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Genetic Variance and Performance of Five Sugarcane Varieties for Physiological, Yield and Quality Traits Influenced by Various Harvest Age

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ABSTRACT

Field experiments was carried out at Shandaweel Agricultural Research Station, Sohag Governorate during 2017/2018 and 2018/2019 seasons. The aim of this research to investigate three harvest dates at ages of(11,12 and 13 months)on the performance of five promising sugarcane varieties G.84-47,G.2003-47, G.2003-49,G.2004-27 and the commercial variety G.T.54-9 as a control. The harvest age up to 13 months recorded the highest values of cane and sugar yields in plant cane (52.08 and 5.95 tons/fed (fed=0.42ha), respectively) and first ratoon crops (55.16 and 6.70tons/fed, respectively).Varieties showed significantly differed in stalk length, stalks number, as well as brix, sucrose, sugar recovery percentages, cane and sugar yields (ton/fed.).The best performance was reported by the following varieties (G2004-27, G2003-47 and GT54-9) under all harvest ages, Also, these varieties registered the best cane yield (52.01,52.35 and 53.94 tons/fed, respectively) and sugar yields (5.48,6.09 and 6.03ton/fed,respectively).Results indicated significantly increasing physiological characters such as, leaf area index (LAI), crop growth rate (CGR),and net assimilation rate (NAR) with increasing harvest age as well as, these traits varied significantly between varieties. There is a positive and significant correlation between CGR, NAR and cane yield, which should be used to predict cane yield. Broad-sense heritability for cane and sugar yields and their traits varied from the lowest trait registered by stalk length(34.23%)to the highest value(95.82%)recorded by sucrose percentage. It could be more effective if selected higher heritability for yield than the lower. Varietal differences in growth and maturity rates should be taken into account when making harvesting decisions.

Keywords: Sugarcane, Harvest Age, Varieties, Genetic Variance, Broad-sense heritability

INTRODUCTION

Sugarcane (*Saccharum hybried ssp* L.) is a world-wide industrial crop cultivated for its diverse uses, among which the most important is sugar. In Egypt, it was grown over 133.8 thousand ha with the total annual cane production of 15.3 million tons (Annual Report of Sugar Crops Council, 2020). Sugar cane is grown in Upper Egypt Governorates, included Sohag Governorate for sugar production, harvesting season extended from January to May. Harvesting age is the major important factor affecting sugarcane yield and quality traits. Similarly, at Shandaweel city, spring harvested crop prove to be better ratoon than autumn because of moderate temperature conductive for stubble sprouting. Sugarcane is harvested in the subtropical regions under conditions of low temperature (early harvesting) and high temperature (late harvest). The adaptation and success of a sugarcane variety depends on their adaptability to the area's agro-climate conditions. Harvesting of sugarcane at a proper time by adopting the right age is necessary to realize the maximum weight of the millable canes produced with the least possible field losses under the given growing environment (Muchow *et al.,* 1998). The variables of climate elements, temperature, solar radiation, relative humidity, and total rainfall accounting for a major difference in harvest age among sugarcane growing countries (Jorge *et al.,* 2010). Some varieties of sugar cane have relatively high concentrations of sucrose in the early season and are defined as early maturation, while others are known as late maturation (Calderon *et al.,* 1996). The crop season also ranges from 20 to 24 months in Hawaii, 13 to 19 months in Jamaica, 12 to 18 months in India, 16 months in Mauritius and 15 months in Queensland, Australia (Salisbury and Ross, 1991). Other factors such as varieties, weather conditions, and soil type may have a more direct bearing on the real maturity of canes than the crop age. However, the percentage of quality of cane juice mainly depends on various factors such as the sugarcane variety, the maturity of the sugarcane in the case of plant cane, weather, and harvesting conditions (Liu and Bull, 2001). On the other hand, harvesting either under-aged or over-aged cane with the improper time of harvest leads to a loss in cane yield, sugar recovery, poor juice quality, and problems in milling (Khandagave and Patil, 2007). Cane and sugar yields is determined by the age of harvesting at which the cane matures (Verma, 2004), basically, sugarcane varieties differ inherently in their time of maturity. Some cane is harvested before achieving maximum sucrose levels due to an increase of cane supply in early-season milling operations (Miller and James, 1977). An essential role of physiological research into crops is to quantify the role of the different plant age and growth processes contributing to differences in cane production and sugar yield. Must have

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physiological parameters for sugar cane to establish parameters for the growth analysis by daily sampling the crop over the entire growing season (Robertson *et al.,* 1996 and Nava *et al.,* 2016).

Genotypic coefficient of variation is not a correct measure to know the heritable variation present and should be considered together with heritability estimates. Genotypic and phenotypic coefficients of variation along with heritability are very essential to improve any trait of sugarcane because this would help in knowing whether or not the desired objective can be achieved from the material (Tyagi and Singh, 1998). Burton (1952) reported the study of genetic coefficient of variation along with heritability estimate as necessary to obtain the true picture of the heritable variations in the population handle .Srivastava (1993) reported, sugarcane genotypes greatly differ in ratooning capacity and to produce profitable ratoon crop. Xie *et al.,* (1989) reported that number of millable cane is the most useful trait to consider when selection imposed for high cane yield .Genotypic variance, heritability, phenotypic and genotypic coefficient of variation decreased from plant cane to first ratoon for the traits, stalk diameter, cane yield and Brix%, while, they increased slightly for number of stalks/fed and purity% (Abu-Ellail *et al.,* 2017). The objectives of this study were to: 1) Finding out the suitable sugarcane varieties with respect to yield and quality under different harvest ages in Sohag Governorate condition .2) Determine the optimum harvesting age for five promising sugarcane varieties .3) Calculate heritability and genetic variability among yield and quality traits.4) Calculate physiological growth analyses.

MATERIALS AND METHODS

Field experiments was carried out at Shandaweel Agricultural Research Station, Sohag Governorate (latitude 26.33N and length 31.42E) grown as plant cane in 2017/2018 and first ratoon 2018/2019 seasons to investigate three harvest dates at ages of (11, 12 and 13 months) on the performance of five promising sugar cane varieties G. 84-47, G.2003-47, G.2003-49, G.2004-27 and the commercial variety G.T.54-9 as a control. A split plot design with three replications was used in both seasons. Harvesting age treatments were allocated in the main plots while sugar cane varieties were randomly distributed in the sub plots. Plot area was 35 m^2, including 5 rows of 1 m apart and 7 m in length. Sugar cane varieties were planted in the last week of February. Added phosphorus at a rate of 30 kg P_2O_5/fed during the preparation of land for planting. Nitrogen fertilizer was added at a rate of 200 kg N / fed in two equal doses, the first after planting 60 days and the second after 30 days. Adding potassium fertilizer at a rate of 48 kg K_2O/fed with the second batch of nitrogen fertilizer. All plots were received normal agronomic practices recommended for the sugarcane crop in clay soil . The following data were recorded at harvest:

Agronomic characters

Cane traits

1. Millable cane stalks length (cm), which was measured from soil surface to the top point of visible dewlap.
2. Millable cane diameter (cm), which was measured at the middle part of stalk.
3. Number of millable cane stalk (10^3/fed)
4. Cane yield (tons/fed) was calculated on the plot basis.

Quality traits

1. Brix% was determined by using the Brix Hydrometer standardized at 20ºC.
2. Sucrose% was determined using "Saccharemeter" according to A.O.A.C. (2005).
3. Purity%= Sucrose%/ Brix% *100: It was calculated according to the following formula of Singh and Singh (1998).
4. Sugar recovery%: was calculated according to Yadav and Sharma (1980).

Sugar recovery% = [Sucrose - 0.4 (brix – sucrose) 0.73].

5. Sugar yield (tons/fed) (fed = 0.42ha): was estimated according to the following equation:

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

Physiological characters

The physiological growth analyses used in this trial were calculated according to (Watson, 1952 and Hall *et al.*, 1993) as follows:

1. Number leaves per plant
2. Number tillers per plant
3. Specific leaf area (cm²/g) = (Leaf area / Leaf weight)
4. Leaf area index = (leaf area / plant) / (soil area / plant).
5. Crop growth rate (g/cm²/day) = $(W_2-W_1) / (t_2-t_1)$
6. Relative growth rate (g/g/day) = $(\log W_2- \log W_1) / (t_2-t_1)$
7. Net assimilation rate (g/m^2/day) = $(W_2-W_1) (\log A_2-\log A_1) / (A_2-A_1) (t_2-t_1)$, where: W_1 and W_2 respectively refer to dry weight at time t_1 and t_2 in days.

Estimation of Genetic parameters

Calculation of heritability and genotypic and phenotypic variances were estimated using the following steps from (1 to 5):

1. Genotypic and phenotypic variances were calculated using the following formula [Hill *et al.*, 1998]:

Genotypic variance (σ^2_g) = GMS–EMS/*r* (1)

Where **GMS is genotypic mean square, EMS is error mean square, *r* is number of replication**

Phenotypic variance (σ^2_p) = $\sigma^2_g + \sigma^2_e$ (2)

2. Estimation of Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) were evaluated according to the methods as follows [Singh and Chaudhary 1960]:

Genotypic coefficient of variation (GCV) = ($\sigma^2_g /\bar{X}$) ×100 (3)

Phenotypic coefficient of variation (PCV) = ($\sigma^2_p/\bar{X}$) × 100 (4)

Where, **σ^2_g is genotypic variance σ^2_p is phenotypic variance and $\bar{X}$ is general mean.**

3. Estimation of broad-sense heritability (h^2) was calculated following the formula described by [Allard 1960 and Johnson *et al.*, 1955]:

Heritability (h^2_b) = (σ^2_g/σ^2_p) × 100 (5)

Where, σ^2_g is genotypic variance and σ^2_p is phenotypic variance

The collected data were statistically analyzed according to the method described by Snedecor and Cochran (1981). Treatment means were compared using revised LSD at 5% level of difference as outlined by Steel and Torrie (1980).

RESULTS AND DISCUSSION

A. Harvest age effects on:

Agronomic traits

Results in Tables (1 and 2) pointed out that late harvest date increased significantly values of in stalk diameter, stalk height, stalk number, and cane yield, in the plant cane and first ratoon crops. Significant differences between harvest dates were observed. Harvest age (13 months) recorded the highest mean values of stalk height (286.04 and 286.76 cm), stalk diameter (2.64 and 2.51 cm) and cane yield (52.08 and 55.16 ton/fed), as well as, the highest for stalks number/fed (44.59 and 45.87 thousand /fed). Otherwise, the lowest values of stalks number (38.96 and 40.77 thousand /fed) and cane yield (45.07 and 47.05 ton/fed) in the plant cane and first ratoon crops, respectively were registered under harvest age (11 months). Jadhav *et al*., (2000) they found that stalk height and diameter were increased gradually as harvesting time was delayed. Cane yield was significantly increased from (72.82 to 97.46 ton/ha) with delaying harvesting from 10 to 16 months (Mequanent and Ayele, 2014). Hagos *et al.*, (2014) indicated that stalk height was significantly increased by increasing harvesting age.

The tested sugarcane varieties varied significantly with increasing harvest dates in plant cane and first ratoon crops. GT.54-9 variety had the highest values of stalk diameter (2.72 and 2.58 cm), the number of stalks (43.88 and 45.24 thousand /fed), and cane yield (52.87 and 55.00 ton /fed) at plant cane and first ratoon crops, respectively. The increase in cane yield for GT.54-9 variety was strongly related to the higher stalk performance i.e. stalk diameter and stalks number at harvest which reflected consequently on cane yields. Whereas variety G.84-47 recorded the highest stalks height (291.18 and 290.79 cm), while, it had the thinnest diameter (2.28 and 2.16 cm) and lowest cane yield (43.57 and 45.26 tons/fed) at plant cane and first ratoon crops, respectively. The variety (G2004-27) registered the lowest values of stalk height (262.93 and 269.30 cm) at plant cane and first ratoon, as well as it had the lowest number of stalks per feddan at plant cane crop (40.78 thousand /fed), while the lowest stalks number (42.46 thousand /fed) in first ratoon crops was registered by (G2003-47) variety. These differences could be attributed to the genetic structure of the varieties assessed for cane yield. Sohu *et al.,* (2008) and Abu-Ellail *et al*., (2018), pointed out that the significant variance between the sugarcane varieties in stalk height in both seasons and their crops-year interaction. Sundra (1989) reported significant reduction in stalk height in ratoon crop compared to the plant cane height, this reduction in ratoon crop might be due to interference of differential ratooning capacity of genotypes studied.

Table 1. Mean of stalk height, stalk diameter and stalk number (10^3/fed) of five sugarcane varieties as affected by harvest date during plant cane (PC) and first ratoon (FR)

Varieties	Harvest age (Months)	Stalk height (cm)			Stalk diameter (cm)			No. stalks (10^3/fed)		
		PC	FR	Mean	PC	FR	Mean	PC	FR	Mean
G.T 54-9	11	283.20	278.93	281.07	2.53	2.38	2.46	40.58	41.95	41.27
	12	286.13	293.03	289.58	2.73	2.63	2.68	44.56	45.92	45.24
	13	292.00	295.06	293.53	2.89	2.72	2.81	46.51	47.84	47.18
Mean		287.11	289.01	288.06	2.72	2.58	2.65	43.88	45.24	44.56
G.84-47	11	275.80	285.50	280.65	2.14	2.03	2.09	39.4	40.74	40.07
	12	294.46	293.23	293.85	2.30	2.17	2.24	41.47	42.61	42.04
	13	300.93	294.80	297.87	2.41	2.28	2.35	44.36	47.53	45.95
Mean		290.40	291.18	290.79	2.28	2.16	2.23	41.74	43.63	42.69
G.2003-47	11	266.70	275.96	271.33	2.34	2.35	2.35	38.7	39.62	39.16
	12	275.73	281.00	278.37	2.49	2.43	2.46	41.55	42.52	42.04
	13	284.43	283.66	284.05	2.53	2.49	2.51	43.46	45.23	44.35
Mean		275.62	280.21	277.92	2.45	2.42	2.44	41.24	42.46	41.85
G.2003-49	11	252.43	266.83	259.63	2.45	2.36	2.41	38.67	41.48	40.08
	12	275.60	273.83	274.72	2.50	2.48	2.49	41.53	43.42	42.48
	13	281.20	282.20	281.70	2.67	2.55	2.61	43.44	45.38	44.41
Mean		269.74	274.29	272.02	2.54	2.46	2.50	41.21	43.43	42.32
G.2004-27	11	251.80	269.06	260.43	2.30	2.15	2.23	37.46	40.04	38.75
	12	265.33	260.73	263.03	2.42	2.34	2.38	41.47	43.01	42.24
	13	271.66	278.10	274.88	2.71	2.53	2.62	43.41	45.15	44.28
Mean		262.93	269.30	266.11	2.48	2.34	2.41	40.78	42.73	41.76
Mean of H	11	265.99	275.26	270.62	2.35	2.25	2.30	38.96	40.77	39.87
	12	279.45	280.36	279.91	2.49	2.41	2.45	42.12	43.50	42.81
	13	286.04	286.76	286.40	2.64	2.51	2.58	44.24	46.23	45.23
	Mean	277.16	280.79	278.98	2.49	2.39	2.44	41.77	43.50	42.64
LSD at 5%										
Harvest age (H)				1.08			0.11			1.04
Varieties (V)				1.49			0.09			0.20
H x V				NS			0.17			0.51

Table 2. Mean of sugar recovery%, cane yield and sugar yield (ton/fed) of five sugarcane varieties as affected by harvest age during plant cane (PC), and first ratoon (FR)

Varieties	Harvest age (Months)	Sugar recovery%			Cane Yield (ton/fed)			Sugar Yield (ton/fed)		
		PC	FR	Mean	PC	FR	Mean	PC	FR	Mean
G.T 54-9	11	8.95	9.48	9.22	51.51	52.02	51.77	4.61	4.93	4.77
	12	11.50	11.96	11.73	52.21	55.10	53.66	6.01	6.59	6.30
	13	12.03	13.07	12.55	54.89	57.88	56.39	6.60	7.57	7.08
Mean		10.83	11.50	11.17	52.87	55.00	53.94	5.72	6.33	6.03
G.84-47	11	9.66	10.10	9.88	40.40	41.21	40.81	3.90	4.16	4.03
	12	11.01	10.93	10.97	44.57	45.86	45.22	4.91	5.01	4.96
	13	11.21	10.31	10.76	45.74	48.71	47.23	5.13	5.02	5.08
Mean		10.63	10.45	10.54	43.57	45.26	44.42	4.63	4.73	4.68
G.2003-47	11	10.18	11.06	10.62	48.25	50.74	49.50	4.91	5.61	5.26
	12	11.15	12.21	11.68	52.88	53.11	53.00	5.89	6.48	6.19
	13	12.09	13.07	12.58	53.01	56.09	54.55	6.41	7.33	6.87
Mean		11.14	12.11	11.63	51.38	53.31	52.35	5.72	6.46	6.09
G.2003-49	11	9.48	8.46	8.97	41.02	43.29	42.16	3.89	3.66	3.78
	12	11.62	10.86	11.24	51.04	52.89	51.97	5.93	5.74	5.84
	13	10.40	11.88	11.14	52.18	55.72	53.95	5.42	6.62	6.02
Mean		10.50	10.40	10.45	48.08	50.63	49.36	5.05	5.27	5.16
G.2004-27	11	8.69	9.43	9.06	44.19	47.97	46.08	3.84	4.53	4.18
	12	10.33	11.28	10.8	52.54	55.34	53.94	5.43	6.24	5.83
	13	11.30	12.10	11.7	54.58	57.42	56.00	6.17	6.95	6.56
Mean		10.11	10.94	10.52	50.44	53.58	52.01	5.10	5.86	5.48
Mean of H	11	9.39	9.71	9.55	45.07	47.05	46.06	4.23	4.58	4.40
	12	11.12	11.44	11.28	50.65	52.46	51.55	5.63	6.01	5.82
	13	11.41	12.09	11.75	52.08	55.16	53.62	5.95	6.70	6.32
	Mean	10.64	11.08	10.86	49.27	51.56	50.41	5.27	5.76	5.52
LSD at 5%										
Harvest age (H)				0.21			0.63			0.29
Varieties (V)				0.32			1.04			0.23
H x V				0.35			0.51			0.17

The varieties × harvesting age interaction was highly significant for stalk length, stalks number, and cane yield except stalk diameter was no-significant. In terms of crops mean of cane yield and number of stalks per feddan, 13 months' age of harvesting gave a significant value ($p<0.05$) higher than 11 months by about (13.44 and 16. 41%). Significant increase in cane yield was recorded with an increase in harvest age from 10 to 14 months (Muchow *et al.*,1998). The highest values of stalk diameter (cm), number of stalks (10^3/fed) and cane yield (tons/fed) obtained from a variety (G.T.54-9) followed by variety (G.2003-47) which harvested after 13 months, whereas the lowest value registered by harvesting variety (G.2004-27) followed by variety (G.84-47) after 11 months, the highest values in harvesting age were valid at 13 months. In agreement with the current result, Khandagave and Patil (2007) reported the presence of difference in cane and sugar yields between the ages of harvesting. Sugarcane varieties differ in their ability to mature under various harvest ages (Calderon *et al.*, 1996).

Data in Tables 2 and 3 showed delaying harvest age from 11 up to 13 months significantly increased brix, sucrose, sugar recovery percentages, and sugar yield in plant cane, first ratoon crops. According to the significant effect of harvest ages, it noted that harvest age (13 months) registered the highest mean values of brix (20.75 and 20.97%), sucrose (17.09 and 17.82 %), sugar recovery (11.41 and 12.09%) and sugar yield (5.95 and 6.70 tons/fed) at plant cane and first ratoon, respectively, except purity % in plant cane and first ratoon (81.51 and 82.35%), whereas the harvest age (11 months) recorded the lowest ones. The increase could be due to positive impact of harvest age on the yield components (plant height and cane yield) which allow accumulation of additional soluble solids (brix) or sucrose by delaying the harvest age (Rostron ,1972). These results are in agreement with those obtained by Muchow *et al.,* (1998), and Hagos *et al.,* (2014) who reported the harvest age had a very significant influence on the percentage of brix, sucrose, and purity. Endris *et al.*, (2016) observed that maximum sugar yield value (tons / ha) was reported at 14 months of harvesting age. Jadhav *et al.*, (2000) noted major differences among harvesting ages in reducing sugars percentage.

A significant difference ($p<0.005$) of most quality traits was observed among the five sugarcane varieties in the plant cane and first ratoon crops. Sugar cane variety G.2003-47 significantly over passed the four varieties in sucrose (16.60 and 17.67 %), sugar recovery (11.14 and 12.11 %), and sugar yield (5.72 and 6.46 tons/fed), however, variety (G.84-47) recorded the highest brix percentage (20.21 and 21.03 %) in both plant cane and first ratoon crops. Nevertheless, G.84-47 recorded the lowest sugar yield (4.63 and 4.73 ton/fed), the results due to the fact that this variety is the lowest one in of stalk diameter and cane yield per feddan as well as the weight of stalk/plant. The highest purity percentage was registered by variety (G.T.54-9) in plant cane (84.30%) and first ratoon crops (86.45%). The increase in sugar yield may be attributed to an increase in the percentage of sucrose, the percentage of sugar recovery that represented the yield of sugar as a final product. Kumara and Bandara (2002) and Shridevi *et al.,* (2016) they found significant differences among evaluated sugarcane varieties for Brix and sucrose percentages. Nayamuth *et al*., (2005) proposed that varieties could be classified into three distinct maturity groups (early, mid, and late) based on their sucrose accumulation patterns.

The varieties × harvesting age interaction was highly significant except purity% for all studied characters. In terms of the crops mean of sugar yield, the best performance was reported by the following varieties (GT.54-9, G.2003-47, and G.2004-27, respectively) under harvest age (13-month), while the following varieties (G.T.54-9, G.2003-47and G.2003-49, respectively) were better under the age of 12 months, whereas the variety (G.84-47) gave the lowest sugar yield under the age of 13 months. Such variations may be due to the genetic makeup of the sugarcane varieties. Kumara and Bandara (2002) and Sohu *et al.*, (2008) found that varied significant differences among evaluated cane varieties for sugar yield. Di Bella *et al.*, (2009) found significant cultivar x harvest age interactions for cane and sugar yields in ratoon crops.

Table 3. Mean of Brix%, sucrose% and purity% of five sugarcane varieties as affected by harvest age during plant cane (PC), and first ratoon (FR)

Varieties	Harvest age (Months)	Brix%			Sucrose%			Purity%		
		PC	FR	Mean	PC	FR	Mean	PC	FR	Mean
	11	15.02	16.94	15.98	13.05	14.12	13.59	77.04	86.88	81.96
G.T 54-9	12	19.62	19.32	19.47	16.86	17.22	17.04	87.27	85.93	86.60
	13	20.27	20.05	20.16	17.56	18.52	18.04	87.58	86.63	87.11
Mean		18.30	18.77	18.54	15.82	16.62	16.22	84.30	86.45	85.38
	11	17.22	18.08	17.65	14.37	15.05	14.71	79.48	83.45	81.46
G.84-47	12	21.32	21.76	21.54	16.86	16.91	16.89	77.48	79.08	78.28
	13	22.08	23.24	22.66	17.28	16.73	17.01	74.35	78.26	76.31
Mean		20.21	21.03	20.62	16.17	16.23	16.20	76.90	80.02	78.46
	11	18.06	19.14	18.60	15.12	16.29	15.71	79.00	83.72	81.36
G.2003-47	12	20.45	20.50	20.48	16.75	17.80	17.28	81.71	81.91	81.81
	13	21.34	21.44	21.39	17.93	18.91	18.42	83.63	84.02	83.82
Mean		19.95	20.36	20.16	16.60	17.67	17.13	81.53	83.21	82.37
	11	16.96	16.90	16.93	14.12	13.11	13.62	83.55	83.25	83.40
G.2003-49	12	20.17	20.08	20.13	17.13	16.36	16.75	85.31	84.93	85.12
	13	20.78	21.13	20.96	16.11	17.66	16.89	76.24	77.53	76.88
Mean		19.30	19.37	19.34	15.79	15.71	15.75	81.50	81.78	81.64
	11	16.26	17.01	16.64	13.15	14.09	13.62	77.31	80.87	79.09
G.2004-27	12	18.28	18.26	18.27	15.33	16.25	15.79	83.95	83.86	83.91
	13	19.30	18.98	19.14	16.57	17.26	16.92	87.30	85.85	86.58
Mean		17.95	18.08	18.02	15.02	15.87	15.44	83.04	83.67	83.36
	11	16.70	17.61	17.16	13.96	14.53	14.25	79.27	83.58	81.43
Mean of H	12	19.97	19.98	19.98	16.59	16.91	16.75	83.00	83.06	83.03
	13	20.75	20.97	20.86	17.09	17.82	17.45	81.51	82.35	81.93
	Mean	19.14	19.52	19.33	15.88	16.42	16.15	81.34	82.96	82.15
LSD at 5%										
Harvest age (H)				1.12			0.52			0.5
Varieties (V)				0.27			0.28			1.08
H x V				0.13			0.31			NS

B. Effects of harvest age on physiological characters

Leaf area index (LAI) and Specific leaf area (SLA)

As shown in Figure (1) estimated leaf area index (LAI) and specific leaf area (SLA) per sugarcane plant were significantly increased with increasing harvest age treatments in plant cane and first ratoon. Results showed that there were significant differences ($P < 0.05$) between harvest ages in terms of LAI % and SLA, which was highest at 13 months of harvest compared by other harvest ages throughout the two growing season.

The tested sugar cane varieties differed significantly in LAI and SLA in both seasons. Variety G.2003-47 gave the highest values of LAI (63.88) and SLA (37.15 cm^2/mg), respectively, at 11 months of harvest age. While GT.54-9 variety gave the lowest values (52.71) and (20.99 cm^2/mg), respectively. The promising varieties (G.2003-47 and G.2003-49) recorded the highest values for both traits in the second age of harvest (12 months). However, the late harvest age (13 months) resulted in higher LAI and SLA in variety G. 84-47 which registered (77.96) and (39.28 cm^2/mg), respectively, for both traits at maturity compared with other varieties, while the lowest one is G.2003-47 which registered (63.79) and (24.94 cm^2/mg). Mean LAI increased with time and decreased with crop cycles, plant cane and first ratoon (Sandhu *et al.*, 2012).

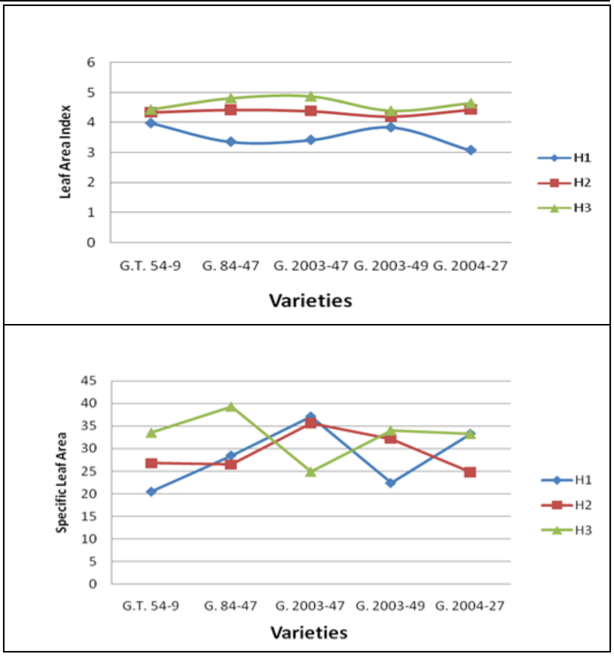

Figure 1. Mean of leaf area index and leaf specific area of five sugarcane varieties as affected by different harvest age

Interaction between tested sugar cane varieties and harvest ages had a significant effect on the LAI in both seasons but SLA was insignificant. Generally, the highest were obtained from planting G.84-47 variety at 13 months of harvest age. There was association of LAI with cane yield especially during the early stages of growth (Irvine, 1975). The above results suggest that selection and breeding might operate on SLA and LAI to improve the yield potential in sugar. Singels and Donaldson (2000) reported that sugarcane LAI is directly related to yield, there are fewer studies regarding the trend in this relationship through growth stage and crop cycles (plant cane, first and second ratoon).

Number of leaf/plant (NL) and Number of tillers /plant (NT)

Mean values of leaf and tillers numbers per plant over the years presented in (Figure 2) show that varieties G.84-47, G.2004-27 and G.203-49 had higher number of leaf /plant (NL) than varieties GT.54-9 and G.2003-47, whereas the number of tillers/plant (NT) was significantly higher in varieties G.84-47and G.2003-47 than in other varieties.

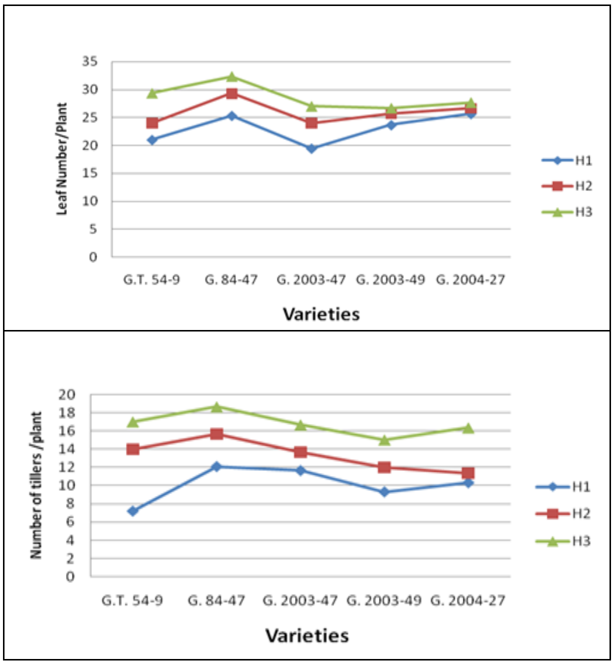

Figure 2. Mean of leaf number and number of tillers /plant of five sugarcane varieties as affected by different harvest age

There are significant differences among varieties affected by harvest ages, however, NL and NT increased with advancing age up to 13 months of harvest ages . In a 11–14-months cropping cycle, sugarcane can produce more than 40 fully expanded leaves on one stem (Robertson *et al.*, 1998). Varieties (G.84-47 and G.2003-47) appeared best performance for NL and NT under all harvest ages. In this respect increasing of formed leaves on the growing plants could be due to increasing the leaf area. The number of tillers was influenced by the varieties and harvest cycles (Silva *et al.*, 2017). Interaction between tested sugar cane varieties and harvest ages had a no significant effect on the NL and NT in both seasons. Generally, the highest number were obtained from varieties i.e., G.84-47 (32.33 and 18.67/plant) and GT.54-9 (29.33 and 17.00/plant), respectively at third harvest age (13 months). The reduction in leaf appearance rate and change in leaf size is associated with changes in the partitioning of assimilate and deposition of sucrose, which commences in the lower nodes (Wood *et al.*, 1997). It may be hard to predict sugarcane yield accurately when plants are young because further increase in tillers can compensate for poor early growth (Sandhu *et al.*, 2012). Cultivars did not differ with respect to leaf length but they differed for leaf area index (LAI), leaf number, throughout the growing season (Nava *et al.*, 2016).

Crop growth rate (CGR) and Relative growth rate (RGR)

Data presented in (Figure 3) showed a significant difference ($P < 0.05$) between harvest ages in terms of CGR and RGR, which was highest at 13 months of harvest compared by other harvest ages throughout the two growing seasons.

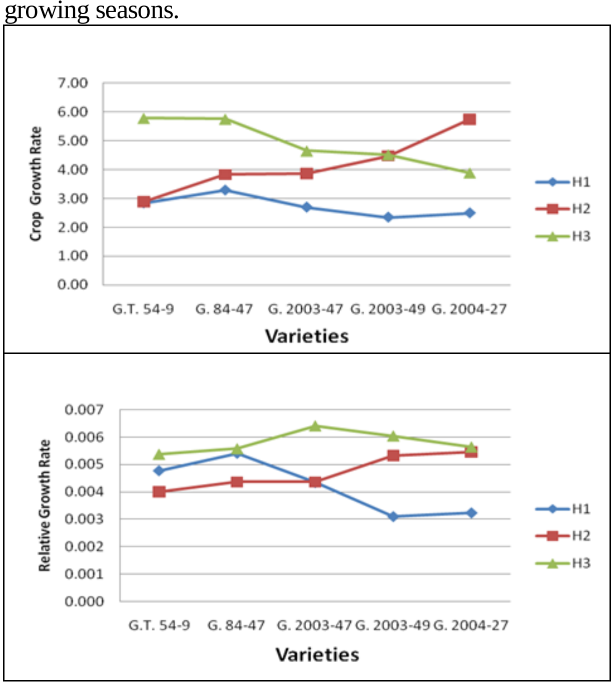

Figure 3. Mean of crop growth rate and relative growth rate of five sugarcane varieties as affected by different harvest age

The changes in CGR and RGR of the plant were significantly increased irregularly with different harvest data. The evaluated sugar cane varieties differed significantly in CGR and RGR in both seasons. The highest Crop growth rate per day (3.29 g/day) was recorded by variety G.84-47 under the first harvest age (11 months), meanwhile, the lowest rate was (2.35 g /day) registered by variety G.2003-49, as well as this variety recorded the highest crop growth rate per day (4.48 g/day) at the second harvest age (12 months). Variety GT.54-9 gave the highest growth rate per day (5.78 g/day) at 13 months of harvest age. While the same variety gave the lowest growth rate per day at 11 months of harvest age (2.88 g/day). (Casler and Van Santen 2000), who indicated that there is a lack of information on the crop growth stage at which the visual growth rate is most closely related to yield. Given the long growing sugarcane season, determining the most effective time is critical. The relative growth rate increased irregularly with delayed harvest age up to 13 months. The promising varieties G. 2004-27 registered the highest rate (0.0054 mg/g/day) at the second harvest (12 months) while the G. 2003-47 variety recorded the highest rate (0.0064 mg/g/day) at the third harvest age (13 months), while variety G.2003-49 recorded the lowest rate (0.0031 mg/g/day) at 11 months of harvest during plant cane and first ratoon crops. Clearly indicate that each of relative growth rate (RGR) and crop growth rate (CGR) were significant with different harvest and varieties interaction in plant cane and first ratoon crops. The results are in agreement with those obtained by Singh and Rao, (1987) who reported that varieties which gave higher cane yield also had higher RGR and, CGR but were inferior to low-yielding varieties in respect of LAR and SLW. In sugarcane should be targeted for LAI and CGR measurements to predict sugarcane yields. Also, CGR is solely based on the total biomass per plot, and maybe the best time to rate the varieties' biomass production capacity (Sandhu *et al.*, 2012**).**

Net assimilation rate (NAR)

Results in (Figure 4) showed that a significant difference (*P* < 0.05) between harvest ages in terms of the NAR, which it rapidly increased with advancing age up to 12 months then it decreased up to 13 months, on the other hand, the CGR and LAI, increased up 13 months after planting. There was significant variation among the tested sugar cane varieties in NAR was reported in plant cane and first ratoon crops. The highest net assimilation rate per day (4.39,4.72 and 4.07 g/m^2/day, respectively) recorded by variety G. 2003-47 under different harvest age (11,12 and 13 months). Meanwhile, the lowest rate was (2.17, 2.31 and 2.07 g/m^2/day, respectively) registered by variety G.84-47. The net effect of these changes in the development of pattern is that leaf area per stalk also tends to decline slowly as the crop matures, the potential yield of improved cultivars can only be obtained if it is matched by skillful physiological parameters. (Allison *et al.*, 1997). Introduction efforts of improving crop yields by increasing the maximum photosynthetic efficiency have generally not been successful (Cock 2003). These results are in line with those of (Pati,l 2008) that the NAR of sugarcane achieves the optimum at the age of 160-200 days after planting. The higher NAR value might be due to availability of certain nutrients to plant leaves and increase the efficiency of photosynthesis, and more available space for air circulation and a light interception which increased photosynthetic efficiency and improved CGR, LAI, and ultimately NAR (Yadav 1991; Khan *et al.*, 2011).

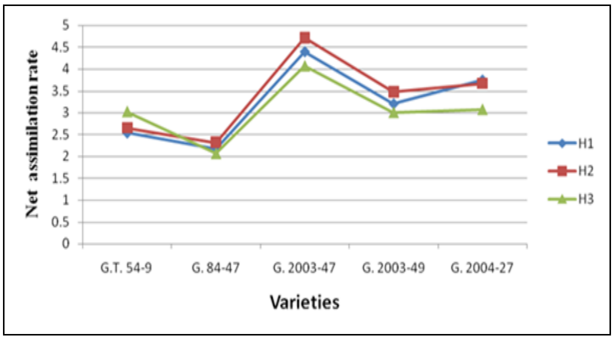

Figure 4. Mean of net assimilation rate of five sugarcane varieties as affected by different harvest age

Correlations between physiological characters

Data in Table 4 indicated that number of leaf/plant had significant and positive correlation with number of tillers/plant, specific leaf area, and crop growth rate. Number of tillers /plant had significant and positive correlation with crop growth rate and relative growth rate, while it positive and non-significant with leaf area index and specific leaf area. Silva *et al*., (2017) found a positive correlation between the number of tillers, number of green leaves and leaf area index. Leaf area index showed positive and highly significant correlations with specific leaf area, crop growth rate and positive and non significant with relative growth rate, while specific leaf area had appositive and non significant correlations with crop growth rate and relative growth rate. There was highly significant correlation between crop growth rate and relative growth rate. Shih and Gascho (1980) reported a positive correlation between LAI and sugarcane biomass yield and crop growth rate. Pincelli and Silva (2012) studied morphological changes in sugarcane cultivars and they found non-significant a correlation between LAI and tiller (NT). Leaf area index (LAI) is effective to evaluate the end yield, and the highest values during the development cycle would be related to the higher-end cane and sugar yields (Leme *et al.*, 1984 and Reis *et al.*, 2013). Some physiological traits were directly or indirectly associated with crop growth and yield (Chumphu *et al.*, 2019 and Silvia *et al.*, 2007).

Table 4. Phenotypic (r_p) correlation coefficients among growth traits of five sugarcane varieties

Characters	Number of leaf per Plant (NL)	Number of tillers per plant (NT)	Leaf area index (LAI)	Specific leaf area (SLA)	Crop growth rate (CGR)	Relative growth rate (RGR)
NL	1.00	0.683	0.551**	0.090*	0.444*	0.420
NT		1.00	0.424	0.079	0.680*	0.466*
LAI			1.00	0.602**	0.493**	0.362
SLA				1.00	0.179	0.079
CGR					1.00	0.726**
RGR						1.00

*** and ** denote significance at 0.05 and 0.01 levels of probability, respectively**

C. Heritability degree and genetic variability

Broad-sense heritability percentage

Results in (Figure 5) showed significant differences for broad-sense heritability estimates (h^2) among all studied traits in both crops. The plant cane heritability of cane and sugar yields (89.67 and 95.77 %) was approximately higher than the first ratoon by about (22.93 and 3.11%). Plant cane heritabilities for cane yield and sugar yield their traits varied from the lowest trait registered by stalk length (34.23%) to the highest value (95.82%) recorded by sucrose percentage. First ratoon heritabilities of the same traits were somewhat greater than plant cane crop, with Brix percentage (95.89%), sugar yield (95.77%), purity percentage (94.76%), sugar recovery percentage (90.30%), sucrose percentage (89.83%), cane yield (89.67%), stalk diameter (72.735%), stalk number (68.57%), and stalk length (55.84) (Figure 5). In both crops, brix and sugar yield had relatively high heritability with a plant cane crop of (90.06 and 95.89 %, respectively) and a first ratoon crop of (92.65 and 95.77 %, respectively). Heritabilities for stalk diameter and length and number of millable stalks were low for both crops.

Sanghera *et al.,* (2015) indicated that the high heritability of cane and sugar yield can use them as selection criteria. High heritability estimates were recorded for millable cane number; stalk diameter and single cane weight (Chaudhary, 2001). It could be more effective that yield components were selected to increase yield because of lower heritability for yield and higher heritability for yield components (Hogarth, 1971).

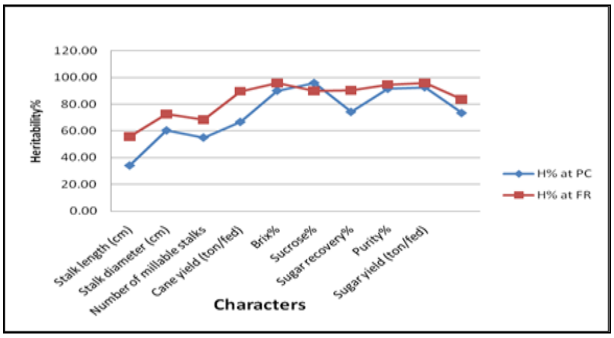

Figure 5. Broad-sense heritability of studied traits under harvest age treatments

Genetic variability

The results in (Figure 6) showed small varied significant differences between phenotypic and genotypic coefficients of variation (PCV and GCV) for most of the traits.

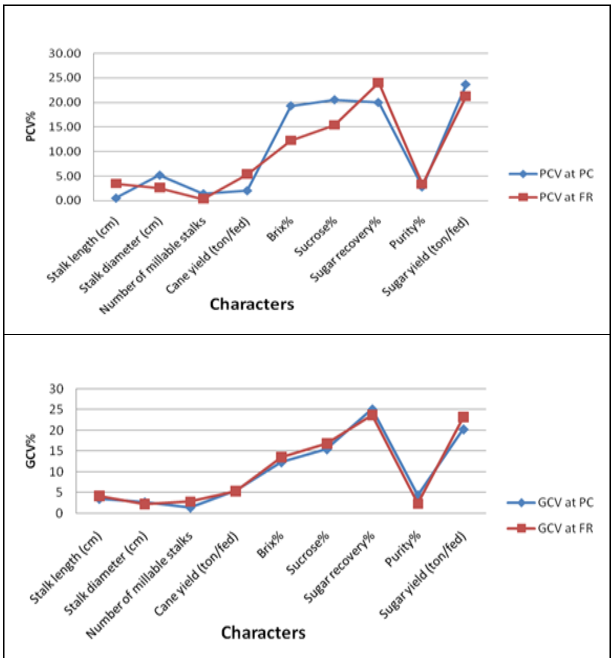

Figure 6. Phenotypic (PCV %) and genotypic coefficient of variance (GCV %) for studied traits

The genotypic coefficient of variation gave a relative measure of genetic variation in the varieties. Although there was a tendency for the PCV% and GCV% to be slightly greater in the first ratoon crop, both crop estimates were close. Sucrose and sugar yield showed the most variation while stalk length, stalk diameter and stalk number, the components of cane yield, demonstrated moderate variation. Sucrose %, brix, and sugar yield displayed the least variation between PCV and GCV%. While GCV% is useful for describing the relative amounts of trait variability in varieties, they give only a partial indication of the genetic potential to improve a trait. Phenotypic coefficient of variation (PCV %) decreased from plant cane to first ratoon crop for stalk diameter, cane yield, sugar recovery and purity% while, it increased for stalk length, number of stalks /fed., brix%, sucrose% and sugar yield. Masri *et al.,* (2014), reported that genotypic variance and GCV decreased from plant cane crop to second ratoon crop for cane yield while they increased slightly for number of stalks per fed. Bhatnagar (2003) had reported high values of genotypic and phenotypic coefficients of variations for number of millable cane and single stalk weight in the plant can.

CONCLUSION

The research demonstrated that cultivars GT54-9, G.2003-47, and G.2004-27 were adaptable to early and late-season harvest. In order to get a maximum accumulation of sucrose and sugar production in the Shandaweel region with the least possible field losses, it is necessary to harvest sugar cane at a proper time of maturity. The study also recommended that G.2003-47 and GT-54-9 achieve a high sugar yield due to high early-age sucrose accumulation. Therefore, it was economically recommended to adjust the harvest age to 13 months for the major sugarcane varieties in order to obtain optimum sugar yield at the Shandaweel City with efficient time consumption.

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التباين الوراثى وأداء خمسة أصناف من قصب السكر للصفات الفسيولوجية والمحصول والجودة التى تأثرت بعمر الحصاد

فراج فرغل برعى أبو الليل ، احمد فتحي إبراهيم جادالله وإبراهيم سعيد الجمل
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تم إجراء تجربتين حقليتين بمحطة البحوث الزراعية في شندويل بمحافظة سوهاج (خط العرض 26.33 شمالا وطول 31.42 شرقا) في مواسم 2018/2017 و 2019/2018 لدراسة تأثير ثلاثة أعمار حصاد مختلفة (11 و 12 و 13 أشهر) على أداء خمسة أصناف قصب السكر الواعدة G.84-47، G.2003-47، G.2003-49، G. 2004-27 والصنف التجاري (GT54-9) كصنف مقارنة. تم استخدام تصميم القطع المنشقة مرة واحدة في كلا الموسمين ، مع ثلاثة مكررات. 1- أوضحت النتائج أن جميع الصفات التي تم تحليلها تأثرت إلى حد كبير بتمديد سن الحصاد من سن 11 إلى 13 شهرًا. سجل عمر الحصاد حتى 13 شهرًا أعلى قيم محصول العيدان والسكر في الغرس (52.08 و 5.95 طن / فدان (فدان = 0.42 هكتار) ، على التوالي) ومحاصيل الخلف الأولى (55.16 و 6.70 طن / فدان ، على التوالي) . 2- من ناحية أخرى ، أظهرت الأصناف اختلافًا كبيرًا في طول الساق ، وعدد السيقان ، وكذلك البريكس ، والسكروز ، ونسبة ناتج السكر ، ومحصول العيدان ومحصول السكر (طن / فدان). تم الإبلاغ عن أفضل أداء من خلال الأصناف التالية (G2004-27 و G2003-47 و GT54-9) تحت جميع أعمار الحصاد ، كما سجلت هذه الأصناف أفضل محصول عيدان (52.01 و 52.35 و 53.94 طن / فدان على التوالي) و أفضل محصول سكر (5.48 و 6.09 و 6.03 طن / فدان على التوالي). 3- أشارت النتائج إلى زيادة معنوية في الخصائص الفسيولوجية مثل دليل مساحة الورقة (LAI) ، ومعدل نمو المحاصيل (CGR) ، ومعدل صافى التمثيل الضوئى (NAR) مع زيادة عمر الحصاد أيضًا ، وتختلف هذه السمات بشكل كبير بين الأصناف. هناك ارتباط إيجابي وكبير بين CGR و NAR وعائد قصب السكر ، والذي يجب استخدامه للتنبؤ بعائد محصول العيدان. تراوحت درجة التوريث لمحصول العيدان ومحصول السكر وخصائصها من أدنى قيمة مسجلة بطول الساق (34.23٪) إلى أعلى قيمة (95.82٪) مسجلة بنسبة السكروز. يمكن أن يكون أكثر فعالية اذا تم الاختيار على أساس درجة التوريث الأعلى للغلة من الأقل ، يجب أن تؤخذ الفروق المتنوعة في معدلات النمو والنضج في الاعتبار عند اتخاذ قرارات الحصاد.

الكلمات المفتاحية: قصب السكر ، عمر الحصاد ، الأصناف ، التباين الجيني ، درجة التوريث فى المعنى العام.