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Variability, Heritability, and Performance of Some Sugarcane Varieties under Three Surface Irrigation Regimes

Farrag F. B. Abu-Ellail, Tarek M. Attafy, Ahmed E. Attia and Abdel-Nasser El-Bakry

Farrag F. B. Abu-Ellail
Ahmed E. Attia
Abdel-Nasser El-Bakry
Sugar Crops Research Institute
Agricultural Research Center
Giza
12619
Egypt

Tarek M. Attafy
Agricultural Engineering Research Institute
Agricultural Research Center
Giza
12619
Egypt

Corresponding author:
Farrag Abu-Ellail
farrag_abuellail@arc.sci.eg

Abstract

A field experiment was carried out at El-Mattana Agricultural Research Station, Luxor Governorate, Egypt, during three growing seasons, where sugarcane was grown as a plant cane, 1st and 2nd ratoon crops, respectively, to find out the effect of three irrigation water regimes (100, 85, and 70% of the irrigation requirement IR) on productivity of five sugarcane varieties, namely G.T.54-9, G.2003-47, G.2004-27, G.84-47, and G.99-80. A randomized complete block design with four replications in a split-plot arrangement was used. The results showed that 1st ratoon crop consumed the most irrigation water, followed by the 2nd ratoon crop and the plant cane crop. Irrigating at 70% IR was the highest in application efficiency, followed by 100% and 85% IR. The cane and sugar yields decreased with the decrease in the irrigation regime; however, water productivity increased with reduced irrigation regimes. The highest phenotypic (PCV %) and genotypic coefficient of variance (GCV %) values and broad-sense heritability% were recorded for sugar and cane yields in the plant cane and ratoon crops under the studied irrigation water regimes. The results showed a significant difference among the evaluated varieties in ratooning ability (RA) and most studied traits. Sugarcane G.2004-27 and G.2003-47 varieties exhibited higher ratooning ability, recording higher cane and sugar yields in both ratoon crops compared to G.84-47 and G.99-80, which had poor performance concerning the same trait in the 2nd ratoon crop. This study suggests selecting varieties with high productivity of cane and sugar yields in addition to water deficit tolerance based on traits contributing to the crop that has high PCV%, GCV%, and heritability along with the mean value would be effective. The results suggested planting the G.2004-27 variety under normal and water-deficit conditions, and it can be used as a parent in breeding programs to improve the tolerance of sugarcane varieties to water deficit while recommending planting the G.T.54-9 variety under normal irrigation conditions.

Keywords:
Performance, heritability, ratooning ability, sugarcane varieties, water regime

INTRODUCTION

Sugarcane (*Saccharum spp.hybrids*) is a robust perennial tillering crop. In Egypt, it is grown for a five-year crop cycle, including a plant cane and four ratoon crops, on average. It occupies about 142 hectares along the Nile River, in El-Minia, Sohag, Qena, Luxor, and Aswan governorates. Growth traits of sugarcane, in terms of tillering, stalk height and diameter is sharply affected by water supply, especially during the hot and dry summer season, extended from June to August. In semi-arid regions, water stress significantly reduces sugarcane yield and quality, where proper water is necessary for sugarcane to obtain optimal growth (El Mawla *et al.,* 2016 and Bekheet, 2006). Therefore, innovative techniques of irrigation should be created as a way to increase cane productivity and reduce the water footprint (Bhatt *et al*., 2022). In Egypt, irrigation water is a finite resource. So, its optimal management is of paramount importance to reduce losses, and production costs and ensure high crop productivity. The surface irrigation system, particularly the furrow method, is most often utilized for sugarcane. However, it has been associated with significant water loss due to high running-off and poor distribution. Raising irrigation efficiency becomes a crucial requirement, especially in water scarcity conditions. Globally, sugarcane irrigation water requirements ranged from 12000 to 35000 m^3/ha on average, depending on soil type, growing season, and regional weather conditions (Shrivastava *et al.,* 2011). So, it is very important to apply innovative techniques to raise productivity per unit area with the least amount of irrigation water (Hemeid *et al.,* 2017). In Egypt, sugarcane water requirements under surface irrigation ranged from 34,255 to 51,055 m^3/ha, combined with a low application efficiency of 55% (Taha and Zohry, 2018). The application of an adequate amount of irrigation water encourages consumption by the ratoon crop and increases cane and sugar production, while excess irrigation water prevents nutrient uptake (Singh *et al.,* 2007) and causes waterlogging and hinders aeration (Ghaffar *et al.,* 2013), which results in water losses and yield reduction. Through effective water resource management, irrigation efficiency and sugarcane productivity can be significantly improved (Afghan, 2003). Irrigation levels technique is one of the water-saving technologies that are relatively inexpensive and easy to execute, promotes crop's natural response to drought conditions, and enhances water productivity (Webber *et al.,* 2009). The main characteristic of sugarcane varieties with poor ratooning capacity was a significant drop in cane yield, particularly between the plant cane and the 2nd ratoon. The ability to maintain yield as the number of ratoon crops increases is known as ratooning ability in sugarcane, and it is a desirable trait because it boosts the economics of sugarcane production. The ability to use ratios to select superior sugarcane cultivars with acceptable cane production was proved successful (Abu-Ellail *et al.,* 2019). Ratoon crops sprout from underground buds that remain after plant crop harvesting (Hunsigi and Krishna, 1998). The ratio of the yields of the 2nd ratoon crop to the plant crop was used to define the ratooning ability (Milligan *et al.,* 1996). The main countries that grow cane typically harvest two or more ratoons (Bashir *et al.,* 2012). Crop cycles have a detrimental impact on cane and sugar yields. So, it is critical to search for sugarcane quality related to the ratooning ability to be used as a breeding program selection attribute (Abu-Ellail *et al.,* 2018). The ability of different genotypes of sugarcane to generate successful ratoon crops varies substantially (Srivastava *et al.,* 1993). Heritability estimates predict genetic gain through selection, while genotypic coefficients of variation are crucial for improving sugarcane genotypes and choosing the best genotypes because they allow one to determine whether the desired outcome can be attained from the material (Tyagi and Singh, 1998). The most effective genotype should be chosen based on sugar yield to maximize the selection's effectiveness and heredity (Shanthi *et al.,* 2008). Significant genotypic effects indicate the existence of genetic variability among the genotypes and the possibility of utilizing them in genetic improvement (Abu-Ellail *et al.,* 2017). Heritability and genetic diversity are helpful factors that can aid in crop improvement

(Anshuman *et al.*, 2002). To get a true picture of the heritable variations in the population under investigation, the genetic coefficient of variation combined with heritability estimates must be studied (Burton, 1952). The objectives of this study were to determine the most tolerance variety among the tested varieties to be planted under water deficit conditions, in addition to, estimating the variability and heritability of traits in the tested variates under studied irrigation regimes to know their potential to be used in the breeding program to improve tolerance of water deficit.

MATERIALS AND METHODS

Site description:

A field experiment was executed at El-Mattana Agricultural Research Station, Luxor Governorate, Egypt (latitude 25° 41' 0" N, longitude 32° 39' 0" E. and altitude 82 m) during 2020/2021, 2021/2022 and 2022/2023, where sugarcane was grown as a plant cane, 1st and 2nd ratoon, successively. The physical properties of the experimental site were estimated according to (Black *et al.*, 1965) and shown in Table 1. The climate of the experimental site is classified as semi-arid, with hot summer and cool winter. Monthly climatic data for the experiment site during the three growing seasons were obtained from "Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center Table 2.

Table 1. Some physical properties of the experimental site

Depth, cm	Particle size distribution, %			Soil texture	FC, %	PWP, %	Bd, g cm^{-3}
	Clay	Sand	Silt				
0-20	37.75	33.83	28.42	Clay loam	47.15	19.13	1.18
20-40	38.89	34.00	27.11	Clay loam	42.15	17.15	1.26
40-60	36.62	34.24	29.14	Clay loam	44.23	15.45	1.33

FC: Field capacity, PWP: Permanent wilting point, Bd: Bulk density

Table 2. Average monthly meteorological data for the experiment site

Month	2020				2021				2022			
	T_{mini}, °C	T_{max}, °C	RH, %	WS, m/s	T_{mini}, °C	T_{max}, °C	RH, %	WS, m/s	T_{mini}, °C	T_{max}, °C	RH, %	WS, m/s
Jan.	5.1	20.2	52.5	2.5	7.9	24.5	40.7	2.1	4.8	19.6	49.3	2.4
Feb.	7.5	23.6	44.4	2.6	8.5	25.4	38.3	2.7	6.6	23.6	43.8	2.6
Mar.	11.6	29.6	31.7	2.9	11.9	30.5	27.1	3.0	9.3	27.2	29.6	3.2
Apr.	15.1	32.6	26.1	3.2	15.9	35.4	18.8	2.8	18.6	38.2	16.7	2.7
May	21.0	38.5	20.2	3.1	21.7	40.7	15.5	3.2	21.0	38.4	17.9	3.6
June	23.3	41.4	18.5	3.5	23.3	41.1	19.0	3.8	24.0	40.5	21.9	3.9
July	25.0	41.6	20.5	3.6	25.4	41.8	20.8	3.5	24.3	40.6	21.1	3.7
Aug.	24.7	41.5	21.6	3.1	24.8	42.2	20.7	3.3	25.8	41.7	24.3	3.6
Sept.	24.6	42.4	23.3	3.0	22.6	39.5	27.9	3.6	22.8	40.1	26.5	3.3
Oct.	21.5	38.2	27.3	2.2	19.3	35.9	30.3	2.8	20.4	37.0	28.8	2.5
Nov.	12.7	27.3	46.2	2.5	15.7	31.3	37.3	2.1	14.2	29.3	41.8	2.3
Dec.	10.7	26.1	41.6	1.9	8.6	22.9	48.8	2.4	9.7	24.5	45.2	2.1

***** Cumulative precipitation was 0.38, 0.14 and 4.5 mm, in 2020, 2021 and 2022, respectively
T: temperature, RH: relative humidity, WS: wind speed

Experimental layout and design:

The experimental field was plowed twice perpendicularly by a chisel plow and leveled conventionally. Unit area was 42 m^2 with 7 ridges of 6 meters in length and 1.0 m apart. Sugarcane varieties were planted as a plant cane crop in the last week of February 2020, which was harvested next year in the last week of February. Thereafter, sugarcane was grown as a 1^{st} and 2^{nd} ratoon in the 2021/2022 and 2022/2023 seasons, respectively. Phosphor was added at the rate of 30 kg P_2O_5/feddan (fed: 4200 m^2) in the form of calcium super phosphate (15 % P_2O_5) during land preparation. Nitrogen was applied at (200,215 and 230 kg N/fed) as urea (46.5% N) in plant cane, first ratoon, and second ratoon, respectively in two equal doses; two months after planting and one month later. Potassium was given at 50 kg K_2O/fed, in the form of potassium sulfate (48% K_2O) with the second dose of nitrogen fertilizer. The other agricultural practices of growing sugarcane were carried out as recommended by Sugar Crops Research Institute. The present work included fifteen treatments representing the combinations among three irrigation regimes based on soil water depletion as a percentage of irrigation requirement (100, 85, and 70%) and five sugarcane varieties namely G.T.54-9, G.2003-47, G.2004-27, G.84-47 and G.99-80. The treatments were allocated in a Randomized Complete Block Design using a split-split plot arrangement with four replications, where irrigation regimes were applied in the main plots, while cane varieties were grown in the subplot, each plot included seven furrows. The main plots, dedicated to irrigation regimes, were separated with a 2-m width ditch to prevent water lateral seepage.

Irrigation scheduling

In order to ensure a full stand of cane plants, all plots were flooded twice; at planting and one week later. Thereafter, the studied irrigation treatments were scheduled according to agricultural recommendations based on the growth stage and the climatic season as follows: Applying irrigation at 15-day in Spring, 12-day in Summer, and 21-day intervals in Autumn and Winter, successively, with a total of 21 irrigations per growing season. Irrigation was withheld one month before harvesting.

Discharge rate

Irrigation water was supplied to each plot using a plastic spile tube with an internal diameter of 4 inches (≈ 10.0 cm) and a length of 1.0 m. Water was carried through a ditch and the hydraulic head was kept in place by a metal baffle at the ditch's end. The discharge rate of the spile tube was estimated according to the following equation (Michael, 1997):

$$Q = 0.65 \text{ X } 10^{-3} \text{ X } a\sqrt{2g(h_u - h_d)}$$

In which: Q is discharge rate from the pipe (l s^{-1}), **a** is cross sectional area of the tube (cm^2), g is acceleration due to Gravity (981 cm s^{-2}), h_u is effective head at upstream end (cm), and h_d is effective head at downstream end (cm). Nearly all furrows used a flow rate of 1.0 l s^{-1}.

Soil moisture content

Soil samples were collected from layers of 0-60 cm depth from the soil surface and the gravimetric method was used to calculate the moisture contents. The wet soil samples were weighed and then dried for 24 hours in an oven at 105 °C before being weighed again. The moisture content on a dry basis was calculated using the following equation:

$$\theta = \frac{W_w - W_d}{W_d}$$

In which: θ is moisture content on a dry weight basis (%), W_w is weight of wet soil sample (g) and W_d is weight of dry soil sample (g).

Irrigation water requirement:

Soil moisture content was determined on a dry basis before and at field capacity of each event. The irrigation water requirements for each water regime were calculated using the fallowing equation according to (Israelson and Hansen, 1962):

$$IR = \frac{\theta_{fc} - \theta_b}{E_S} \text{ X } D_i \text{ X } B_i$$

In which: ***IR*** is irrigation water requirements, mm/event; θ_{fc} is soil moisture content at field capacity for every layer, %; θ_b is soil moisture content prior to irrigation for every layer, %; D_i is depth of every soil layer, 15 cm; B_i is bulk density for every layer; gm/cm^3 and E_S irrigation system efficiency; %. Total applied water for each main plot during the growing season was collected and seasonal applied water calculated.

Application efficiency (E_a, %)

Application Efficiency is an expression of the percentage of irrigation water applied on the farm that is beneficially used by plants. It was defined mathematically as reported by James (1988) as follows:

$$E_a = \frac{\text{Average depth of water stored into the root zone}}{\text{Average depth of water applied}} * 100$$

Agronomic traits:

The following data were recorded at harvest:

Growth traits:

1. Millable cane diameter (cm): which was measured at the middle part of stalk.
2. Stalk weight was calculated by dividing the stalk yield of plot by its number of millable stalk.
3. Number of millable canes 1000 /fed.

Quality traits:

1. Brix (%) was determined by using the Brix Hydrometer standardized at 20 ºC.
2. Sucrose (%) was determined using "Saccharemeter" according to (A.O.A.C., 2005).
3. Sugar recovery was calculated according to the following equation of Yadav and Sharma (1980):

$$\text{Sugar recovery} = 0.73\,\{\text{Sucrose} - 0.4\,(\text{brix} - \text{sucrose})\}$$

Where: 0.4 and 0.73 are constants.

Yield

1. Cane yield (ton/fed) (fed = 0.42 ha) was calculated.
2. Sugar yield (ton/fed) was estimated according to the following equation:

$$\text{Sugar yield} = \text{Cane yield, ton fed}^{-1}\ \text{X Sugar recovery, \%}$$

Water productivity (WP, kg/m^3)

Water productivity (WP) is a partial-factor productivity that evaluates how the irrigation regime converts water into cane or sugar. It is defined as the ratio of a certain yield to the seasonal applied water in kg m^{-3}. Water productivity for cane or sugar yield was calculated according to the following method (Michael, 1997):

$$WP = \frac{\text{Cane or sugar yield, kg/fed}}{\text{Total applied water}, m^3/\text{fed.}}$$

Heritability and Variability:

Broad-sense heritability (H %) on a variety mean basis was estimated using variance components following the formula according to (Johnson *et al.*, 1955):

$$H = \sigma^2 g / (\sigma^2 g + \sigma^2 e / r + \sigma^2 gc / rc)$$

In which: **(σ^2g)** and **(σ^2e)** refer to genotypic and error variance respectively; the divisor **(r)** refers to the number of replications; **(σ^2gc)** refers to variety by crop interaction variance; the divisor **(c)** refers to number crops.

Genetic and phenotypic coefficients of variance (GCV and PCV%): It provides the measure of traits genetic and phenotypic variation relative to its mean estimated according to (Burton and Devance, 1953). The GCV and PCV facilitate comparisons among traits with different units and scales and give perspective to the variation as

$$GCV = (\sigma^2 g / \text{general mean})\ X\ 100$$

$$PCV = (\sigma^2 p / \text{general mean}) \times 100$$

Where, σ^2p and σ^2g, are phenotypic and genotypic variance, respectively.

Ratooning ability (RA):

It was estimated as mentioned by (Milligan *et al.*, 1996) as follows:

$$RA_i = (SR_i / PC_i)\ X\ 100$$

In which: ***RAi*** is ratooning ability of trait ***i*** %; **SR*i*** is 2nd ratoon crop value for trait ***i*** and **PC*i*** is the plant cane crop value for trait ***i***.

Data analysis:

Data for each crop in the three seasons were separately analyzed and a combined analysis of variance across the 3-season crop cycle was done. The collected data were statistically analyzed using the CoStat statistical software program. The least significant difference (LSD) was used to compare the treatment means (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

1. Seasonal irrigation requirement:

The monthly irrigation requirement at 100% irrigation regime for three growing seasons is shown in Fig. 1. Sugarcane plants grown as a 1st ratoon crop (2nd season) consumed the highest quantity of irrigation water, compared to that consumed by the 2nd ratoon and/or the plant cane crop, which consumed the least amount of water. These results may be due to that the root system of the cane crop had not reached its full size and proliferation as soon as the 1st and 2nd ratoons did Meantime, higher temperature degrees combined with a reduction in the relative humidity prevailed in the 2nd season increase the water requirement (Table 2).

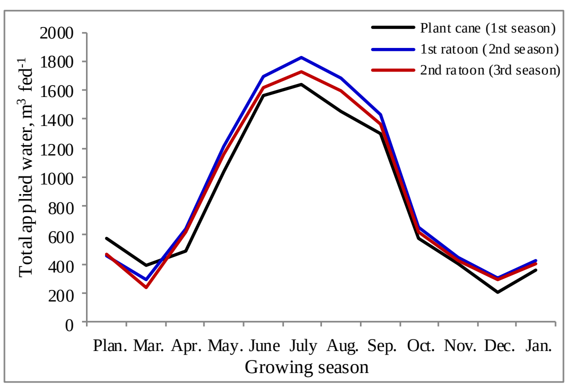

Fig. 1. Average monthly irrigation requirement for sugarcane crop at 100% IR

Statistical analysis showed a substantial variance among the applied irrigation regimes in irrigation water requirement (Table 3). The average of the three irrigation regimes pointed to an increase of 10.6% and 5.2% in irrigation water requirement in the 2nd season (1st ratoon) compared with that given for the plant cane and 2nd ratoon crop, respectively as well as higher cane numbers, probably resulting in higher consumption of water by cane plants of the 1st ratoon.

Table 3. Average seasonal irrigation requirement, IR (m^3 fed^{-1})

Irrigation regime	Growing seasons			Mean
	2020/2021	2021/2022	2022/2023	
	Average seasonal requirement			
100% IR	9983	11072	10518	10524
85% IR	8573	9481	9011	9022
70% IR	7162	7889	7504	7518
Mean	8573	9481	9011	9021

2. Application efficiency (E_a, %)

The results in Table 4 clearly that irrigating sugarcane at 70 % of the irrigation requirements (IR) was significantly the most efficient irrigation regime among the three studied ones, followed by 100 % IR and 85 % IR, in the three growing seasons. However, it is worth mentioning that applying water at 100% IR achieved satisfactory application efficiency (>80%). The disparities in the application efficiency can be explained by the percentage of water held in the root zone to water conveyance during irrigation events. The preceding soil moisture level was greater in the 100% IR treatment than that of the other two regimes (85 and 70% IR), which resulted in faster water advancement and less penetration depth, which increased application efficiency over the 85% IR treatment. Conversely, the preceding soil moisture level was lower in the 70% IR treatment, which caused slow water advancement, little intake time, and higher infiltration of water in the root zone, which in turn increased the application efficiency notably with little amount of the applied water. These findings are consistent with those obtained by (Mazibuko 2003).

Table 4. Average application efficiency, Ea (%)

Irrigation regime	Growing season			Mean
	2020/2021	2021/2022	2022/2023	
	Application efficiency			
100% IR	81.5	80.3	80.8	81
85% IR	78.2	75.0	77.3	77
70% IR	85.0	83.4	84.4	84
Mean	81.6	79.6	80.8	80.6

3. Growth traits

Data in Tables 5 and 6 cleared that the tested sugarcane varieties differed significantly in stalk diameter, stalk weight, and number of millable canes per feddan in the concerned cane crop cycle. Sugarcane G.T.54-9 variety showed significant superiority over the other ones in stalk weight, diameter, and number of millable canes/fed, while G.84-47 and G.99-80 recorded the lowest values, in the three growing seasons. An insignificant variance was found between G.2004-27 and G.84-47 varieties in the 1st ratoon, as well as between G.2003-47 and G.2004-27 in the 2nd ratoon, in stalk weight. Likewise, an insignificant difference, in the number of millable canes/fed, was detected between (G.84-47 and G.99-80) and (G.2003-47 and G.2004-27) grown as a plant cane crop, as well as between G.2004-27 and G.84-47 grown as a 2nd ratoon. The difference between varieties in this trait could be mainly due to the capability of the variety in teller production, which in turn was reflected in the final number of millable canes/fed. El-Shafai (1996) and Abu-Ellail *et al.*, (2019) reported the variations in these growth parameters among cane varieties. Concerning the influence of irrigation regimes on sugarcane growth traits, the results indicate that growth traits (stalk weight, stalk diameter and number of millable canes/fed) significantly increased as the irrigation regime was raised from 70 to 85 and 100% IR, respectively in the three growing seasons. Applying irrigation at 100% IR increased cane stalk diameter of the plant cane crop by 4.5 and 9.2 % compared to 85 and 70 % IR. Similar results were found in the 1st and 2nd ratoons. Cane diameter similarly responded to the studied irrigation regimes in the three seasons. Meanwhile, irrigating canes at 100% IR raised the number of millable canes/fed by (13.9 and 18.6 %), (9.7 and 16.4 %) and (8.3 and 14.9 %) in comparison with that irrigated at 85% or 70% IR, in the plant cane, 1st ratoon and 2nd one, successively. These findings might be explained by the fact that water is crucial for the strengthening of leaf cells, the elongation of stalk cells, and the photosynthesis process, as referred by Van Dillewijn (1952), who claimed that water is quantitatively the most important nutrient for sugarcane. Increasing irrigation regimes encourage vegetative growth by promoting the transformation of total sugars to convertible sucrose used in growth (Dorenboss and Kassam, 1979). As for the interaction effects, the results revealed that the studied growth traits of sugarcane were markedly influenced by the interaction of cane varieties and irrigation regimes, in the three growing seasons, except for stalk diameter in the 3rd season. Insignificant variance was noticed in stalk height between (G.2004-27 and G.84-47) in the 2nd season, when they received irrigation at 70% IR. However, they differed substantially in this trait in case of irrigating them at 85% and/or 100% IR. In the 3rd season, G.2003-47 and G.2004-27 were not statistically different in stalk weight, when irrigation was applied at 85% IR, while they differed noticeably as they were irrigated at the highest or the lowest levels *i.e.*, 100 or 70% IR. Insignificant difference in the number of millable canes/fed produced by G.2004-27 and G.84-47 grown as a 1st ratoon, when they were watered at 70% IR, while G.2004-27 appreciably attained higher values of this trait, in case of irrigating them at the two higher levels of irrigation. In the 2nd ratoon, insignificant variance was noticed in the number of millable canes/fed between G.2003-47 and G.84-47, as they irrigated at 85% IR. However, they differed significantly at the higher and/or lower levels of irrigation. The results showed that the best combination attained the highest values of the three studied growth traits was planting G.T.54-9 irrigated at 100% IR, in the three growing seasons. Similar results were achieved by Yahaya *et al.*, (2010) and Hemeid *et al.*, (2017), who observed a decrease in growth traits when irrigation water was reduced.

Table 5. Stalk diameter (cm) and stalk weight (Kg) of the tested sugarcane varieties as affected by the irrigation regimes (IR) in the three growing seasons

Irrigation regimes (I)	Stalk diameter (cm)						Stalk weight (Kg)					
	1st season (2020/2021)						1st season (2020/2021)					
	Sugarcane varieties (V)						Sugarcane varieties (V)					
	G.T.54-9	G.2003-47	G.2004-27	G.84-47	G.99-80	Mean	G.T.54-9	G.2003-47	G.2004-27	G.84-47	G.99-80	Mean
100% IR	3.20	2.60	2.80	2.30	2.70	2.72	1.25	1.13	1.17	1.14	1.07	1.15
85% IR	2.70	2.30	2.50	2.20	2.60	2.46	1.22	1.13	1.31	1.14	1.11	1.18
70% IR	2.50	2.20	2.10	2.10	2.80	2.34	1.14	0.97	1.26	1.10	1.02	1.10
Mean	2.80	2.37	2.47	2.20	2.70	2.51	1.20	1.07	1.24	1.12	1.07	1.14
LSD at 0.05	**V = 0.27 I = 0.18 V X I = ns**						**V = 0.07 I = 0.11 V X I = 0.09**					
	2nd season (2021/2022)						2nd season (2021/2022)					
100% IR	2.70	2.50	2.60	2.25	2.70	2.55	1.22	1.09	1.19	1.09	1.13	1.14
85% IR	2.60	2.20	2.30	2.15	2.80	2.41	1.17	1.06	1.28	1.05	1.11	1.13
70% IR	2.40	2.00	2.20	2.10	2.40	2.22	1.14	1.08	1.27	0.96	1.11	1.11
Mean	2.57	2.23	2.37	2.17	2.63	2.39	1.18	1.08	1.25	1.03	1.12	1.13
LSD at 0.05	**V = 0.12 I = 0.23 V X I = 0.19**						**V = 0.01 I = 0.04 V X I = 0.02**					
	3rd season (2022/2023)						3rd season (2022/2023)					
100% IR	2.60	2.30	2.50	2.30	2.50	2.44	1.18	1.18	1.10	1.03	1.02	1.10
85% IR	2.40	2.20	2.10	2.20	2.40	2.26	1.07	1.08	1.11	1.10	1.03	1.08
70% IR	2.20	2.00	2.40	1.80	2.60	2.20	1.03	0.95	1.01	1.00	0.99	1.00
Mean	2.40	2.17	2.33	2.10	2.50	2.30	1.09	1.07	1.07	1.04	1.02	1.06
LSD at 0.05	**V = 1.18 I = 2.30 V X I = ns**						**V = 0.10 I = 0.07 V X I = ns**					

Table 6. Number of millable canes (1000/fed) and sugar recovery % of the tested sugarcane varieties as affected by the irrigation regimes (IR) in the three growing seasons

Irrigation regime (I)	Number of millable canes (1000/fed)						Sugar recovery %					
	1st season (2020/2021)						1st season (2020/2021)					
	Sugarcane varieties (V)						Sugarcane varieties (V)					
	G.T.54-9	G.2003-47	G.2004-27	G.84-47	G.99-80	Mean	G.T.54-9	G.2003-47	G.2004-27	G.84-47	G.99-80	Mean
100% IR	46.60	43.40	44.70	41.70	38.50	42.98	9.48	9.67	8.35	9.02	7.37	8.78
85% IR	41.60	40.50	38.50	35.50	34.50	38.12	10.09	10.02	9.27	9.27	7.72	9.27
70% IR	40.50	38.40	36.20	34.50	33.30	36.58	10.70	10.32	9.36	9.45	8.13	9.59
Mean	42.90	40.77	39.80	37.23	35.43	39.23	10.09	10.00	8.99	9.25	7.74	9.21
LSD at 0.05	**V = 0.95 I = 1.23 V X I =1.56**						**V = 0.2 I = 0.3 V X I = 0.5**					
	2nd season (2021/2022)						2nd season (2021/2022)					
100% IR	48.00	45.70	45.60	42.50	36.30	43.62	9.43	9.94	8.12	8.83	6.80	8.63
85% IR	43.90	42.60	40.60	39.40	32.40	39.78	9.43	9.68	8.88	9.26	7.34	8.92
70% IR	41.80	40.50	37.50	37.40	31.00	37.64	10.02	9.68	9.72	9.61	7.64	9.33
Mean	44.57	42.93	41.23	39.77	33.23	40.35	9.63	9.77	8.91	9.23	7.26	8.96
LSD at 0.05	**V = 0.21 I = 0.32 V X I = 1.04**						**V = 0.12 I = 0.26 V X I = 0.52**					
	3rd season (2022/2023)						3rd season (2022/2023)					
100% IR	41.00	38.50	39.30	40.80	34.10	38.74	9.24	8.61	8.12	8.00	6.02	8.00
85% IR	38.60	36.50	37.30	36.30	31.80	36.10	9.13	9.42	8.60	8.35	6.70	8.44
70% IR	36.80	34.40	35.20	33.90	30.70	34.20	9.69	9.33	8.80	8.48	7.33	8.73
Mean	38.80	36.47	37.27	37.00	32.20	36.35	9.35	9.12	8.51	8.28	6.68	8.39
LSD at 0.05	**V = 0.36 I = 0.41 V X I =1.12**						**V = 0.10 I = 0.20 V X I = ns**					

4. Juice quality traits

Brix and sucrose are among the most important quality traits of the sugarcane crop. Data in Tables 6 and 7 illustrated that the tested sugarcane varieties differed significantly in brix, sucrose and sugar recovery percentages in the concerned cane crop cycle. Quality traits were significantly affected by studied factors and their interaction; except the interaction for the brix in the 3rd season. Sugarcane G.T.54-9 variety showed significant superiority over the other ones in brix, sucrose, and sugar recovery% while G.99-80 recorded the lowest values of these traits, in the three growing seasons. An insignificant difference, in the brix% was found between (G.2004-27 and G.84-47) in the 1st season, between (G.2003-47 and G.2004-27) and (G.2003-47 and G.84-47) in the 2nd season and between (G.2003-47 and G.2004-27) and (G.2004-27 and G.84-47) in the 3rd season. An insignificant difference, in the sucrose was found between (G.T.54-9 and G.2003-47) in the 2nd season and between (G.2004-27 and G.84-47) in the 3rd season. The commercial variety G.T.54-9 is still superior in quality traits compared to other varieties at the plant cane and both ratoons with brix percentages of 21.8, 20.7, and 20.0%, and sucrose percentages of 15.4, 16.1, and 14.9%. The variety G2003-47 was in the second rank while G.99-80 recorded the lowest percentages. The variation in these juice quality traits is most likely caused by the genetic variability among the studied cane varieties. Similar results were reported by Abu-Ellail *et al.,* (2019) and El-Bakry (2018), Gomaa (2000) who revealed that the promising G.2003-47 sugarcane variety showed significant superiority in juice quality traits (sucrose, brix, and sugar recovery) over the other tested ones. Also G.2004-27 and G.84-47 sugarcane varieties differed significantly in quality traits. Concerning the influence of irrigation regimes on sugarcane quality traits, the results indicate that brix and sucrose significantly decreased as the irrigation regime was raised from 70 to 85 and 100% IR, in the three growing seasons. Applying irrigation at 70% IR increased the brix and sucrose of the plant cane crop by 3.9 and 3.6 % compared to 85% IR, and by 6.7 and 8.3 % compared to 100% IR. Similar results were found in the subsequent seasons. These findings agree with those presented by (Yang *et al.*, 1995) and (Hemeid *et al.*, 2017). The plant cane season had the greatest brix percentages, while the 1st ratoon had the highest sucrose percentages. As for the interaction effects, the results revealed that the studied quality traits of sugarcane were influenced by the interaction of cane varieties and irrigation regimes, in the three growing seasons, except for brix% in the 3rd season. The highest brix percentage was 22.5% which was obtained by variety G.T.54-9 at 70% IR in season one, while the highest sucrose percentage was 16.9% which was obtained by the same variety G.T.54-9 at 70% IR in season two.

Table 7. Brix (%) and Sucrose (%) of the tested sugarcane varieties as affected by the irrigation regimes (IR) in the three seasons

Irrigation regime (I)	Brix (%)						Sucrose (%)					
	1st season (2020/2021)						1st season (2020/2021)					
	Sugarcane varieties (V)						Sugarcane varieties (V)					
	G.T.54-9	G.2003-47	G.2004-27	G.84-47	G.99-80	Mean	G.T.54-9	G.2003-47	G.2004-27	G.84-47	G.99-80	Mean
100% IR	21.10	20.10	19.70	20.20	18.50	19.92	15.30	15.20	13.80	14.60	12.50	14.28
85% IR	21.80	20.30	20.40	20.40	19.40	20.46	16.10	15.60	14.90	14.90	13.10	14.92
70% IR	22.50	21.70	20.80	21.20	20.10	21.26	16.90	16.30	15.10	15.30	13.70	15.46
Mean	21.80	20.70	20.30	20.60	19.33	20.55	16.10	15.70	14.60	14.93	13.10	14.89
LSD at 0.05	**V = 0.13 I = 0.44 V X I =0.26**						**V = 0.18 I = 0.15 V X I = 0.23**					
	2nd season (2021/2022)						2nd season (2021/2022)					
100% IR	20.20	18.10	18.40	19.10	18.00	18.76	15.00	14.90	13.20	14.10	11.80	13.80
85% IR	20.90	19.70	19.30	19.40	18.60	19.58	15.20	15.10	14.20	14.60	12.50	14.32
70% IR	21.00	20.40	19.90	20.30	19.00	20.12	15.80	15.30	15.20	15.20	12.90	14.88
Mean	20.70	19.40	19.20	19.60	18.53	19.49	15.33	15.10	14.20	14.63	12.40	14.33
LSD at 0.05	**V = 0.09 I = 0.35 V X I =0.15**						**V = 0.22 I = 0.28 V X I = 0.29**					
	3rd season (2022/2023)						3rd season (2022/2023)					
100% IR	19.10	18.10	18.40	18.10	17.90	18.32	14.50	13.60	13.20	13.00	11.00	13.06
85% IR	20.20	19.20	19.20	19.00	18.00	19.12	14.70	14.70	13.90	13.60	11.70	13.72
70% IR	20.70	20.20	19.20	19.60	18.30	19.60	15.40	14.90	14.10	13.90	12.40	14.14
Mean	20.00	19.17	18.93	18.90	18.07	19.01	14.87	14.40	13.73	13.50	11.70	13.64
LSD at 0.05	**V = 1.02 I = 0.32 V X I = ns**						**V = 0.12 I = 0.31 V X I =0.23**					

5. Cane and Sugar yields

Cane and sugar yields (ton/fed) are very important traits concerning both the farmer and industry; these traits are presented in Tables 8. The tested sugarcane varieties differed significantly in cane and sugar yield. Sugarcane G.T.54-9 variety showed the significant superiority over the other ones in cane and sugar yield, while G.99-80 recorded the lowest values of these traits, in the three growing seasons. Insignificant variance was found between varieties G2003-47 and G.84-47 in the 1st season, between G.T.54-9 and G.2004-27 in the 2nd season, as well as between variety G.2003-47 and two varieties G.2004-27 and G84-47 in the 3rd season, in cane yield. The sugar output between (G.2003-47 and G.2004-27) cultivated as plant cane crops also showed a negligible variation. The highest cane yield was 58.54, 58.1, and 48.54 ton fed-1 and sugar yield was 5.38, 5.66, and 4.50 ton fed^{-1} which attained by the variety G.T.54-9 at 100% IR. The difference among the evaluated cane varieties in these growth traits is probably attributed to the variance in their genetic makeup. The difference among cane varieties in these traits was also reported by Bekheet (2006), El-Geddawy *et al.*, (2004), and Gary *et al.*, (2000). Regarding the influence of irrigation regimes on cane and sugar yield, the results indicate that cane and sugar yield significantly affected by irrigation regime. The cane and sugar yield decreased with the decrease in the irrigation regime; with the exception of variety G2004-27, the highest sugar yield was attained at 85% IR. These results concur with those of (Bahrani *et al.*, 2009) who observed that cane and sugar yield was reduced under water stress and that the crop was dehydrated by high temperatures. According to (Ghaffar *et al.*, 2013), irrigation at 40% moisture stress reduced cane yield by up to 47.17%. Additionally, (Hemeid *et al.*, 2017) revealed that sugar yield was not significantly influenced by the decrease in irrigation water at the plant cane and first ratoon; conversely, sugar yield was not significantly influenced. Season two (1st ratoon) had the highest cane and sugar yield, followed by season one (plant cane), then season three (2nd ratoon). In three seasons, the 100% IR treatment produced the highest cane and sugar yield, with cane yields of 49.98, 51.66, and 42.98 ton fed^{-1} and sugar yields of 4.30, 4.85, and 3.61 ton fed^{-1}. Decreasing the irrigation regime from 100% IR to 85% IR decreased cane yield in three seasons by 9.5, 8.3 and 9.2 % and sugar yield by 4.7, 4.6 and 5.7 %; while decreasing the irrigation regime from 100% IR to 70% IR decreased cane yield in three seasons by 17.0, 19.8 and 20.7 % and sugar yield by 9.7, 14.2 and 16.0 %. As for the interaction effects, the results revealed that the cane and sugar yield were influenced by the interaction of cane varieties and irrigation regimes, in the three growing seasons.

Table 8. Cane yield (ton/fed) and sugar yield (ton/fed) of the tested sugarcane varieties as affected by the irrigation regimes (IR) in the three growing seasons

Irrigation regime (I)	Cane yield (ton/fed)						Sugar yield (ton/fed)					
	1st season (2020/2021)						1st season (2020/2021)					
	Sugarcane varieties (V)						Sugarcane varieties (V)					
	G.T.54-9	G.2003-47	G.2004-27	G.84-47	G.99-80	Mean	G.T.54-9	G.2003-47	G.2004-27	G.84-47	G.99-80	Mean
100% IR	58.10	48.86	52.21	47.34	41.34	49.57	5.51	4.72	4.36	4.27	3.05	4.38
85% IR	50.89	45.72	50.34	40.43	38.43	45.16	5.13	4.58	4.67	3.75	2.97	4.22
70% IR	46.02	37.21	45.59	37.97	33.97	40.15	4.92	3.84	4.27	3.59	2.76	3.88
Mean	51.67	43.93	49.38	41.91	37.91	44.96	5.19	4.38	4.43	3.87	2.93	4.16
LSD at 0.05	V = 1.21 I = 1.18 V X I = 2.11						V = 0.13 I = 0.16 V X I = 0.28					
2nd season (2021/2022)							2nd season (2021/2022)					
100% IR	58.54	49.90	54.11	46.37	40.87	49.96	5.52	4.96	4.39	4.10	2.78	4.35
85% IR	51.23	45.07	52.09	41.51	35.91	45.16	4.83	4.36	4.62	3.84	2.64	4.06
70% IR	47.84	43.74	47.74	35.75	34.52	41.92	4.79	4.23	4.64	3.43	2.64	3.95
Mean	52.54	46.24	51.31	41.21	37.10	45.68	5.05	4.52	4.55	3.79	2.68	4.12
LSD at 0.05	V = 0.96 I = 1.30 V X I =1.42						V = 0.06 I = 0.08 V X I =0.15					
3rd season (2022/2023)							3rd season (2022/2023)					
100% IR	48.54	45.37	43.21	41.92	34.87	42.78	4.49	3.91	3.51	3.35	2.10	3.47
85% IR	41.23	39.51	41.34	40.07	32.91	39.01	3.76	3.72	3.55	3.35	2.21	3.32
70% IR	37.84	32.75	35.59	33.74	30.52	34.09	3.67	3.06	3.13	2.86	2.24	2.99
Mean	42.54	39.21	40.05	38.58	32.77	38.63	3.97	3.56	3.40	3.19	2.18	3.26
LSD at 0.05	V = 0.63 I = 0.87 V X I =1.65						V = 0.12 I = 0.05 V X I = ns					

6. Water productivity

Water productivity is related to yield (cane or sugar) and applied water; it is a measure of how much output may be obtained per unit of irrigation water. This indicator is very important in irrigation system management by analyzing how much water is lost and developing initiatives to enhance irrigation system performance (Molden *et al.*, 2003). Table 9 presents the water productivity for cane and sugar yield, the tested sugarcane varieties differed significantly in water productivity, in the involved cane crop cycle. Sugarcane G.T.54-9 variety showed the significant superiority over the other ones in water productivity, while G.99-80 recorded the lowest values, in the three growing seasons. Insignificant variance was found in water productivity for cane yield between varieties G.T.54-9 and G.2004-27, G.2004-27 and G.2003-47, and G.84-47 and G.99-80 in the 1st season, as well as between G.T.54-9 and G2004-27, and G2003-47 and

G84-47 in the 2nd season, likewise between G2003-47 and G84-47, and G.2004-27 and G.84-47 in the 3rd season. Insignificant variance was found in water productivity for sugar yield between varieties G.2003-47 and G.2004-27 in the 1st season, as well as between G.2003-47 and G.2004-27 in the 3rd season. According to the results, reducing irrigation regimes increased water productivity, resulting in a decrease in applied water. Similar results were obtained by (Wiedenfeld and Enciso, 2008) who found a decrease in water productivity associated with an increase in applied water. (Ghaffar *et al.*, 2013) mentioned increasing water production by imposing water stress. Season two (1st ratoon) had the highest water productivity, followed by season one (plant cane), then season three (2nd ratoon), this result is consistent with the result of cane and sugar yield. During the three growing seasons, decreasing the irrigation regime from 100% IR to 85% IR increased water productivity for cane by 5.34, 7.08, and 5.94% and for sugar by 11.03, 11.39, and 10.13%; whereas decreasing the irrigation regime from 100% IR to 70% IR increased water productivity for cane by about 15.7, 12.6, and 11.2% and for sugar by about 25.9, 20.5, and 17.8%. The highest water productivity for cane overall three seasons was 6.68, 6.05, and 5.04 kg m^{-3} which obtained by varieties G.T.54-9, G.2004-27 and G. T.54-9 respectively at 70% IR. The highest water productivity for sugar overall three seasons was 0.64, 0.62, and 0.49 kg m^{-3} which obtained by the variety G.T.54-9 at 70% IR. As for the interaction effects, the results revealed that the water productivity for cane and sugar were significantly influenced by the interaction of cane varieties and irrigation regimes, in the three growing seasons.

Table 9. Effect of irrigation regimes, cane varieties and the interaction on water productivity for cane and sugar yields basis (kg canes and sugar/m³ water) in the three growing seasons

Irrigation regime (I)	Water productivity for cane yield (kg m^{-3})						Water productivity for sugar yield (kg m^{-3})					
	1st season (2020/2021)						1st season (2020/2021)					
	Sugarcane varieties (V)						Sugarcane varieties (V)					
	G.T.54-9	G.2003-47	G.2004-27	G.84-47	G.99-80	Mean	G.T.54-9	G.2003-47	G.2004-27	G.84-47	G.99-80	Mean
100% IR	5.86	5.00	5.23	4.64	4.29	5.01	0.54	0.47	0.40	0.39	0.36	0.43
85% IR	5.98	5.26	5.87	4.84	4.42	5.27	0.55	0.50	0.54	0.43	0.37	0.48
70% IR	6.68	6.11	6.37	4.99	4.82	5.79	0.64	0.57	0.60	0.47	0.44	0.54
Mean	6.17	5.45	5.82	4.83	4.51	5.36	0.58	0.51	0.51	0.43	0.39	0.48
LSD at 0.05	I = 0.25 V = 0.53 I X V = 0.91						I = 0.01 V = 0.01 I X V = 0.02					
2nd season (2021/2022)							2nd season (2021/2022)					
100% IR	5.25	4.41	4.89	4.51	4.28	4.67	0.51	0.45	0.42	0.42	0.38	0.44
85% IR	5.58	4.82	5.49	4.82	4.26	5.00	0.58	0.49	0.53	0.46	0.38	0.49
70% IR	5.83	4.72	6.05	4.85	4.81	5.25	0.62	0.53	0.59	0.47	0.43	0.53
Mean	5.55	4.65	5.48	4.73	4.45	4.97	0.57	0.49	0.51	0.45	0.40	0.48
LSD at 0.05	I = 0.14 V = 0.15 I X V = 0.26						I = 0.01 V = 0.02 I X V = 0.03					
3rd season (2022/2023)							3rd season (2022/2023)					
100% IR	4.61	3.99	4.11	4.31	3.41	4.09	0.43	0.34	0.33	0.35	0.27	0.34
85% IR	4.58	4.45	4.59	4.38	3.65	4.33	0.42	0.39	0.42	0.37	0.30	0.38
70% IR	5.04	4.50	4.74	4.36	4.07	4.54	0.49	0.42	0.42	0.37	0.33	0.40
Mean	4.74	4.31	4.48	4.35	3.71	4.32	0.44	0.39	0.39	0.36	0.30	0.38
LSD at 0.05	I = 0.10 V = 0.19 I X V = 0.33						I = 0.02 V = 0.01 I X V = 0.03					

7. Ratooning ability (RA)

The results in Table (10) revealed that ratoon ability was significantly affected by variates, water regimes and their interaction. The ratoon ability of most of the promising varieties was decreased with decreased water irrigation regimes which significantly differed in their ratooning ability for most growth and quality traits. Ratoon ability (RA) of cane and sugar yields (Table 10) indicated that an increase in cane and sugar yields may be linked to an increase in the RA, but the rank of RA differed from one irrigation regime to another. The varieties were ranked under 100, 80, and 70 irrigation regimes (IR) showed two varieties (G.2003-47 and G.2004-27) had the highest RA under 100 IR, but under 85 IR the highest RA for cane yield recorded by variety, G.T.54-9 surpassed other varieties. On the contrary, under 70 IR the new variety G.2004-27 had the rank 1 greater than others for the cane and sugar yields. Changes in RA and ratoon crop yields are usually related to differences in sugarcane varieties' performance abilities under diverse environments (Chapman *et al.,* 1992), and a limited RA diversity was detected among sugarcane varieties (Arbelo *et al.,* 2021). The highest RA% of cane yield and sugar yield values were recorded by varieties (G.2003-47, G.2004-27, and G.T.54-9) under a 70% irrigation regime, indicating little change between plant cane and 2nd ratoon crop for most promising varieties. The mean values of the studied sugarcane crop cycle manifested that stalk diameter, the number of millable canes, and cane yield of the evaluated varieties decreased gradually as the crop cycle advanced with age from the plant cane, up to the 2nd ratoon crop. Data in Table 10 show the difference in cane yield and sugar yield and it is related traits. G.T.54-9 and G.2004-27, grown as plant cane or 2nd ratoon, were unaffected and insignificant. However, in the 1st ratoon, G.2004-27 surpassed G.2003-47 significantly in most growth characters. The promising varieties G.2004-27 and G.2003-47 had the best ratooning ability (RA) of a number of millable canes, sugar, and cane yields, while the lowest value of this criterion was recorded by G.99-80. These results were similar to those reported by Sundra (1989), who recorded a significant reduction in most traits in the ratoon crop compared to that of the plant cane and referred to the reduction in ratoon crop as the interference of differential ratooning capacity of the studied varieties. Also, data showed that the G.84-47 recorded the lowest cane yield. The highest ratooning ability (RA) value for cane and sugar yields was recorded by the variety G.2004-27 followed by the varieties G.2003-47 , and G.84-47 significantly stable in their performance but did not exceed the check cultivar GT. 54-9. All promising varieties were decreased in older crop cycles which is in accordance with the results of Milligan et al., (1996) who found that cane yield has been suggested as being indicative of better ratooning cultivars. Also, a limited RA diversity was detected among genotypes (Arbelo *et al.,* 2021).

Table. 10 Ratooning ability (RA) % for five sugarcane varieties under 100%, 85% and 70% of irrigation regimes (IR)

Growth and quality traits	G.T.54-9 RA	Mean	G.2003-47 RA	Mean	G.2004-27 RA	Mean	G.84-47 RA	Mean	G.99-80 RA	Mean
Ratooning ability (RA) under Irrigation regimes (IR: 100%)										
Stalk diameter (cm)	100	2.73	93	2.27	89	2.43	81	2.18	88	2.63
Stalk weight (Kg)	104	1.19	94	1.09	94	1.24	90	1.05	95	1.10
Number of millable canes (1000/fed)	88	44.10	89	42.17	98	40.93	88	39.50	89	33.97
Cane yield (ton/fed)	84	55.06	93	48.04	89	49.84	84	45.21	83	39.03
Brix (%)	91	21.00	90	14.94	93	14.52	90	14.66	97	13.55
Sucrose (%)	95	15.43	89	15.20	96	14.40	89	14.80	88	12.63
Sugar yield (ton/fed)	81	5.04	83	4.44	81	4.54	78	3.85	69	2.78
Ratooning ability (RA) under Irrigation regimes (IR: 85%)										
Stalk diameter (cm)	89	2.60	96	2.33	100	2.40	92	2.22	84	2.57
Stalk weight (Kg)	88	1.17	96	1.10	96	1.20	93	1.11	85	1.09
Number of millable canes (1000/fed)	93	42.73	97	40.90	102	40.47	92	38.10	90	34.20
Cane yield (ton/fed)	99	50.89	86	45.72	81	50.34	82	40.43	86	38.43
Brix (%)	93	20.73	95	19.20	94	19.33	93	19.50	93	18.47
Sucrose (%)	91	15.27	94	15.07	93	14.00	91	14.20	89	12.20
Sugar yield (ton/fed)	76	4.80	81	4.42	74	4.20	89	3.73	73	2.65
Ratooning ability (RA) under Irrigation regimes (IR: 70%)										
Stalk diameter (cm)	88	2.43	91	2.17	110	2.33	86	2.07	93	2.63
Stalk weight (Kg)	90	1.12	98	1.03	97	1.12	91	1.04	80	1.01
Number of millable canes (1000/fed)	91	39.43	90	37.10	97	36.90	98	36.40	92	32.70
Cane yield (ton/fed)	82	46.02	88	37.21	90	45.59	89	37.97	78	33.97
Brix (%)	92	20.77	93	20.00	92	19.47	92	19.63	91	18.77
Sucrose (%)	91	15.60	91	14.93	93	14.13	91	14.07	91	12.37
Sugar yield (ton/fed)	81	4.36	80	3.60	80	3.64	73	3.27	75	2.37

8. Heritability and Variability

Data in (Table 11) indicate phenotypic variance (PCV %) and genotypic variance (GCV %) increased from plant cane to 1st and 2nd ratoon for sucrose and Brix percentages, but they decreased for stalk diameter, stalk weight, number of stalks per faddan and cane yield. Significant variation was found in phenotypic and genetic variation and the degree of heritability was affected by the decrease in irrigation water requirements and crop years' cycles. Results show the highest GCV (%) and PCV (%) values were observed for sugar yield, number of stalks/fed, stalk weight, and cane yield in the plant can, 1st and 2nd ratoon crops. Low values of GCV and PCV in plant cane and ratoon crops were recorded for characters viz., stalk diameter and juice quality such as sucrose%, Brix%, and sugar yield. Stalk diameter registered low heritability coupled with low GCV and PCV as a percent of the mean suggesting selection will be less effective for these traits. Abu-Ellail *et al.*, (2017) reported that phenotypic and genotypic coefficient of variation decreased from plant cane to the 1st ratoon for the traits, stalk diameter, cane yield, Brix%, and the number of stalks/fed. Bhatnagar *et al.*, (2003) found that a high value of genotypic and phenotypic coefficients of variation was exhibited by the number of stalks, sugar yield, and cane yield in both plant and ratoon crops. The selection for yield contributing characters with the high genotypic and phenotypic coefficient of variability and low depression in ratoon crops will be more effective for the development of genotypes with ratoon ability (Gowda *et al.*, 2016). The genotypic coefficient of variations is not a correct measure to know the heritable variation present and should be considered together with heritability estimates. Broad-sense heritability estimates (Table 11) were high for stalk weight and cane yield, while they were low for stalk diameter and number of milable canes in plant cane, first, and second ratoon crops. Broad-sense heritability (H%) increased for sucrose% with older crops, while, it decreased for stalk weight, number of stalks/fed, cane yield, and juice quality traits. In addition, the results reported high estimates of broad sense heritability and genetic variances for cane and sugar yield. High heritability and genotypic coefficient of variations % estimates across crops were recorded for cane yield, stalk diameter, and Brix %; this suggests that simple selection for these traits would be effective. Xie *et al.*, (1989) and Walker (1965) reported that the number of millable cane and stalk diameter are the most useful traits to consider when selection is imposed for high cane yield where the millable cane is a reasonable selection criterion for high cane yield. Mohamed and El-Taib (2007) and Mali *et al.*, (2009), revealed that the heritability and genetic variability obtained by sugar yield followed by cane yield indicate the importance of these traits for sugarcane choosing the best varieties in ratoon crops. Abu-Ellail *et al.*, (2017) and Abu-Ellail (2015) reported that heritability decreased from plant cane to 1st ratoon for the traits, the significant genotypic effects indicated the existence of genetic variability among the varieties and the possibility of utilizing them in genetic improvement. Knowledge of variability and heritability of characters is essential for identifying those amenable to genetic improvement through selection (Vidya *et al.*, 2002).

Table 11. Broad sense heritability (H %), phenotypic (PCV %) and genotypic (GCV %) coefficient of variation for growth and quality traits during three crop cycles (plant cane (PC), first ratoon (FR) and second ratoon (SR)

Traits	Stalk diameter (cm)			Stalk weight (kg)			Number of stalks/fed			Cane yield (ton/fed)			Brix%			Sucrose%			Sugar yield (ton/fed)		
	PC	FR	SR	PC	FR	SR	PC	FR	SR	PC	FR	SR	PC	FR	SR	PC	FR	SR	PC	FR	SR
Genetics components under Irrigation regimes (IR: 100%)																					
H%	70.59	67.62	43.14	87.19	86.36	71.56	79.18	76.28	55.79	92.69	91.91	73.28	96.47	93.15	91.24	88.41	91.63	97.27	98.21	96.57	73.01
PCV%	8.52	8.91	6.67	31.13	27.74	23.64	24.92	27.91	25.16	31.2	28.29	27.66	13.84	12.41	11.22	14.31	15.17	16.46	33.03	37.65	31.25
GCV%	7.19	7.31	4.01	30.21	26.11	21.84	21.72	26.71	23.32	26.15	25.14	25.16	12.61	11.13	10.61	13.04	14.06	15.31	32.90	36.15	26.12
Genetics components under Irrigation regimes (IR: 85%)																					
H%	63.57	59.68	53.19	73.13	68.33	61.59	78.13	65.88	62.31	82.12	76.23	71.34	79.24	82.41	94.75	83.62	87.75	91.23	84.31	81.57	75.03
PCV%	7.55	6.66	6.20	42.16	34.32	26.14	33.64	29.22	23.41	23.64	21.32	18.34	15.13	11.65	10.05	15.64	16.57	17.69	39.11	33.54	30.27
GCV%	6.12	5.33	4.51	20.36	19.16	16.74	18.33	16.54	13.64	13.18	15.16	13.19	13.54	10.11	9.54	14.12	15.21	16.36	33.92	37.16	28.32
Genetics components under Irrigation regimes (IR: 70%)																					
H%	53.41	48.78	42.16	63.14	61.22	52.41	74.64	71.11	66.45	73.42	64.41	53.25	68.34	73.65	81.12	71.14	83.35	86.24	81.14	78.33	71.01
PCV%	6.53	5.24	5.01	31.32	27.11	23.23	30.14	26.32	21.06	25.45	23.54	19.78	16.47	12.64	11.12	16.71	15.13	12.32	30.16	27.54	24.27
GCV%	4.33	4.11	3.65	19.41	16.17	13.88	15.31	14.31	12.54	12.65	11.45	10.16	11.67	10.52	9.89	13.09	11.05	10.56	24.12	20.15	18.36

CONCLUSION

In conclusion, the study demonstrates a generally positive relationship between decreasing irrigation regimes to (70%), and juice quality of the sugarcane varieties. However, a negative association was found between decreasing water regime and growth traits or cane yield and sugar yield. Growth traits, cane yield, Sugar yield, and ratooning ability of G 2004-27 were less sensitive than those of the other tested varieties to water deficit indicating the possibility of recommendation to cultivate it under water deficit conditions and using it in The breeding program to develop tolerance variates to water deficit. The results found that varieties GT.54-9 and G.2004-27 got the highest cane and sugar yields under 70% irrigation regimes in Plant cane and ratoons crops. However, the varieties G.2003-47, GT.54-9, and G.2003-47 had the 1st rank of ratoon ability (RA) for cane and sugar yields under all irrigation regimes. On the contrary, variety G.99-80 ranked as the last one for RA in most studied traits. The study recommended the variety G.T.54-9 is preferable to get the highest cane yield/fed, in case of the abundance of water (100 % irrigation regimes).

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التباين والتوريث والأداء لبعض أصناف قصب السكر تحت ثلاثة مستويات للري السطحي

فراج فرغل برعي أبو الليل[1] - طارق محمود عطافي[2] -أحمد السيد عطية [1] - عبد الناصر البكري[1]
[1] معهد بحوث المحاصيل السكرية - مركز البحوث الزراعية - الجيزة - مصر
[2] معهد بحوث الهندسة الزراعية - مركز البحوث الزراعية – الجيزة - مصر

الملخص العربي

أجريت تجربة حقلية بمحطة بحوث المطاعنة الزراعية بمحافظة الأقصر بمصر خلال ثلاثة مواسم زراعية حيث تمت زراعة قصب السكر فى الغرس ومحصولي الخلفة الأولي والثانية على التوالي لمعرفة تأثير ثلاثة مستويات ري سطحي مختلفة (100، 85، و 70٪ من الاستهلاك المائي IR) على إنتاجية خمسة أصناف من قصب السكر وهي (G.T.54-9، G.2003-47، G.2004-27، G.84-47، و G.99 -80.) . تم استخدام تصميم القطاعات العشوائية الكاملة بأربعة مكررات في ترتيب القطع المنشقة. أظهرت النتائج أن محصول الخلفة الأولي استهلك أكبر كمية من مياه الري، يليه محصول الخلفة الثانية ومحصول الغرس . أظهرت النتائج أن مستوي الري بنسبة 70% من الإحتياج المائي هو الأعلى في كفاءة الإضافة للري ، يليه 100% و85%. انخفضت إنتاجية محصول العيدان ومحصول السكر مع انخفاض كمية المياة المضافة ؛ ومع ذلك، زادت إنتاجية المياه مع انخفاض مستوي مياة الري المضافة . تم تسجيل أعلى القيم للتباين المظهري (PCV٪) ومعامل التباين الوراثي (GCV٪) والتوريث بالمعنى الواسع لمحصولي السكر والعيدان في محصول الغرس والخفات تحت مستويات مياه الري المدروسة. أظهرت النتائج وجود فرق معنوي بين الأصناف المدروسة في القدرة على الراتون (التخليف RA) ومعظم الصفات المدروسة. أظهرت أصناف قصب السكر G.2004-27 وG.2003-47 قدرة أعلى على الراتون (التخليف) ، حيث سجلت إنتاجية أعلى من محصول السكر والعيدان في كل من محصول الخلفة الاولي مقارنة مع G.84-47 وG.99-80، والتي كان أداءها ضعيفًا فيما يتعلق بنفس الصفة في محصول الخلفة الثانية . تقترح هذه الدراسة اختيار الأصناف ذات الإنتاجية العالية من محصول العيدان ومحصول السكر بالإضافة إلى تحمل العجز المائي على أساس الصفات المساهمة في المحصول التي تحتوي على نسبة عالية من PCV٪ وGCV٪ ونسبة التوريث إلى جانب المتوسط العام . أشارت النتائج إلى أنه ينصح بزراعة الصنف G.2004-27 تحت الظروف الطبيعية وظروف العجز المائي ويمكن استخدامه كأم في برامج التربية لتحسين تحمل أصناف قصب السكر للعجز المائي بينما أشارت النتائج إلى أنه ينصح بزراعة الصنف G.T. 54-9 في ظل ظروف الري الطبيعي .

الكلمات المفتاحية: الأداء، التوريث، القدرة على التخليف ، أصناف قصب السكر، مستويات الري السطحي.