cane weight, while Q27=(G2004-27,N4), Q30=(G 2005-47,N4) and Q25=(GT 54-9,N4) were the highest in sugar yield. In addition, Q24=(G.2003-47, N3),, Q26=(G.99-80 ,N4), and Q32=(G.2003-47, N4) were the best genotypes in brix% , sucrose% and sugar recovery% Q26=(G.99-80 ,N4), Q29=(G.2009-11,N4) and Q32=(G.2003-47, N4) were the highest genotypes in number of millable cane and the percentage of sucrose. On the other hand, results in Figure 5 presented that Q27=(G.2004-27,N4) and Q30= In addition, Q24=(G.2003-47, N3),, Q26=(G.99-80 ,N4), and Q32=(G.2003-47, N4) were the best genotypes in brix% , sucrose% and sugar recovery% Q26=(G.99-80 ,N4), Q29=(G.2009-11,N4) and Q32=(G.2003-47, N4) were the highest genotypes in number of millable cane.

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