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RESEARCH ARTICLE

Stability and ratooning ability of some sugarcane genotypes under Upper-Egypt conditions

Ebid, M.H.M. *, A. El-Bakry and E.M.M. Yousif

Sugar Crops Research Institute, Agricultural Research Center, 12511 Giza, Egypt.

Abstract

The present study was carried out at El-Mataana Agricultural Research Station, Agricultural Research center, Luxor Governorate (Latitude 25°41′N, Longitude 32°39′E) in three crop seasons 2018/19, 2019/20 and 2020/21 (PC, FR and SR) to evaluate stability and ratoon ability of five sugarcane genotypes, namely (G.84-47, G.2003-47, G.2004-27 and C.57-14 compared with the commercial variety GT.54-9) under three-row distances (80, 100 and 120 cm). A strip block design was used. The results recorded that, the new variety G.2004-27 had the high cane and sugar yields followed by the cultivated variety GT.54-9 without significant difference between them only in sugar yield trait, whereas the lowest values were recorded by C.57-14 genotypes. The genotype G.2004-27 and the commercial variety GT.54-9 got their highest cane and sugar yields under 100 cm row distance in SR crop. The commercial variety GT.54-9 and G.2003-47 (new variety) had the 1st rank of RA under 80 cm row distance for cane yield, while under 100 cm row distance the cultivar GT.54-9 ranked in 1st where the new variety G.2003-47 ranked in 1st one under 120 cm row distance in the same trait. Although, the promising variety G.2003-47 was the most stable genotype in cane and sugar yields across tested environments.

Keywords: Performance and stability; Ratoon; Row distance; Sugarcane.

1. Introduction

Sugarcane (*Saccharum spp*.) crop is important one of the main crops for sugar production in the world. In Egypt cultivated sugarcane area more than 99% depends on one variety i.e. GT.54-9 and the total production of Egypt sugarcane sugar is representing about 81.7% of domestic demand. (Anonymous, 2021), Successful sugarcane breeding program requires necessary germplasm collection with flowering ability and desired traits to achieve the program objectives.

Sugarcane cropping system changed according to the specific conditions of each region or country, the level of farming advancement reflected the pragmatic skill of the growers, field administrators and agronomists in adapting the technologic under the influence and determination of environmental, economic and political factors. (e.g., Wilson *et al.*, 1996; Mariotti *et al*., 2006)

As has been supposed, the crop canopy will be defined by the combination of spacing, tillering model and leaves alignment. Due to management necessity and economic requirements, sugarcane plants are not showed in an ideal geometrical disposition in terms of light capture and even other resources. The most designs is to plant in rows with variable inter-row spacing but mostly between 1.00 to 1.80 meters, trying to adjust requirements of mechanization and other economic drivers, like drainage, weed control and plant propagation rate (Richard *et al.*, 1991; Kapur *et al.*, 2011). The rapid canopy closing in wider row spacing has a significant uncontrolled

***Corresponding author: Mahmoud H.M. Ebid**
Email: mahmoud.ebid@arc.sci.eg
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in weed control cost but, conversely, is said the cost of seed cane decrease significantly with increase in row spacing (Singels and Smit, 2002) and a compromise between those two contrasting factors should be met. However, the alleged higher cost of seed cane is a point requiring clearing.

Ratoon cane is very important in sugarcane production. The underground portion of the strikes gives rise to a succeeding crop that, after the harvest of sugarcane, which is called a ratoon crop. Sugarcane ratooning is a planting system that is generally adopted by each sugarcane-producing country. However, the number of ratoons varies from 1–8 (Singh *et al.*, 2015). The proportion of the ratoon cane is generally around 80% of the cultivated area in Egypt (Anonymous, 2021). The average proportion is 50–55% in tropical areas, while approximately 40–45% in subtropical areas (Gomathi *et al.*, 2013).

Ratooning increases the income of sugarcane growers due to the saving cost in cultivation, and increases the income of industry because of mature earlier, better juice quality and thus improves sugar recovery at times of the crushing season compared with plant cane (Singh *et al.*, 2015; Aslam *et al.*, 2020)

Good ratooning in sugarcane is useful for the farming communities as its production costs lower than the plant crop. Genetic variation among sugarcane genotypes for ratooning potential has been reported previously by researchers (Bhatnagar *et al.,* 2003; Rafiq *et al.,* 2006).

Many experiments conducted on plant cane and ratoon cane reported lower yields from wide row spacing (130, 140 and 180 cm) compared with narrow row spacing (90 and 60 cm), Sharma (1982) and Abd El-Lattief (2016).

The role in the amount of water transpired and solar radiation intercepted by cane crop canopy which intern affects ultimately the dry matter produced and the photosynthesis processes and sugar extracted by plant that more correlated with planting density. Moreover, planting density broadly affect millable cane length, diameter and weight as individual plants which contribute to yield of cane, according to Collins (2002). Plant density is a function of intra and inter-row spacing. Sugarcane has a high compensating ability to maintain potential cane yield under different cases of row spacing and population density (Netsanet *et al*., 2014).

The planting density directly effects on the millable cane diameter, millable cane height and number of millable canes which are positively correlated with cane yield per unit area (Nazir *et al.,* 1999). One of the most serious factors reducing sugarcane yield is inappropriate planting density (Bashir *et al.,* 2000). Optimal planting density results in perfect plant population density and hence a high number of millable canes per unit area which is the key component of cane yield (Mahmood *et al.,* 2005; Gadallah *el al.,* 2020).

Sugarcane (*Saccharum spp.*) improvement programs worldwide depend on collection of many sugarcane genetic resources. Interspecific hybridization involving cultivated and wild species of *Saccharum* has formed the basis of varietal improvement programs (Amalrai and Balasundaram, 2016). Breeders and agronomists charged with the responsibility of selecting commercial variety among promising varieties. Egyptian sugarcane breeding program objectives are high cane and sugar yields and good ratooning ability (Mohamed *et al*., 2019). The commercial GT.54-9 variety was superior in and variety G.2003-47 was superior in brix%, sucrose% and SR%, meanwhile, variety G.2004-27 attained the highest number of MC/fed (Gadallah *et al.,* 2020).

The objective of this paper to evaluate stability and ratoon ability of five sugarcane genotypes compared with the commercial variety under three-row distances and the performance of these genotypes for ratooning ability and stability under different row distance.

2. Materials and methods

The present study was carried out at El-Mattaana location, Agriculture Research Center Station, Luxor Governorate (Latitude 25°41′N, Longitude 32°39′E) five sugarcane genotypes complex hybrids of *Saccharum spp.* namely G.84-47, G.2003-47, G.2004-27 and C.57-14 compared with the commercial variety GT.54-9 (genotypes parentage in Table 1) were used for stability and ratooning ability under different three row distance, as well as, yield and some of its attributes. Sugarcane seed sets were planted as spring in second week of March 2018 as plant cane crop. Cane harvest was after 12 months from planting or harvest of plant cane or harvest of first ratoon. Crop seasons, plant cane (PC), 1st (FR) and 2nd (SR) ratoon crops during 2018/19, 2019/20 and 2020/21 harvest seasons, respectively. The experiments were planted at El-Mataana. All genotypes were planted with three different row spacing (80, 100 and 120 cm row distance) rates of seeds was twenty five 3-budded cane pieces in each row. The experiments were laid out in a strip block design with three replications. The experimental unit area was 60 m^2, including 15, 12 and 10 rows in the case of spacing 80, 100 and 120 cm spacing, respectively and 5 m in length. The experimental soil was clay having pH of 7.72, EC (1.8 dsm^{-1}) and with organic matter of 0.95 (%).

Table 1. Sugarcane genotypes used in this study and their parentage.

Genotypes	Parentage	Production location
G.84-47	NCo.310 x ? (Polly cross)	Local's fuzz
G.2003-47	CP.55-30 x 85-1697	Local's fuzz
G.2004-27	CP.55-30 x Roc.22	Local's fuzz
C.57-14	C.88-553 x (Polly cross)	Imported fuzz
GT.54-9	NCo.310 x F.37-925	Egypt Cultivated variety

Each row was planted by 21 three budded cane cuttings. Field was irrigated immediately right after planting and all other agronomic practices were carried out as recommended by Sugar Crops Research Institute (Nitrogen fertilizer was applied as urea which was split into two equal doses; after 60 and 90 days from planting in the plant cane crop, whereas, after 30 and 60 days from harvest of previous cane crop in 1st and 2nd ratoon crops, phosphorus was added once during seed-bed preparation as calcium super phosphate and potassium was added once as potassium sulfate with the 2nd dose of N fertilizer. The other agricultural practices were done as recommended.

Middle rows were harvested and data were recorded at harvest, for the three crop years; plant cane (PC), first ratoon (FR) and second ratoon (SR) as follows:

2.1. Growth traits

- Millable cane height, cm: Measured from the soil surface up to the top visible dewlap as average of fifteen plants were taken at random from middle of each subplot.
- Millable cane diameter, cm: The same stalks were measured from the middle internode diameter.

2.2. Juice quality traits

A sample of 20 millable cane stalks from each plot were taken at random, topped, stripped, cleaned then squeezed by an electric pilot mill and the extracted juice was left to settle to remove the foams and setting the sediments before starting analysis of the following characters:

- Sucrose percentage: calculated according to the following equation (A.O.A.C., 2010).
- Sucrose percentage = direct reading of saccharimeter x 1.04

- Where, 1.04 is a constant factor.
- Sugar recovery was calculated according to the formula described by Yadav and Sharma (1980).
- Sugar recovery = [S – 0.4 (B-S)] x 0.73
- Where: B =Brix reading was estimated by using Brix hydrometer, S =Sucrose percentage, 0.4 and 0.73 constants.

2.3. Yield traits

Millable canes of the middle three rows from each plot were harvested to determine the following measurements:

- Number of millable canes in thousand/fed
- Stalk weight (kg) was determined as mean of millable cane weight.
- Cane yield (ton/fed) millable cane weight (kg/plot), which was converted to ton/fed.
- Sugar yield (ton/fed) was calculated according to the following formula
- Sugar yield (ton/fed) = (cane yield (ton/fed) x sugar recovery percentage)/100

2.4. Ratoon ability (RA)

The other two methods estimate the RA of a genotype as the average performance of the FR and SR in comparison with the PC yield. The method described by Dunckelman (1982) calculated the RA of a trait i as RAi = ((FR/PC) + (SR/PC))/2.

2.5. Statistical analysis

A split plot design with three replications was used. Seed rates were allocated in the main plots, while sugarcane genotypes were randomly distributed in the sub plots.

Analyses of variance for collected data were performed according to Gomez and Gomez (1984). The comparison among means was done using the least significant difference test (LSD).

The data obtained on different characters was analyzed for correlation coefficient using statistical software SPSS software (SPSS for Windows, SPSS Inc., Chicago, USA) for calculating correlation coefficients.

The following stability statistics were estimated for cane and sugar yields:

- The linear regression coefficient (bi) of genotypes mean on environmental index and the deviation mean square from regression (S^2_{di}) according to method of Eberhart and Russell (1966).
- Stability variance (σ^2_i) of genotypes estimated by Shukla (1972) equations.
- The ecovalence stability index (Wi) was estimated as developed by Wricke (1962).

3. Results and discussion

3.1. Growth traits

The combined data of the three cycles and three row distances for five genotypes in Table 2 showed that, the millable cane height and diameter (cm) were significantly different. The results cleared that, the millable cane height was increased by 10 and 4.2 cm for sugarcane grown as a 1st and 2nd ratoon, respectively, and the highest value was recorded in first ratoon (FR). On the contrary, the millable cane diameter was decreased by 12 and 31 mm for sugarcane stalk as a 1st and 2nd ratoon, respectively, and the highest value was recorded in plant cane (PC). Whereas, the significantly tallest millable cane was recorded in 100 cm than 80 and 120 cm row distance, on the other hand, the thickest millable cane was recorded in 120 cm and decreased the millable cane diameter for 100 then 80 cm row distance. While, the genotype G.2004.27 had the tallest millable cane and C.57-14 genotype the shortest one with significant difference between them (40.8 cm), on the contrary, the genotype C.57-14 recorded thickest cane millable cane (2.84 cm) than other studied genotype, while the thinnest one was G.84-47 genotype (2.38 cm).

The interaction between crop cycle (A) and row distance (B) was significant in both millable cane height and diameter. When, the millable cane height was increased from PC to FR and it was decreased for SR under both 80 and 100 cm row distance, while, the millable cane height was increased from PC to FR then SR under 120 cm row distance. As same, the increasing of millable cane diameter was recorded with increasing of row distance from 80 to 100 cm then decreased under 120 cm row distance that in all plant crop cycle. Where, millable cane diameter was increased with an increase of row distance either from PC to FR then SR.

The interaction between crop cycle (A) and genotypes (C) was significant in both millable cane height and diameter. Where, the millable cane height was increased significantly from PC to FR and it was decreased for SR for all genotypes except cultivated variety G.T54-9 and C.57-14 genotype was no significant difference between millable cane height in 1st and 2nd ratoon and the highest values were recorded by G.2004-27 and G.84-47 genotypes in 1st ratoon with no significant difference between them. Whereas, millable cane diameter for all genotypes was decreased from plant crop (PC) to First ratoon (FC) as same as to second ratoon (SR), were the highest significant value was recorded by C.57-14 genotype.

Table 2. Mean performance of five genotypes and three crop cycles for millable cane height and diameter under three row distances

Row distance (B)	Genotype (C)	Millable cane height (cm)				Millable cane diameter (cm)			
		Crop cycle (A)			Average	Crop cycle (A)			Average
		PC	FR	SR		PC	FR	SR	
80	GT.54-9	281.7	295.7	299.7	292.3	2.73	2.68	2.44	2.62
	G.2004-27	297.7	319.0	311.7	309.4	2.84	2.70	2.48	2.67
	G.84-47	295.0	317.7	302.0	304.9	2.37	2.37	2.22	2.32
	G.2003-47	285.0	293.0	282.7	286.9	2.58	2.55	2.34	2.49
	C.57-14	265.7	285.0	277.3	276.0	2.96	2.78	2.65	2.80
	Mean	285.0	302.1	294.7	293.9	2.70	2.62	2.43	2.58
100	GT.54-9	313.7	317.0	301.7	310.8	2.89	2.67	2.47	2.67
	G.2004-27	315.7	327.3	317.0	320.0	2.87	2.71	2.53	2.70
	G.84-47	315.7	325.3	307.3	316.1	2.45	2.40	2.30	2.38
	G.2003-47	290.7	296.7	287.7	291.7	2.66	2.58	2.37	2.53
	C.57-14	268.7	279.0	273.0	273.6	2.98	2.85	2.69	2.84
	Mean	300.9	309.1	297.3	302.4	2.77	2.64	2.47	2.63
120	GT.54-9	263.7	267.0	277.3	269.3	2.98	2.69	2.50	2.72
	G.2004-27	297.7	301.0	298.3	299.0	2.99	2.88	2.58	2.81
	G.84-47	294.0	300.0	290.3	294.8	2.55	2.42	2.34	2.44
	G.2003-47	276.0	279.0	273.3	276.1	2.71	2.62	2.39	2.57
	C.57-14	245.7	253.7	270.7	256.7	3.05	2.91	2.68	2.88
	Mean	275.4	280.1	282.0	279.2	2.86	2.70	2.50	2.69
	GT.54-9	286.3	293.2	292.9	290.8	2.87	2.68	2.47	2.67
	G.2004-27	303.7	315.8	309.0	309.5	2.90	2.76	2.53	2.73
	G.84-47	301.6	314.3	299.9	305.3	2.46	2.40	2.28	2.38
	G.2003-47	283.9	289.6	281.2	284.9	2.65	2.58	2.37	2.53
	C.57-14	260.0	272.6	273.7	268.7	3.00	2.85	2.68	2.84
Average		287.1	297.1	291.3		2.77	2.65	2.46	
LSD at 5%	A	7.11	B	3.6		A	0.2	B	0.1
	C	2.29	AxB	6.24		C	0.1	AxB	0.2
	AxC	3.97	BxC	3.97		AxC	0.2	BxC	0.2
	AxBxC	6.87				AxBxC	0.4		

The interaction between row distance (B) and genotypes (C) in Table 2, was different significantly in both millable cane height and diameter. Where, the millable cane height was increased for all genotypes from 80 to 100 cm row distance then decreased when row distance was 120 cm, Except the C.57-14 genotypes was shorter under 100 then 120 cm row distance than 80 cm row distance, while the tallest mean millable canes were recorded by G.2004-27 and G.84-47 genotypes when planted under 100 cm row pace. Whereas, the millable cane diameter was increased for all genotypes when increased the row distance from 80 to 100 cm then 120 cm row distance, while the thickest mean millable canes were recorded by G.2004-27 and G.84-47 genotypes when planted under 100 cm row pace.

The three ways interaction among crop cycle (A), row distance (B) and genotypes (C) was different significantly in both millable cane height and diameter in Table 2. The different genotypes had various response in millable cane height from crop cycle to other and from close row distance to wide, some genotypes get the highest values of genotypes were recorded under 100 cm row distance at 1st ratoon except C.57-14 genotype recorded the tallest mean millable cane under 80 cm row distance at 1st ratoon, while the highest values were recorded by G.2004-27 (new variety) and G.84-47 (old variety) when planted with 100 cm row distance at 1st ratoon crop with insignificant difference between them, whereas all genotypes had shortest millable cane when planted by 120 cm row distance at same crop cycle. A similar result was recorded by Singels and Smit (2002). On the contrary, the different genotypes had various response in millable cane height from crop cycle to other and from close row distance to wide, some genotypes but the highest values of genotypes were recorded under 120 cm row distance at plant cane, while the thickest mean millable canes was recorded by C.57-14 when planted with 120 cm row distance at 1st ratoon crop, that may be due to the genetic diversity and various responses of genotypes. These results approved with results of Rafiq *et al.* (2006).

3.2. Juice quality traits

The combined data of the three cycles and three row distances for five genotypes in Table 3 showed that, the juice quality traits i.e. sucrose% and sugar recovery% were significantly different, that may be due to the studied genotypes affected by studied factors in these traits.

The results in Table, 3 showed that, sucrose% was increased by significant difference by 0.26 % for juice as a 1st, where was decreased by insignificant difference in 2nd ratoon crop, and the highest value was recorded in first ratoon (FR) crop, while, sugar recovery % data was insignificant difference for the three crop cycles. On the other hand, the highest value of sucrose % and sugar recovery% were recorded in 120 cm row distance and decreased for 100 then 80 cm row distance, without significant difference between 120 and 100 cm row distance. Where, the new variety G.2003.47 had the highest values in sucrose and sugar recovery traits, while, in sugar recovery% the values were recorded by the three variety GT.54-9, G.84-47 and G.2004-27 with insignificant differences among them. On the contrary, C.57-14 genotype recorded the lowest values of sucrose and sugar recovery percentage. That may be due to genetic diversity, as same as, was recorded by Singels and Smit (2002).

The all two way interaction (crop cycle and row distance, crop cycle and genotypes and row distance and genotypes) recorded in Table 3, showed that the two way interaction crop cycle and row distance were different insignificantly in both sucrose and sugar recovery percentage traits. The interaction between crop cycle (A) and genotypes (C) were significant in sucrose and sugar recovery percentages traits. Where, both traits were increased significantly from PC to FR crop for all genotypes except C.57-14 genotype was decreased, and it were decreased insignificantly for all genotypes in SR crop except G.2004-27 and C.57-14 genotypes were increased. Whereas, the interaction between row distance (B) and genotypes (C) in Table 3, were different significantly in sucrose and sugar recovery%. Where, sucrose was significantly increased for all genotypes from 80 to 100 cm row distance while insignificantly increased when row distance was 120 cm.

The three ways interaction among crop cycle (A), row distance (B) and genotypes (C) was different significantly in sucrose% and not significant in sugar recovery %, as showed in Table 3. The different genotypes had various response in sucrose% from crop cycle to other and from close row distance to wide, some genotypes get the highest values of genotypes under 100 cm row distance at 1st ratoon with insignificant difference with the data of same genotypes at first and/or second ratoon under 120 cm row distance, on the contrary else genotypes, C.57-14 genotype recorded the highest mean value under 120 cm row distance at 2st ratoon without significant difference at SR under 100 cm row distance, while the highest values were recorded by G.2003-47 (new variety) when planted with 100 cm row distance at 1st ratoon crop with insignificant difference with other some genotypes. Alike results were recorded by Singels and Smit (2002) and Rafiq *et al*. (2006).

Table 3. Mean performance of five genotypes and three crop cycles for sucrose and sugar recovery percentage under three row distances

Row distance (B)	Genotype (C)	Sucrose% Crop cycle (A)			Average	Sugar recovery% Crop cycle (A)			Average
		PC	FR	SR		PC	FR	SR	
80	GT.54-9	15.66	16.06	15.96	15.89	10.35	10.74	10.60	10.56
	G.2004-27	15.47	15.81	15.95	15.74	10.08	10.44	10.60	10.37
	G.84-47	15.75	16.00	16.00	15.92	10.25	10.60	10.60	10.48
	G.2003-47	16.20	16.66	16.75	16.54	10.72	11.15	11.20	11.02
	C.57-14	14.07	13.83	13.88	13.93	8.82	8.59	8.63	8.68
	Mean	15.43	15.67	15.71	15.60	10.04	10.31	10.33	10.23
100	GT.54-9	16.25	16.32	16.35	16.31	10.88	10.94	10.97	10.93
	G.2004-27	15.91	16.35	16.36	16.21	10.72	10.91	10.97	10.87
	G.84-47	16.19	16.46	16.43	16.36	10.90	10.90	10.87	10.89
	G.2003-47	16.44	16.77	16.60	16.60	11.08	11.21	11.00	11.10
	C.57-14	14.37	14.34	14.52	14.41	9.44	9.05	9.23	9.24
	Mean	15.83	16.05	16.05	15.98	10.60	10.60	10.61	10.60
120	GT.54-9	16.23	16.42	16.35	16.33	10.86	11.13	11.07	11.02
	G.2004-27	16.04	16.39	16.30	16.24	10.82	11.08	11.00	10.97
	G.84-47	16.10	16.71	16.48	16.43	10.76	11.39	11.13	11.09
	G.2003-47	16.22	16.76	16.60	16.53	10.81	11.41	11.10	11.11
	C.57-14	14.55	14.48	14.70	14.58	9.33	9.35	9.53	9.41
	Mean	15.83	16.15	16.09	16.02	10.52	10.87	10.77	10.72
Mean	GT.54-9	16.04	16.27	16.22	16.18	10.70	10.94	10.88	10.84
	G.2004-27	15.81	16.18	16.21	16.07	10.54	10.81	10.86	10.74
	G.84-47	16.01	16.39	16.30	16.24	10.64	10.97	10.87	10.82
	G.2003-47	16.29	16.73	16.65	16.56	10.87	11.26	11.10	11.08
	C.57-14	14.33	14.22	14.37	14.30	9.20	9.00	9.13	9.11
Average		15.70	15.96	15.95		10.39	10.59	10.57	
LSD at 5%	A	0.09	B	0.05		A	n.s	B	0.14
	C	0.06	AxB	n.s		C	0.09	AxB	n.s
	AxC	0.10	BxC	0.10		AxC	0.15	BxC	0.15
	AxBxC	0.17				AxBxC	0.25		

From results in Table 3 recorded that, the sugar recovery% traits very close and related to sucrose % this results approved with Gadallah *et al.* (2020), sugar recovery % had positive and high significant correlation with sucrose %. Where, G.2003-47 variety had the highest values of sucrose and sugar recovery percentages when planted at 100cm row distance as FR crop, without significant difference with variety G.84-47 when planted at 120cm row distance as FR crop in same traits.

3.3. Yield traits

The combined data of the three cycles and three row distances for five genotypes in Tables 4 and 5 showed that, the yield traits i.e. millable cane number (thousand) per fed, mean stalk weigh (kg), cane yield (ton) per fed and sugar yield (ton) per fed data, were significantly different.

3.3.1. Millable cane number per feddan and mean stalk weight

The results in Table (4) showed that, millable cane number/fed (thousand) was increased by significant difference for sugarcane millable cane number from plant cane to 1st ratoon then 2nd ratoon crops by 9% then 32%, respectively. On the contrary, stalk weight was decreased by significant difference by 6 % for 1st ratoon crop and 30% for 2nd ratoon crop, and the highest value was recorded in plant cane (PC) crop. Whereas, the significantly highest millable cane number was recorded in 100 cm than 80 cm then 120 cm row distance, on the other hand, the highest value of stalk weight was recorded in 80 cm and in significantly decreased for 120 then 100 cm row distance. While, G.84-47 variety had the highest value in millable cane number trait, on the contrary, it had the lowest value of stalk weight. These results may be due to the negative correlation between millable cane number and stalk weight traits Gadallah *el al.* (2020). Whereas, C.57-14 genotype recorded lowest value of millable cane number trait and the new variety G.2004-27 had the highest value of stalk weight traits more than the cultivated variety (GT.54-9) without significant between them. That may be due to genetic diversity, as same as, was recorded by Singels and Smit (2002) and Gadallah *el al.* (2020).

The all two way interaction (crop cycle and row distance, crop cycle and genotypes and row distance and genotypes) recorded in Table 4, were different significantly in both millable cane number and weight traits. The interaction between crop cycle (A) and row distance (B) was significant in both millable cane number and weight traits. Where, the millable cane number was increased from PC to FR then SR as same as was increased for crop cycles under both 80, 100 and 120 cm row distance, while, the stalk weight was decreased from PC to FR then SR under all row distance. As same, the increasing of millable cane number was record with increasing of row distance from 80 to 100 to 120 cm row distance. On the contrary, stalk weight was decreased with an increase of row distance from PC to FR then SR. Similar result was recorded by Gadallah *et al.* (2020) they recorded the negative correlation between millable cane number and weight traits.

The interaction between crop cycle (A) and genotypes (C) were significant in millable cane number and not significant in stalk weight traits. Where, millable cane number trait was increased significantly from PC to FR to SR crop for all genotypes, and the highest value was recorded by G.84-47 genotypes at SR crop higher than the next one by 4.49 thousand millable cane. Whereas, the interaction between row distance (B) and genotypes (C) in Table 4, were significant in millable cane number and not significant in stalk weight traits. While, millable cane number was significantly increased for all genotypes from 80 to 100 cm row distance then significantly decreased when row distance was 120 cm than 80 cm.

The three ways interaction among crop cycle (A) x row distance (B) x genotypes (C) was different significantly in number of millable cane and not significant in stalk weight, as cleared in Table 4. The genotypes had various behavior significantly and/or not significantly in millable cane number from PC to FR to SR as same as for different row distance, some genotypes get the highest values of genotypes under 100 cm row distance at 1st ratoon crop with insignificant difference with the value of same genotypes at first and/or 2nd ratoon crop under 120 cm row distance (i.e. GT.54-9 had 52.92 thousand millable cane/fed for different rows distance at FR crop only), on the contrary all of genotypes recorded the highest mean value under 100 cm row distance at different crop cycle with significant difference more than that under 120 cm row distance, while the highest values were recorded by G.84-47 genotype when planted with 100 cm row distance at 2nd ratoon crop with significant difference with all other genotypes. Similar results were recorded by Singels and Smit (2002) and Rafiq *et al.* (2006).

Table 4. Mean performance of five genotypes and three crop cycles for number of millable canes in thousand/fed. and mean stalk weight (kg/plant) under three row distances

Row distance (B)	Genotype (C)	Number of millable canes in thousand/fed.				Stalk weight (kg/plant)			
		Crop cycle (A)			Average	Crop cycle (A)			Average
		PC	FR	SR		PC	FR	SR	
80	GT.54-9	50.50	52.92	72.80	58.74	1.04	1.04	0.76	0.95
	G.2004-27	46.20	55.02	74.73	58.65	1.21	1.03	0.79	1.01
	G.84-47	52.50	57.12	77.00	62.21	0.90	0.85	0.64	0.80
	G.2003-47	52.50	57.54	78.40	62.81	0.92	0.89	0.65	0.82
	C.57-14	37.80	44.52	60.20	47.51	1.20	1.01	0.70	0.97
	Mean	47.90	53.42	72.63	57.98	1.06	0.97	0.71	0.91
100	GT.54-9	51.80	52.92	77.00	60.57	1.03	1.06	0.78	0.96
	G.2004-27	52.13	56.28	82.60	63.67	1.15	1.10	0.77	1.01
	G.84-47	55.33	57.12	88.20	66.88	0.87	0.86	0.56	0.76
	G.2003-47	57.40	58.24	79.60	65.08	0.85	0.89	0.65	0.80
	C.57-14	46.20	51.80	63.00	53.67	1.01	0.87	0.69	0.86
	Mean	52.57	55.27	78.08	61.98	0.98	0.96	0.69	0.88
120	GT.54-9	48.30	52.92	67.20	56.14	1.02	0.99	0.80	0.94
	G.2004-27	46.20	53.76	67.20	55.72	1.17	1.01	0.83	1.01
	G.84-47	46.20	54.18	72.80	57.73	0.94	0.86	0.66	0.82
	G.2003-47	46.20	51.24	63.00	53.48	0.95	0.91	0.78	0.88
	C.57-14	44.10	46.83	57.40	49.44	0.91	0.80	0.65	0.79
	Mean	46.20	51.79	65.52	54.50	1.00	0.92	0.74	0.89
Mean	GT.54-9	50.20	52.92	72.33	58.48	1.03	1.03	0.78	0.95
	G.2004-27	48.18	55.02	74.84	59.35	1.18	1.05	0.80	1.01
	G.84-47	51.34	56.14	79.33	62.27	0.90	0.86	0.62	0.79
	G.2003-47	52.03	55.67	73.67	60.46	0.91	0.90	0.69	0.83
	C.57-14	42.70	47.72	60.20	50.21	1.04	0.89	0.68	0.87
Average		48.89	53.49	72.08		1.01	0.95	0.71	
LSD at 5%	A	0.61	B	0.31		A	0.1	B	n.s
	C	0.96	AxB	0.52		C	0.1	AxB	0.1
	AxC	1.66	BxC	1.66		AxC	n.s	BxC	n.s
	AxBxC	2.87				AxBxC	0.5		

3.3.2. Cane and sugar yield

The results in Table (5) showed that, cane yield/fed was increased by significant difference for sugarcane genotypes growing from plant cane to 1st ratoon then 2nd ratoon crops by 3% then 4%, respectively. In the same trend, sugar yield/fed was increased by significant difference by 5% for 1st ratoon crop and 6% for 2nd ratoon crop, and the highest value was recorded in second ratoon (SR) crop for both cane and sugar yields traits.

Whereas, the significantly highest millable cane number was recorded in 120 cm than 80 cm then 100 cm row distance difference recorded were 1.91 and 5.2 ton/fed, respectively. On the other hand, the highest value of sugar yield was recorded in 100 cm and in significantly decreased for 80 then 120 cm row distance were recorded difference 0.39 and 0.49 ton/fed, respectively. While, G.2004-27 the new variety had the highest value in both cane and sugar yields traits, whereas the cultivated variety had an insignificant difference with this variety in sugar yield trait. On the contrary, the genotype C.57-14 had the lowest values of both traits either. These results may be due to genetic diversity between the studied genotypes, as same as, was recorded by Singels and Smit (2002). Gadallah *et al.* (2020), agrees with those results and added recording of a positive correlation with both traits cane and sugar yields

The all two way interaction (crop cycle x row distance, crop cycle x genotypes and row distance x genotypes) found in Table 5, were different significantly in both cane and sugar yields traits.

Table 5. Mean performance of five genotypes and three crop cycles for cane and sugar yield (ton/fed) under three row distances

Row distance (B)	Genotype (C)	Cane yield (ton/fed.) Crop cycle (A)			Average	Sugar yield (ton/fed.) Crop cycle (A)			Average
		PC	FR	SR		PC	FR	SR	
80	GT.54-9	52.48	55.01	55.46	54.32	5.43	5.91	5.89	5.74
	G.2004-27	55.80	56.85	58.63	57.09	5.62	5.93	6.20	5.92
	G.84-47	47.35	48.50	48.89	48.25	4.86	5.14	5.18	5.06
	G.2003-47	48.25	50.83	50.90	49.99	5.17	5.67	5.72	5.52
	C.57-14	45.59	44.83	42.03	44.15	4.02	3.85	3.62	3.83
	Mean	49.90	51.21	51.18	50.76	5.02	5.30	5.32	5.22
100	GT.54-9	53.33	56.08	60.07	56.49	5.80	6.13	6.58	6.17
	G.2004-27	60.05	62.18	63.86	62.03	6.44	6.78	7.00	6.74
	G.84-47	48.18	49.16	49.47	48.94	5.25	5.36	5.38	5.33
	G.2003-47	49.12	51.60	51.82	50.85	5.44	5.79	5.71	5.65
	C.57-14	46.53	45.00	43.53	45.02	4.39	4.08	4.02	4.16
	Mean	51.44	52.80	53.75	52.67	5.46	5.63	5.74	5.61
120	GT.54-9	49.50	52.40	53.66	51.85	5.38	5.83	5.93	5.71
	G.2004-27	54.16	54.47	56.10	54.91	5.86	6.03	6.16	6.02
	G.84-47	43.58	46.52	47.53	45.88	4.69	5.30	5.29	5.10
	G.2003-47	43.90	46.90	48.75	46.52	4.75	5.35	5.42	5.17
	C.57-14	39.93	37.43	37.17	38.18	3.73	3.50	3.55	3.59
	Mean	46.22	47.54	48.64	47.47	4.88	5.20	5.27	5.12
Mean	GT.54-9	51.77	54.50	56.40	54.22	5.54	5.96	6.13	5.88
	G.2004-27	56.67	57.83	59.53	58.01	5.97	6.25	6.45	6.23
	G.84-47	46.37	48.06	48.63	47.69	4.93	5.27	5.28	5.16
	G.2003-47	47.09	49.78	50.49	49.12	5.12	5.60	5.61	5.45
	C.57-14	44.02	42.42	40.91	42.45	4.05	3.81	3.73	3.86
Average		49.19	50.52	51.19		5.12	5.38	5.44	
LSD at 5%	A	0.30	B	0.15		A	0.14	B	0.10
	C	0.19	AxB	0.27		C	0.50	AxB	n.s
	AxC	0.32	BxC	0.32		AxC	0.80	BxC	0.80
	AxBxC	0.56				AxBxC	1.30		

The interaction between crop cycle (A) x row distance (B) was significant in cane yield trait but not significant in sugar yield trait. Where, the cane yield was increased from PC to FR then SR as same as was increased for crop cycles under both 80 and 100 cm row distance then decreased under 120 cm row distance.

The interaction between crop cycle (A) and genotypes (C) were significant in cane and sugar yields traits. Where, cane yield trait was increased significantly from PC to FR to SR crop for all genotypes by different ranges except C.57-14 genotype was decreased, while the highest value was recorded by G.2004-27 genotypes at SR crop higher than the next one in same cane crop significantly by 3.13 ton, where the lowest genotypes was C.57-14 as same crop cycle (SR). These results may be due to the positive correlation with millable cane number (Gadallah *et al.*, 2020). As same as, sugar yield trait had the same trend was recorded. Whereas, the interaction between row distance (B) x genotypes (C) in Table 5, were significant in cane and sugar yields traits. While, both of traits was significantly increased for all genotypes from 80 to 100 cm row distance then significantly decreased when row distance was 120 cm and the difference ranged various from genotypes to other and the highest value was recorded by G.2004-27 then GT.54-9 genotypes without significant difference between them under 100 cm row distance, on the contrary, the lowest was recorded by c.57-14 genotypes under 120 cm row distance without significant difference between himself under the other row distance. That may be due to genetic differences.

The three ways interaction among all studied factors was different significantly in both of cane and sugar crop traits, as cleared in Table (5). The genotypes had various affected from significantly and/or not significantly in both traits_from PC to FR to SR as same as for different row distance, but all genotypes had the highest values of cane and sugar yields under 100 cm row distance at 2nd ratoon crop except C.57-14 was had the high mean yield when growing under 100 cm row distance but at plant cane that may be due to the stalk weight trait._Singels and Smit (2002) and Rafiq *et al*. (2006) recorded similar results**.**

3.4. Ratoon ability (RA)

RA of cane yield and mean yield of cane (Table, 6) indicated that an increase in cane yield may not increase in the RA, but the rank of RA was differ from row distance to other but the genotypes rank under 80 and 100 cm row distance were almost same for two variety (GT.54-9 and G.2004-27) but differ for other genotypes, on the contrary, under 120 cm row distance the new variety G.2003-47 had the rank 1 as same as itself and the cultivated variety rank under 80 cm row distance but although G.2004-27 had highest cane yield but ranked in fourth under 120 cm row distance, while the genotype C.57-14 got in the last rank under the three row distance, in which the yield of the second genotype is greater than the yield of the first genotype under all row distance, yet they had opposite RA rank.

Two genotypes; G.2004-27 variety, as well as, the cultivated variety GT.54-9 showed continuous superior in their performance for cane yield across the three row distance, since its yield differ significantly from row distance to other, therefore its ratooning ability values nearly equal to the unity. Only one among of the evaluated genotypes; G.2004–27 significantly surpassed the cultivated variety in cane yield during the all row distance (57.09, 62.03 and 54.91 ton/fed vs. 54.32, 56.49 and 51.85 ton/fed in 80, 100 and 120 cm row distance crops, respectively). The highest RA value (1.09) for cane yield were recorded by the genotypes GT.54-9 cultivar under 100 cm row distance and G.2003-47 variety under 120 cm row distance, indicating the superiority of cane yield under 100 cm row distance for GT.54-9 and under 120 cm row distance for G.2003-47 variety over the other row distance crops for this genotypes, whereas the lowest RA value (0.93) for cane yield was recorded by the genotype C.57-14 under row distance 120 cm, indicating the high reduction in cane yield than this genotype for this row distance. Over all tested genotypes, RA were decreased in the wide row distance (120 cm) than the close one 80 and 100 cm row distance except G.2003-47 and G.84-47 varieties were increased under the wide row distance although for decrease their cane yield. Changes in RA and ratoon crop yields are usually, but not necessarily, related (Chapman *et al*., 1992), a limited RA diversity was detected among genotypes (Arbelo *et al.*, 2021).

Table 6. Mean cane yield (ton/fed) and ratoon ability of five genotypes under three row distances

Row distance		80			100			120	
Genotype	Mean	RA	Rank	Mean	RA	Rank	Mean	RA	Rank
GT.54-9	54.32	1.05	1	56.49	1.09	1	51.85	1.07	3
G.2004-27	57.09	1.03	2	62.03	1.05	2	54.91	1.02	4
G.84-47	48.25	1.03	2	48.94	1.02	3	45.88	1.08	2
G.2003-47	49.99	1.05	1	50.85	1.05	2	46.52	1.09	1
C.57-14	44.15	0.95	3	45.02	0.95	4	38.18	0.93	5

3.5. Stability analysis

The pooled analysis of variance revealed that genotypes and environment were significant for cane and sugar yields traits (Table 7). Similar results were recorded by Ahmed (2000), Kumar *et al.* (2018) and Gadallah *et al.* (2020), highly significant genotype x environment interaction was detected, including linear environmental effect concerning for this traits. The highly significant mean squares due to environments (linear) point to differences between the environments and their considerable influences on this trait. A large sum of squares of environments indicates that the environments were diverse, with large differences among environmental means causing most of the variation in cane and sugar yield. The significance of environments mean squares of cane and sugar yields trait led to the conclusion that the performance of sugarcane genotypes regarding this trait differed from one environment to another under the conditions of this study. The mean performance of genotypes over different environments due to G×E interactions is not greatly reliable parameter alone for assessment of their stability for the traits. Therefore, under such condition genotypes should be separated individually in specific environment to maximize cane yield and CCS yield (Gauch, 1990; Ebdon and Gauch, 2002; Kumar *et al.*, 2007).

Table 7. Stability analysis of variance for cane and sugar yield of the five tested sugarcane genotypes over 9 different environments

Source of variation	df	Cane Yield mean squares	Sugar Yield mean squares
Genotypes (G)	4	976.73**	22.23**
Environments (Env.) + (G x Env.)	40	25.58**	0.35
Env. (linear)	1	724.15**	8.83**
G x Env. (linear)	4	6.94**	0.30
Pooled deviation	35	7.75	0.11
Pooled error	72	976.73	0.467833

*** denote to the significance at 0.01 level of probability.*

The mean performance, regression coefficient (b_i), deviation from regression (S^2_{di}), stability variance (σ^2_i) and ecovalence stability index (w_i) were presented in Table, 8. A stable genotype should have relatively low values for these parameters (σ^2_i and W_i). Where, S^2_{di} non-significant and regression coefficient (b_i) greater than unity (bi>1) with mean value higher than the population mean, thus indicating its suitable and stable under favorable environmental conditions, meanwhile the genotype exhibited S^2_{di} non-significant and regression coefficient (bi) less than unity (bi<1) with a mean value higher than the population mean indicated genotype stability and suitability under unfavorable environmental conditions, However, a higher value of S^2_{di} indicates instability of genotypes over varied environments. Alike, results recorded previously by Kumar *et al.* (2007), Tahir *et al.* (2013), Guddadamath *et al.* (2014) and Dubey *et al.* (2017)

The mean values ranged from 42.45 to 58.01 and from 3.86 to 6.22 tons/fed for cane and sugar yield, respectively (Figure, 1). The new variety G.2004-27 was significantly superior to the rest of genotypes for cane yield, while in sugar cane yield the cultivated variety was insignificantly different with it.

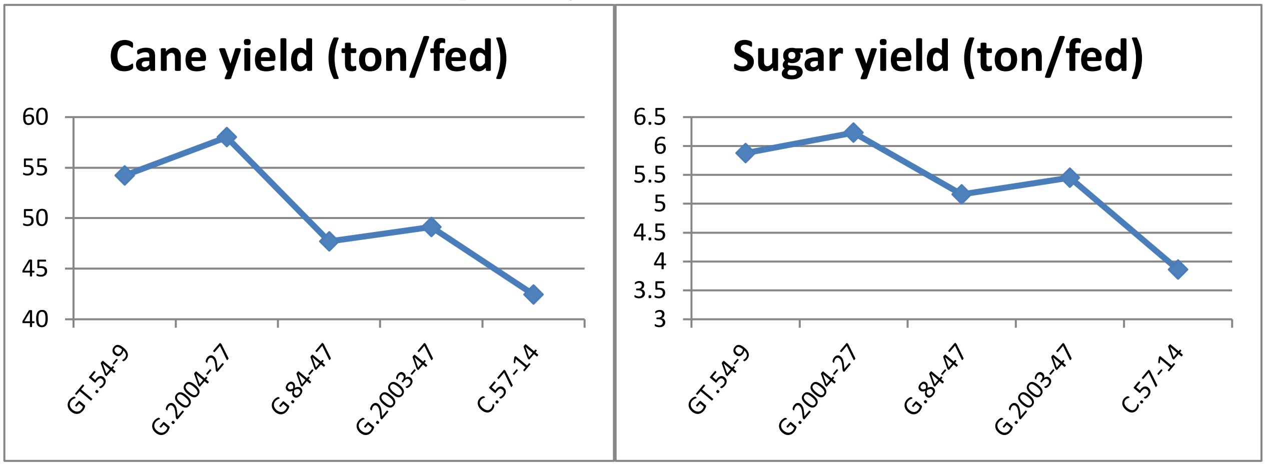

Figure 1. Cane and sugar yield overall means of five genotypes under all studied environments

The regression coefficients (bi) of the studied sugarcane genotypes (Table, 8) ranged from 0.68 to 1.28 and from 0.47 to 1.53 for cane and sugar yield, respectively. The large variation in the regression coefficients showed that genotypes had different environmental reactions. The new variety G.2004-27 and the cultivar GT.54-9 appeared to be more responsive to favorable environments than the other genotypes as indicated by the relatively high regression coefficient value as same as high cane and sugar yields in higher than mean yielding environments. The variety G.84-47 was less reactive to environmental change, as showed by the lower regression coefficient for cane yield, whereas C.57-14 was less reactive to environmental change as showed for sugar yield.

Table 8. Estimates of environment stability parameters statistics for cane and sugar yield of the tested sugarcane genotypes grown under 9 environments

Genotypes	Cane yield (ton /fed)				Sugar yield (ton /fed)			
	b_i	S_{di}^2	σ_i^2	W_i^2	b_i	S_{di}^2	σ_i^2	W_i^2
GT.54-9	1.07	2.07*	2.03	14.71	1.21	0.02	0.02	0.18
G.2004-27	1.28	1.97*	2.64	17.66	1.53	0.03	0.06	0.37
G.84-47	0.68	0.58	0.87	9.16	0.75	0.02	0.01	0.15
G.2003-47	0.97	0.96	0.37	6.77	1.04	0.04	0.03	0.25
C.57-14	1.00	7.34*	9.67	51.40	0.47	0.08*	0.13	0.71

* *denote to the significance at 0.05 level of probability,* b_i *denote to regression coefficient,* S^2_{di} *denote to deviation from regression,* σ^2_i *denote to stability variance and* w_i *denote to ecovalence stability index.*

The results in Table 8 indicate that S^2_{di}, σ^2_i and W_i values for the new variety G.2003-47 which had mean yield less than mean environments yield, b_i value very close to 1 and S^2_d value close to zero and small values of σ^2_i and W_i was more stable than other genotypes in both cane and sugar yield. On the contrary, the genotype C.57-14 had very high S^2_d, σ^2_i and W_i values in cane yield in addition to low b_i value in sugar yield, indicating that it could be classified as being unstable. These results like as showed by Tahir *et al.* (2013) and Gadallah *et al.* (2020).

Based on the different stability analysis, the promising variety G.2003-47 was the most stable in cane and sugar yields across tested environments showing broader adaptability for all studied crop cycle and row distance.

4. Conclusion

All discussed under this study conditions using 100 cm row distance got the highest values in the most traits of most genotypes, and the genotype G.2004-27 got this highest cane and sugar yields under 100 cm row distance in SR crop. Although, the genotypes GT.54-9 and G.2003-47 had the 1st rank of RA under 80 cm row distance, where, under 100 cm row distance the cultivar GT.54-9 ranked in 1st, while the variety G.2003-47 ranked in 1st one under 120 cm row distance. On the contrary, C.57-14 genotypes ranked in the last one for RA under all studied row distance in cane yield trait. Although, the promising variety G.2003-47 was the most stable genotype in cane and sugar yields across tested environments.

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