Volume 21 Issue 16
Originally issued as D5

Global Journal of Science Frontier Research: D
Agriculture and Veterinary
Volume 21 Issue 5 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Genetic Variation and Heritability for Juice Quality and Yield Traits in Selection of Sugarcane Genotypes under Irrigation at Early Stage in Ferké 2 Sugar Estate of Northern Ivory Coast

By Crépin B. Péné, Yavo Michael Béhou & Marcel Silué
International University of Grand Bassam

Abstract- Genetic relationships between important attributes in studying sugarcane populations through breeding and direct selection, are crucial to understand how changes made by selecting one character may cause changes in others. The study aimed to determine the best yielding sugarcane genotypes tested at early selection stage under sprinkler irrigation, in comparison with a check variety (R579). The experiment was designed following a randomized complete block (RCB), with 30 cane genotypes in three replications. Each plot consisted of five dual rows of ten meters, with 0.5 and 1.90 m of inter-row spacing, i.e. 95 m^2 per plot and nearly 6,000 m^2 for the whole experiment. It was carried out on a commercial sugarcane plantation of Ferké 2, in northern Ivory Coast, over two seasons (plant cane and first ratoon) as an early-season crop from, November 29, 2018 to October 26, 2020. In each micro-plot, different agro-morphological traits were collected at harvest from three central dual rows.

Keywords: early season, phenotype, genotype, environmental influence, multivariate analysis, genetic advance.

GJSFR-D Classification: FOR Code: 079901

GENETICVARIATIONANDHERITABILITYFORJUICEQUALITYANDYIELDTRAITSINSELECTIONOFSUGARCANEGENOTYPESUNDERIRRIGATIONATEARLYSTAGEINFERKE2SUGARESTATEOFNORTHERNIVORYCOAST

Strictly as per the compliance and regulations of:

© 2021. Crépin B. Péné, Yavo Michael Béhou & Marcel Silué. This is a research/review paper, distributed under the terms of the Creative Commons Attribution-Noncommercial 3.0 Unported License http://creativecommons. org/licenses/by-nc/3.0/), permitting all non commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Genetic Variation and Heritability for Juice Quality and Yield Traits in Selection of Sugarcane Genotypes under Irrigation at Early Stage in Ferké 2 Sugar Estate of Northern Ivory Coast

Crépin B. Péné [α], Yavo Michael Béhou [σ] & Marcel Silué [ρ]

Abstract- Genetic relationships between important attributes in studying sugarcane populations through breeding and direct selection, are crucial to understand how changes made by selecting one character may cause changes in others. The study aimed to determine the best yielding sugarcane genotypes tested at early selection stage under sprinkler irrigation, in comparison with a check variety (R579). The experiment was designed following a randomized complete block (RCB), with 30 cane genotypes in three replications. Each plot consisted of five dual rows of ten meters, with 0.5 and 1.90 m of inter-row spacing, i.e. 95 m² per plot and nearly 6,000 m² for the whole experiment. It was carried out on a commercial sugarcane plantation of Ferké 2, in northern Ivory Coast, over two seasons (plant cane and first ratoon) as an early-season crop from, November 29, 2018 to October 26, 2020. In each micro-plot, different agro-morphological traits were collected at harvest from three central dual rows. The study showed that most relevant traits in genotype clustering were related to juice quality (recoverable sucrose, sucrose content, purity), yields and some yield components like single stalk height, and single stalk weight. Based on sugar yields, three genotypes over-classing the check variety (R579), namely RCI14/128, RCI11/112, and RCI11/190, were determined for the late selection stage, with 16.4, 15.8 and 15.0 t sugar/ha, respectively. Their cane yields reached 151.5, 164.2 and 132.6 t/ha, respectively, compared to 146.1 t/ha for the check, and belong to two clusters genotypes over six determined. Except for juice purity and cane fiber content, all agro-morphological traits investigated could explain the genetic variation of sugarcane genotypes tested, with stem borer infestation rate, cane and sugar yields, and number of tillers/ha as the most relevant traits in this regard.

Keywords: early season, phenotype, genotype, environmental influence, multivariate analysis, genetic advance.

Author α: School of Science, Technology, Engineering and Mathematics (STEM)/International University of Grand Bassam (IUGB), Ivory Coast; Domain of Natural Sciences/Ivorian Academy of Sciences, Arts and Cultures (ASCAD). e-mail: pene.c@iugb.edu.ci

Author σ: Polytechnic Doctoral College (EDP)/National Polytechnic Institute (INP-HB)of Yamoussoukro, Ivory Coast - R&D Department, SUCAF-CI-SOMDIAA of Ferké, Ivory Coast.

Author ρ: School of Science, Technology, Engineering and Mathematics (STEM)/International University of Grand Bassam (IUGB), Ivory Coast.

I. Introduction

For its high biomass production, and its well-established farming system and processing technologies, sugarcane is a top-ranking candidate for bio energy production and an important source of bio fuel for bio-refineries. Nevertheless, productivity improvements in sugarcane have been almost nil in the past three decades, and production statistics exhibit decreased yields globally [1]. In most cases, increased sugarcane production used to be explained by the expansion of land surface rather than increase in yield [2, 3].

Commercial sugarcane varieties under cultivation are complex polyploids, which heterozygous nature has resulted in generations of higher genetic variability. Information about the nature and magnitude of variability present in genetic materials is of prime importance for breeders to conduct effective selection programs[3-4].. Genotypic and phenotypic coefficients of variation, together with heritability and genetic advance, are key elements to improve any agronomic trait of sugarcane, as this would help in knowing whether or not specific objectives targeted could be achieved from a given crop material [3-5].

Sugarcane used to be the major source of sugar production in Ivory Coast and many tropical countries, where this crop used to be traditionally cultivated mainly for chewing purpose by smallholder farmers. Commercial sugarcane production in Ivory Coast started in 1974 at Ferké 1 plantations on about 5,500 ha[3]. Nowadays, sugarcane is grown on around 30,000 ha and the four sugar mills located in three different regions of the country produce, on yearly basis, about 200,000 t sugar [3, 6]. This production does not meet the domestic consumption, which is estimated to around 240,000 t. The production deficit is being offset by imported sugar, to alleviate the gap between supply and demand of sugar. Besides the expansion of existing sugar mill plantations, a productivity improvement and capacity-building project was implemented in the

© 2021 Global Journals

country from March 2009 to June 2016, with the assistance of the European Union (EU) [7].

Cane and sugar yields are considered as complex characters in sugarcane, which phenotypic and genotypic interrelationships with their component traits would be of prime importance to breeders. Understanding associations between traits is of great importance in breeding and selection studies, particularly for low heritability or hardly measuring attributes [6, 8-10], like cane and sugar yields, recoverable sucrose, number of tillers/ha, and number of attacked internodes by stem borer. Genetic relationships between important attributes in studying sugarcane populations through breeding and direct selection are crucial to understand how changes made by selecting one character may affect the others [3, 6, 11-12]. This knowledge can be used when determining effective selection strategies for particular traits in a sugarcane breeding program [6, 13]. Likewise, the number of millable stalks/ha, single stalk height and single stalk diameter were reported to be positively associated with cane yield [6, 14-15]. Moreover, phenotypic associations between yields and their components in sugarcane showed that selecting for juice quality traits, number of tillers/ha, single stalk diameter and height, should be emphasized in variety development programs where high cane and sugar yields were the primary goal [3, 6, 16].

The objective of present study was to determine the best performing sugarcane genotypes under irrigation at early selection stage for different agro-morphological traits, based on their genetic variations and heritability.

II. Material and Methods

a) Site characteristics

The experiment was conducted on a small portion (0.6 ha) of 80 ha-sugarcane plantation(V4-043) at Ferké 2 sugar estate, under a center pivot irrigation system, in northern Ivory Coast (9°20' - 9°60' N, 5°22 - 5°40', 325 m a.s.l.). The climate of the region is tropical dry, with two different seasons: one, occurring from November to April, is dry and the other, from May to October, is wet. The rainfall pattern is unimodal and centered on August and September which total amount of precipitation reaches almost half of the average annual rainfall (500 mm over 1200 mm/yr). The average daily air temperature yields 27°C, ranging from 21 and 32.5°C as average minimum and maximum daily air temperatures, respectively[18]. Irrigation water requirements in this area for sugarcane reaches 650-700 mm/cycle [19]. Both Ferké sugar mill plantations cover nearly 17,000 ha with 11,500 ha under irrigation and 3,500 ha of rainfed village plantations, lie mainly on shallow or moderately deep soils built up on granites. Main soil units encountered are ferralsols and temporally waterlogged soils in valley bottoms of Bandama and Lokpoho river basins with a sandy-clay texture[18-19].

b) Cane genotypes tested

Except for the control, all genotypes tested were pre-selected sugarcane clones in Ferkéagro-pedological environment at the third stage, i.e. at one genotype per row stage. As genotypes of Reunion Island and Ivorian origin, they resulted from crosses made in Reunion Island, and selection under way at Ivorian sugar estates of Ferké.

c) Assessment of irrigation water requirement

The irrigation water requirement (I),over a given period, was calculated following the climatic water balance method as the difference between maximum evapotranspiration (ETm) and rainfall (R)collected from the closest rain-gauge to the Ferké 2 sugarcane plantation V4-043 subjected to the field experiment, as follows[19].:

$$I = ETm - R \quad (1)$$

$$ETm = Kc \times ETo \quad (2)$$

Where:

Values of crop coefficient Kc were equal to 0.5, 0.8 and 1.0 over tillering, early stem elongation, and late stem elongation stages, which last two, one and half and 8 months, respectively.

Reference evapotranspiration ETo is computed as follows[19].:

$$ETo = \Delta/(\Delta+\gamma) \times Rn$$

$$\Delta/(\Delta+\gamma) = 0.51 + 0.009 \times Ta$$

Rn: Net radiation = a Rg +b, a linear function of global radiation (Rg), which is measured as the average air temperature (Ta = (Tmax+Tmin)/2) in the local automatic weather station.

γ: psychrometric constant = 0.66 mb/°C

Δ: slope of the moisture saturation curve at air temperature E(Ta).

From the equation (1), irrigation water (I) is defined when positive (≥0), otherwise there is no need of watering because of rainfall excess compared to maximum evapotranspiration (ETm), particularly during the period of heavy rainfall from mid-July to mi-October.

d) Experimental design

The study was conducted over two consecutive years, as early-season trial in plant and first ratoon crops, from November 29, 2018 to November 17, 2019 and October 26, 2020 (i.e. 11.5 month-crop cycle), following a randomized complete block design (RCBD) with 30 different genotypes, including the check (R579), in 3 replicates. An experimental plot was made of 5 dual rows of 5 m long with narrow and wide spacings of 0.50 m and 1.90 m, respectively. Cropping operations, like sprinkler irrigation, fertilizer and herbicide applications

© 2021 Global Journals

were performed following usual practices in commercial plantations. NKP fertilizer (16-8.5-23) was applied mechanically at the routine rates of 700 and 720 kg/ha in plant cane and first ratoon, respectively. Pre-emergence chemical weeding based on pendimethalin mixed with clorimuron-ethyl (3.5 l/ha) was also achieved mechanically, two days after planting or harvest.

e) Agronomic traits investigated

At harvest, burned cane fresh production of the three central dual rows of each plot was weighed *in situ,* separately, to determine cane yield. Moreover, 50 millable stalks were randomly chosen within every plot and split longitudinally with a machete, in order to determine the percentage of bored or attacked internode and cane (BIN%, BC%) by stem borer *Eldanasaccharina* W. (Lepidoptera: Pyralidae) [7].

Thirty millable cane stalks were also sampled per plot, on random basis, for juice quality analyses in the laboratory, to determine the recoverable sucrose content and therefore calculate the sugar yield with regard to the cane yield obtained. Prior to sample crushing operations in the laboratory for sucrose analyses, every stalk was cut into 3 pieces of almost equal length while separating them in basal, medial and top parts. This allowed to randomly reconstitute 3 batches of 10 stalks for a better homogenization of the initial field sample by permutation of the pieces so that each reconstituted stalk was composed of parts coming from 3 different initial cane stalks. Eventually, only one batch of 10 reconstituted stalks over 30 (1/3 of initial sample) were crushed for a series of sucrose analyses to determine the sucrose content (Pol%C), fiber content (Fiber %C), juice purity (Purity %C) and recoverable sucrose (SE%C) [6, 7]. Equipment used comprised a Jefco cutter grinder, a hydraulic press (Pinette Emideceau), a digital refractometer BS-RFM742 and a digital polari-meter SH-M100. Methods used in the determination of required juice qualitytraits were reported by Hoarau [20]. The recoverable sucrose was calculated as follows [6-7, 21]:

SE %C=[(0.84 × Pol%C) (1.6 -60/Purity) - (0.05 × Fib %C)] with:

Purity %C=(Pol juice/Brix) × 100 and Pol juice % =Pol factor × Pol read.

Pol%C=Factor n × Pol juice %

Sugar Yield (t/ha) = SE%C x Cane Yield (t/ha).

Factor pol depending on brix value (amount of soluble dry matter in juice measured with a refractometer), is provided by Schmidt table relative to a polarimeter for 26 g of glucose. The fiber content and factor *n* were provided by a table, depending on the weight of fiber cake obtained after pressing 500 g of cane pulp resulting from the crushing of every sample of cane stalks.

f) Determination of genetic parameters

The phenotypic and genotypic variances for each trait were estimated from the RCBD analysis of variance (Table 1). The expected mean squares under the assumption of random effect model were determined from linear combinations as follows (Burton and Davane [22], cited by Shitahum et al [23], Péné and Béhou [3, 6]:

Genotypic variance $(\sigma^2_g)=(MS_g - MS_e)/r$

Environmental variance $(\sigma^2_e)=MS_e$

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

Where MSg and MSe are mean sum of squares for genotypes and error in the analysis of variance, respectively, and *r* the number of replicates.

Genotypic and phenotypic coefficients of variation (GCV, PCV) were computed as follows [3, 6, 24]:

$$GCV=\sigma_g \times 100/\text{grand mean}$$

$$PCV=\sigma_p \times 100/\text{grand mean}$$

According to Shivasubramanian and Menon [25], cited by different investigators [26-29], PCV and GCV values are ranked as low, medium and high with 0 to 10%, 11 to 20% and higher than 20% respectively.

$$\text{Broad sense heritability } h^2=100\times\sigma^2_g / \sigma^2_p.$$

Estimates of broad-sense heritability (h^2) are categorized according to Robinson [30] cited by different authors [25, 31, 38, 42] as low (<30%), moderate (30≤-<60%) or high (≥60%).

Genetic advance (GA) and genetic advance as percent mean (GAM):

$$GA=k\times h^2\times\sigma_p \text{ and } GAM=100\times GA/X.$$

With k: standard selection differential at 5% selection intensity (k=2.063) and X: grand mean of trait X.

Phenotypic and genotypic correlation coefficients r_p and r_g between particular pairs of traits A and B are defined as [24]:

$$r_p=Cov_p\,(A,B)/(\sigma_{pA}\times\sigma_{pB})$$

$$r_g=Cov_g\,(A,B)/(\sigma_{gA}\times\sigma_{gB})$$

where, Cov_p and Cov_g are phenotypic and genotypic covariances, respectively.

Phenotypic correlations between traits were determined following the Pearson correlation coefficient, calculated from means of observed traits for each cane genotype [25].

Genetic improvement in cane and sugar yields may be achieved by targeting traits closely associated to them. A number of attributes have been proposed as indirect selection criteria for genetic improvement of yields in plant breeding programs [26-27]. Heritability represents the relative importance of genetic and

© 2021 Global Journals

environment factors in the expression of phenotypic and genotypic differences among genotypes within a population [3, 6, 28-30]. Therefore, the knowledge of heritability related to important traits and the correlations among them are key issues to determine the best selection strategy [31-32, 38]. Genotypic coefficient of variation (GCV) is another measure of relative genetic variation of a trait within a population [33]. Chaudhary [34] reported high GCV for single stalk weight and millable cane number per unit area. Genotype versus environment interactions (GxE) are a serious concern in breeding programs as they affect decision making in selection. When the ranking of genotypes changes across environments, it requires their evaluation environment-wise to determine their accurate performance [35, 38]. Studies in various sugarcane breeding programs have reported significant G×E interactions for cane and sugar yields [36-38].

g) Statistical analyses

Juice quality and yield traits recorded in this study were subjected to the analysis of variance, using statistical procedures described by Gomez and Gomez [39], and reported by Shitahum et al [23]. Calculations were made by means of R software package version 3.5.1 (Table 1). Differences between means of treatments were determined from Duncan test.

Table 1: Analysis of variance calculations regarding a Randomized Complete Block Design (RCBD)

Source of variation	Degree of freedom	Mean square	Expected mean square
Replication	r-1	MSr	$\sigma^2_e + g\sigma^2_r$
Genotypes	g-1	MSg	$\sigma^2_e + r\sigma^2_g$
Error	(r-1)(g-1)	MSe	σ^2_e

R: number of replicates; g=number of genotypes; MSr mean square due to replicates; MSg=mean square due to genotypes; MSe mean square of error; σ^2_g, σ^2_r, and σ^2_e stand for variances due to genotypes, replicates and error respectively.

III. Results and Discussion

a) Climatic conditions over plant cane and first ratoon

Total rainfall recorded in first ratoon decreased by 29% compared to that of plant cane (Figure 1), i.e. it varied from 936.4 to 762.4 mm, respectively. Total reference evaporation (ETo) decreased by 5% from plant cane to first ratoon, i.e. it varied from 1334 to 1267 mm, and the average daily temperature, from 27.5 to 26.3°C (-4%), respectively. Total water deficit over the dry season (from November to June) to be met by irrigation water gave 664 mm in plant cane and 561 mm in first ratoon. Total irrigation water applied reached 554 and 454 mm in plant cane and first ratoon, respectively.

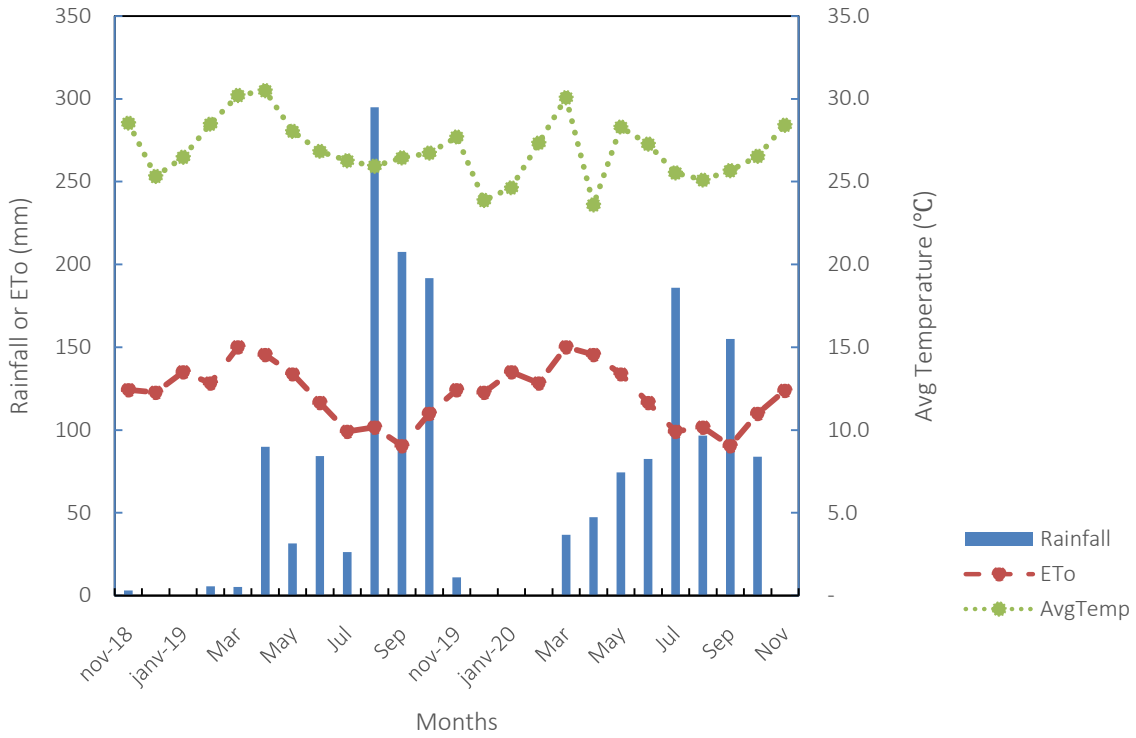


Figure 1: Climate of the experimental site over crop cycle (plant and 1rst ratoon) in Ferké 2, Ivory Coast. Total rainfall and irrigation water requirement: plant cane (R: 936.4, I: 664 mm), first ratoon (R: 762.4, I: 561 mm)

© 2021 Global Journals

b) Performance of cane genotypes tested

Highly significant differences ($P<0.01$) were observed for all agro-morphological traits investigated, not only for the first ratoon but also for the aggregate data of both crop cycles (Tables3 and 4). Based on sugar yields, three genotypes, namely RCI14/128, RCI11/112, and RCI11/190 performed better than the control variety (R579), with 16.4, 15.8 and 15.0 sugar/ha, respectively, compared to 13.2 t/ha. Their cane yield performances reached 151.5, 164.2 and 132.6 t/ha, respectively, compared to 146.1 t/ha for the check. Higher juice quality traits, like purity, sucrose content, and recoverable sucrose percent and were obtained with genotype RCI11/190, while the higher cane yield with moderate quality traits were observed with RCI11/112. Genotype RCI14/128 was a good compromise with higher juice quality and yield traits.

Table 2: Mean values of sugarcane juice quality and yield traits at first ratoon in Ferké 2 Sugar estate

Genotypes	Juice quality traits					Yield traits (t/ha)	
	Purity%	Sucrose%	Fiber%	Recoverable sucrose%	Internode bored %	Cane	Sugar
R579_(T)	87.2 ab	13.3 ab	12.7 e	9.6 abc	4.7 ab	123.1 abc	11.7 bc
RCI11/112	88.1 ab	13.6 ab	13.4 bcde	9.8 abc	4.1 ab	164.5 a	15.9 ab
RCI11/134	86.7 ab	12.5 b	13.2 bcde	8.9 bc	3.1 ab	148.8 ab	13.2 abc
RCI11/135	86.7 ab	12.0 b	13.0bcde	8.5 bc	3.8 ab	130.5 abc	11.1 bc
RCI11/162	87.9 ab	13.5 ab	13.8 bcde	9.7 abc	3.8 ab	127.6 abc	12.4 bc
RCI11/165	85.3 ab	12.1 b	13.4 bcde	8.4 bc	6.0 ab	137.7 abc	11.6 bc
RCI11/166	89.3 ab	13.8 ab	13.7 bcde	10.0abc	5.6 ab	133.3 abc	13.4 abc
RCI11/190	91.5 a	15.7 a	13.8 bcde	11.8 a	2.5 ab	119.6 abc	14.1 abc
RCI12/191	87.7 ab	13.2 ab	14.2 abc	9.4 abc	1.9 b	115.5 abc	10.8 bc
RCI12/192	86.6 ab	14.8 ab	14.8 a	10.5 abc	1.7 b	116.1 abc	12.1 bc
RCI13/110	87.9 ab	13.1 ab	12.9 de	9.5 abc	3.1 ab	146.5 ab	13.9 abc
RCI13/13	88.8 ab	13.9 ab	13.6 bcde	10.1 abc	3.9 ab	132.3 abc	13.3 abc
RCI13/139	87.0 ab	12.5 b	13.8 bcde	8.9 bc	4.2 ab	115.7 abc	10.3 bc
RCI13/16	87.3 ab	13.0 ab	13.6 bcde	9.3 bc	3.0 ab	156.5 ab	14.5 abc
RCI13/173	88.0 ab	13.6 ab	13.7 bcde	9.8 abc	4.3 ab	130.7 abc	12.8 abc
RCI13/174	84.1 b	12.1 b	13.7 bcde	8.3 bc	2.3 ab	60.3 d	5.1 d
RCI13/177	89.5 ab	14.4 ab	13.3 bcde	10.6 abc	2.2 ab	99.8 bcd	10.5 bc
RCI13/179	87.9 ab	13.3 ab	13.8 bcde	9.6 abc	3.0 ab	115.7 abc	11.1 bc
RCI13/180	86.8 ab	13.0 ab	13.2 bcde	9.3 bc	3.6 ab	130.0abc	12.3 bc
RCI13/187	87.4 ab	13.2 ab	13.1 bcde	9.5 abc	3.4 ab	150.1 ab	14.3 abc
RCI13/193	87.7 ab	13.3 ab	13.3 bcde	9.5 abc	3.2 ab	115.8 abc	11.1 bc
RCI13/194	87.6 ab	13.8 ab	12.9 cde	10.0abc	4.0 ab	142.6 abc	14.1 abc
RCI13/195	83.7 b	12.1 b	14.3 ab	8.2 c	3.4 ab	129.7 abc	10.6 bc
RCI13/196	88.1 ab	14.2 ab	13.5 bcde	10.3 abc	2.1 ab	119.9 abc	12.3 bc
RCI14/111	88.1 ab	13.3 ab	13.2 bcde	9.6 abc	4.3 ab	147.7 ab	14.1 abc
RCI14/128	90.9 a	14.6 ab	13.4 bcde	10.8 ab	6.7 a	167.7 a	18.2 a
RCI14/159	87.6 ab	13.5 ab	13.2 bcde	9.7 abc	3.3 ab	123.1 abc	12.0bc
RCI14/171	86.5 ab	12.8 b	13.7 bcde	9.1 bc	5.6 ab	107.2 abc	9.6 bc
RCI14/188	90.1 ab	13.8 ab	14.0abcd	10.1 abc	2.4 ab	82.5 cd	8.3 cd
RCI14/189	86.9 ab	12.8 b	12.9 de	9.2 bc	6.2 ab	94.5 bcd	8.7 cd
Mean	87.6	13.3	13.5	9.6	3.7	126.2	12.1
CV (%)	2.7	8.5	4.2	10.7	54.0	22.5	24.7
Replications	*	ns	ns	*	***	ns	*
Genotypes	*	***	***	***	**	***	***

*CV: coefficient of variation. ns: non-significant *: significant ** or ***: highly significant*

© 2021 Global Journals

Table 3: Mean values of sugarcane juice quality and yield traits regarding plant cane and first ratoon on aggregate, in Ferké 2 Sugar estate

Genotypes	Juice quality criteria					Yield traits (t/ha)	
	Purity%	Sucrose%	Fiber%	Recoverable sucrose%	Internode bored %	Cane	Sugar
R579_(T)	86.1 cd	12.9 bcde	12.2 e	9.2 cdef	4.9 ab	146.1 ab	13.2 abcde
RCI11/112	87.9 abcd	13.5 bcde	13.1 cde	9.7 bcdef	5.7 a	164.2 a	15.8 ab
RCI11/134	85.9 cd	12.3 efg	12.8 cde	8.6 efg	3.7 ab	153.5 ab	13.2 abcde
RCI11/135	87.0bcd	12.4 defg	12.9 cde	8.9 defg	3.9 ab	145.1 ab	12.9 abcde
RCI11/162	86.2 cd	13.1 bcde	12.8 cde	9.3 cdef	3.5 ab	136.9 ab	12.7 abcde
RCI11/165	85.1 d	12.3 defg	13.0cde	8.6 efg	5.6 a	117.4 bc	10.1 efg
RCI11/166	87.0bcd	13.2 bcde	13.0cde	9.4 bcdef	5.5 a	149.3 ab	14.0 abcde
RCI11/190	90.4 a	15.3 a	13.3 bcd	11.4 a	3.2 ab	132.6 ab	15.0 abc
RCI12/191	85.0 d	11.8 fg	13.8 bc	8.2 fg	2.0 ab	140.4 ab	11.2 cdefg
RCI12/192	87.5 abcd	14.5 ab	14.1 ab	10.4 abcd	1.4 b	121.1 abc	12.6 abcde
RCI13/110	86.8 cd	12.9 bcde	12.2 e	9.2 cdef	3.4 ab	157.0 ab	14.4 abcd
RCI13/13	87.5 abcd	13.4 bcde	12.9 cde	9.7 bcdef	4.2 ab	134.6 ab	13.0abcde
RCI13/139	86.7 cd	13.1 bcde	13.0 cde	9.3 cdef	3.6 ab	131.2 ab	12.4 abcde
RCI13/16	85.6 cd	12.6 cdef	13.3 bcd	8.9 cdefg	2.9 ab	153.9 ab	13.7 abcde
RCI13/173	87.8 abcd	13.8 bcd	13.3 bcd	10.0bcde	3.2 ab	136.1 ab	13.6 abcde
RCI13/174	84.9 d	12.6 cdef	13.1 cde	8.8 defg	2.1 ab	92.5 c	8.4 g
RCI13/177	88.9 abc	14.2 abc	12.9 cde	10.4 abc	3.0 ab	120.0 bc	12.5 abcde
RCI13/179	87.0bcd	13.0 bcde	13.5 bcd	9.3 cdef	4.2 ab	132.0 ab	12.2 bcde
RCI13/180	85.8 cd	12.7 cdef	13.3 bcd	9.0cdef	3.3 ab	141.2 ab	12.8 abcde
RCI13/187	86.5 cd	13.2 bcde	12.4 de	9.4 bcdef	3.0 ab	148.7 ab	14.0abcde
RCI13/193	87.2 bcd	13.0bcdefg	12.9 cde	9.3 cdef	3.9 ab	133.4 ab	12.4 abcde
RCI13/194	87.2 bcd	13.8 bcde	12.1 e	9.9 bcde	5.5 a	144.5 ab	14.3 abcde
RCI13/195	82.1 e	11.5 g	14.6 a	7.7 g	3.0 ab	135.6 ab	10.4 defg
RCI13/196	87.7 abcd	14.0abcd	13.0 cde	10.1 bcde	2.8 ab	137,5 ab	13.9 abcde
RCI14/111	87.5 abcd	13.5 bcde	13.1 cde	9.7 bcdef	5.4 a	152.7 ab	14.8 abc
RCI14/128	90.2 ab	14.6 ab	13.0 cde	10.8 ab	6.0 a	151.5 ab	16.4 a
RCI14/159	86.6 cd	13.1 bcde	13.0cde	9.4 cdef	2.8 ab	128.1 ab	12.0bcdef
RCI14/171	86.1 cd	13.0bcdef	13.4 bcd	9.2 cdef	4.9 ab	123.0 abc	11.2 cdefg
RCI14/188	88.2 abcd	13.4 bcde	13.6 bc	9.6 bcdef	2.3 ab	90.3 c	8.6 fg
RCI14/189	86.8 cd	13.2 bcde	12.4 de	9.5 bcdef	5.3 ab	114.2 bc	10.9 cdefg
Mean	86.8	13.2	13.0	9.4	3.8	135.5	12.7
CV (%)	2.7	8.6	6.6	11.0	56.5	20.5	21.9
Replications	*	*	ns	*	***	ns	**
Genotypes	***	***	***	***	***	***	***

*CV: coefficient of variation. ns: non-significant *: significant ** or ***: highly significant*

c) *Multivariate analyses of agronomic traits observed in sugarcane*

The principal component analysis shows that most relevant traits in genotype clustering are related to juice quality (recoverable sucrose, sucrose content, purity), yields and yield components (sugar yield, cane yield, stalk height, stalk weight), (Figure 2, Table 2). The three high yielding genotypes determined are RCI14/128, RCI11/112, and RCI11/190 with 16.4, 15.8 and 15.0 t/ha, respectively (Table 3). They belong to cluster 2, 4 and 1, respectively (Table 4). In contrast, the least relevant traits in genotype clustering are millable cane stalk/ha, number of internodes, fiber content, and bored internode rate. The least productive genotypes are RCI13/174 (8.4 t/ha) on the one hand, and RCI14/188 (8.6 t/ha) and RCI11/165 (10.1 t/ha) on the other hand, which belong to clusters 4 and 3, respectively. The dendrogram deduced from hierarchical ascendant classification analysis exhibits 6 different cluster genotypes(Figure 2), which average agro-morphological characteristics are displayed in Table 4.

© 2021 Global Journals

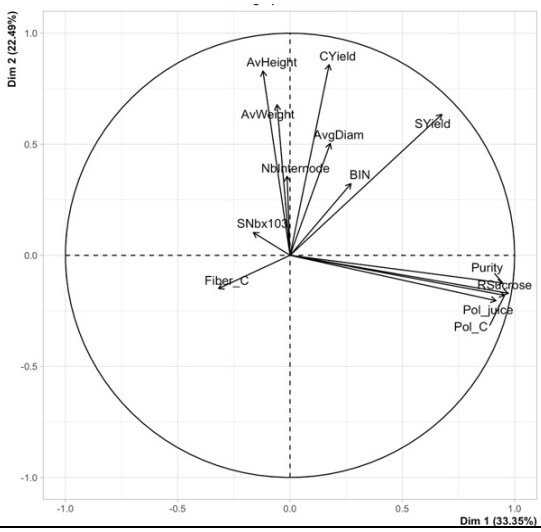


Figure 1a: Correlation circle of agronomic traits investigated, in 1-2 factor plane

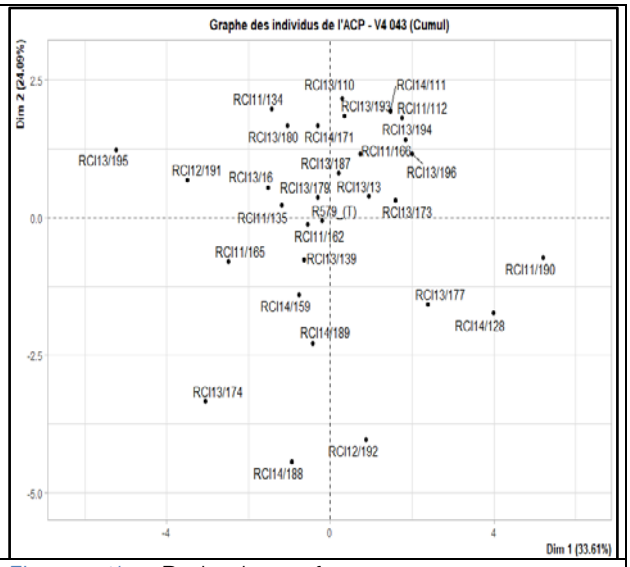


Figure 1b: Projection of sugarcane genotypes following their agronomic performances, in 1-2 factor plan

Figure 1: Results of principal component analysis regarding aggregate data of plant cane and first ratoon crops, obtained in Ferké 2 sugar estate

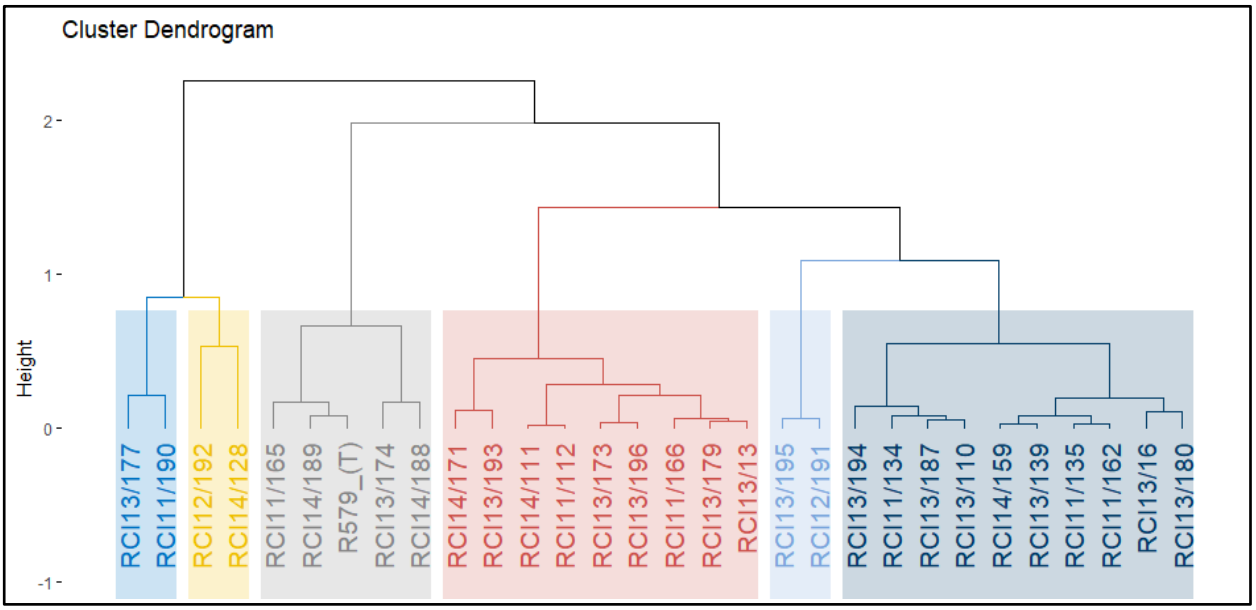


Figure 2: Dendrogram deduced from the cluster analysis of all 30 cane genotypes tested in Ferké 2 sugar estate, based on different agronomic traits observed in plant cane and first ratoon on aggregate

© 2021 Global Journals

Table 4: Average juice quality, yield traits of sugarcane cluster genotypes over plant cane, and first ratoon on aggregate, in Ferké 2 Sugar Estate (Ivory Coast)

Cluster Genotyes	Juice quality traits					Yield traits (t/ha)	
	Purity%	Sucrose%	Fiber%	Recoverable sucrose%	Internode bored %	Cane	Sugar
Cluster 1	83.6	11.7	14.2	8.0	2.5	138.0	10.8
Cluster 2	86.3	12.9	13.0	9.1	3.8	103.6	9.5
Cluster 3	86.5	12.9	12.8	9.2	3.7	143.2	13.2
Cluster 4	87.3	13.4	13.1	9.6	4.5	141.4	13.6
Cluster 5	88.9	14.6	13.6	10.6	3.7	136.3	14.5
Cluster 6	89.7	14.8	13.1	10.9	3.1	126.3	13.8
Mean	87.0	13.4	13.8	9.6	3.5	131.5	12.6

d) Phenotypic correlations between pairs of agro-morphological traits

Juice quality traits (pol juice, purity, sucrose content, and recoverable sucrose) were positively, tightly,and highly significantly correlated between pairs with coefficients ranging from 0.80** to 0.99**. Similar correlation was obtained with cane and sugar yields which coefficient (r=0.86***) matches that magnitude. Juice quality traits were also positively, significantly correlated highly, but moderately, to sugar yield with coefficients ranging from 0.31 to 0.39. In contrast, they were loosely correlated negatively and not significantly (P=0.05) to cane yield, with coefficients ranging from -0.16 to -0.11. The millable stalk number per hectare was positively and moderately correlated to cane and sugar yields, with 0.27 and 0.21, respectively, as coefficients. Agro-morphological characters like stalk diameter and stalk height were moderately and significantly correlated to stalk weight with coefficients of 0.27 and 0.37, respectively. The cane Fiber content was correlated positively to internode number (r=0.32), but negatively to cane and sugar yields (-0.25, -0.23) as reported by different investigators [3, 5, 40-41]. It was negatively correlated to stem borer infestation rate (r=-0.18), in contrast of findings of these investigators. More importantly, it was positively correlated to the recoverable sucrose, in line of observations made by Péné and Béhou[42], and in contrast of findings obtained in the same agro-ecological context [43].

e) Genotypic correlations between pairs of agro-morphological traits

Juice quality traits were positively and strongly correlated between pairs with coefficients ranging from 0.89** to 0.98**. Similar correlation was observed not only with cane and sugar yields (r=0.83**). Other strong and positive correlations occurred between cane yield and the average stalk height (r=0.80**), and between single stalk weight and agro-morphological traits like single stalk height (r=0.77**) and single stalk diameter (r=0.70**). In contrast, a negative and strong correlation was observed between the millable stalk number and single stalk diameter(r=-0.71**), indicating that the higher the number of tillers/ha, the smaller stalk diameter was due to competition for light and soil nutrients. As reported by several researchers [27, 30], such tight genotypic correlations indicate that selection based on single stalk weight, and millable stalk number could lead to improvement in agro-morphological traits like stalk diameter, stalk height and yield traits. In the present study, correlations observed between the internode number and other agro-morphological traits were loose, in contrast of findings reported by these researchers.

Juice quality traits were also positively correlated, but moderately, to sugar yield with coefficients ranging from 0.49 to 0.63, in line of findings obtained by Péné and Béhou[3, 42] in the same agro-ecological context.

© 2021 Global Journals

Table 5: Phenotypic and genotypic correlation matrix of agro-morphological traits investigated (respectively below and above diagonal) regarding aggregate data of both plant and first ratoon crops

Genotypes	Pol juice	Purity	Pol%C	Fiber%	CYield	RSucrose	SYield
Pol juice	1.00	0.89**	0.99**	-0.03	-0.07	0.97**	0.49
Purity	0.80**	1.00	0.94**	-0.36	0.11	0.96**	0.63**
Pol%C	0.98**	0.80**	1.00	-0.18	-0.01	1.00	0.55**
Fiber%	0.18	0.11	0.02	1.00	-0.34	-0.25	-0.43
CYield	-0.16	-0.12	-0.12	-0.25	1.00	0.03	0.83**
RSucrose	0.97**	0.87**	0.99**	0.00	-0.11	1.00	0.59**
SYield	0.33	0.31	0.38	-0.23	0.86**	0.39	1.00
$SNbx10^3$	-0.03	-0.02	-0.04	0.05	0.27	-0.04	0.21
AvWeight	-0.07	-0.10	-0.08	0.04	0.25	-0.09	0.19
AvHeight	-0.16	-0.24	-0.12	-0.24	0.50*	-0.13	0.39
AvDiam	-0.05	0.04	-0.02	-0.10	0.19	-0.01	0.16
NbInternode	0.13	0.13	0.08	0.32	0.02	0.08	0.07
BIN%	-0.09	-0.04	-0.06	-0.18	0.24	-0.05	0.21

Genotypes	SNbx103	AvWeight	AvHeight	AvgDiam	NbInternode	BIN%
Pol juice	-0.13	-0.14	-0.22	0.03	-0.03	0.05
Purity	-0.26	-0.22	-0.28	0.17	-0.14	0.34
Pol%C	-0.17	-0.13	-0.24	0.09	-0.09	0.14
Fiber%	0.20	0.06	0.21	-0.29	0.44	-0.59
CYield	0.41	0.51*	0.80**	0.23	0.13	0.44
RSucrose	-0.19	-0.15	-0.26	0.11	-0.12	0.20
SYield	0.23	0.34	0.50	0.24	0.05	0.50
$SNbx10^3$	**1.00**	-0.22	0.31	-0.71**	-0.44	-0.29
AvWeight	-0.01	**1.00**	0.77**	0.70**	0.41	-0.18
AvHeight	0.15	0.37	**1.00**	0.23	0.32	0.09
AvDiam	-0.19	0.27	0.29	**1.00**	0.32	0.30
NbInternode	-0.12	0.17	0.10	0.18	**1.00**	-0.01
BIN%	-0.14	0.10	0.07	0.01	-0.03	**1.00**

f) Phenotypic and Genotypic Coefficient of Variation (PCV, GCV)

All PCV and GCV values determined, which ranged from 4.8 to 89% on the one hand, and from 4.4 to 80.5% on the other hand, varied from low to high (Table 6). As far as PCV is concerned, higher values were observed for traits like cane yield, sugar yield, recoverable sucrose, millable stalk number/ha, single stalk weight, single stalk height, and stem borer infestation rate. Moreover, higher GCV values were observed for traits like cane yield, sugar yield, millable stalk number, single stalk weight, and stem borer infestation rate. In line of findings reported by different investigators [44 -45], higher GCV and PCV values indicated that selection might be effective on traits investigated and their expression be relevant to the genotypic potential. Agronomic traits exhibiting relatively high GCV, with values ranging from 29 to 80.5%, might respond favorably to selection, as reported by Ebid et al [46]. Regardless the trait considered in this study, the phenotypic coefficient of variation was higher than the genotypic ones suggesting that apparent variations were not only due to genetics but also to environmental influences. However, differences between PCV and GCV for most traits were small in line of observations made by different investigators [3, 25, 30,42,47], indicating a good perspective for genetic progress through selection under the agroecological conditions of this study.

g) Phenotypic, Genotypic and Environmental Variances

Regardless the trait considered, phenotypic variance data determined were higher than the genotypic ones. This shows a greater influence of environment on genetic variations, in line of observations made by different authors [19, 27, 46]. No matter the trait considered, genotypic variance calculated was higher than environmental one, suggesting important variations among genotypes, in line of their higher or moderate values of broad sense heritability ($h^2 \geq 56.8\%$) ranging from 53.6 to 87%. Except for the single stalk weight, the heritability observed ranged from 74 to 87%, which values are much higher than the threshold 60%.

h) Heritability and Genetic Advance

Except for the single stalk weight, higher heritability values ranging from 74 to 87% were observed on all traits investigated (Table 6). Estimates of mean genetic advance (GAM) are categorized similarly to GCV and PGV according to Falconer and Mackay [26] cited by several authors [27-28, 30, 47-48]. Therefore, except for juice purity (8.5%) and cane fiber content (19.8%), higher values of genetic advance were observed for all traits investigated likecane yield (57%), sugar yield (67%), millable stalk number (52%), single stalk weight (46%), and stem borer infestation rate (150%). Higher values of GAM suggest that a significant proportion of

© 2021 Global Journals

the total variance might be heritable and selection of corresponding traits would be effective. In sugarcane, several authors reported similar values on single stalk weight [30, 51-52]. As indicated by Vidya et al [53], knowledge of variability and heritability of characters is essential for identifying those relevant to genetic improvement through selection. Moreover, the effectiveness of selection will depend not only on heritability but also on genetic advance, as reported by different authors [54-55].

Higher levels of mean genetic advance observed for yield (57%), sugar yield (67%), millable stalk number (52%), single stalk weight (46%), and stem borer infestation rate (150%) were the result of moderate or high broad sense heritability, combined with high GCV for these traits, in line of findings reported by Bakshi [54]. According to this author, cited by Péné and Béhou [55], heritability estimates together with expected genetic gain were more useful than heritability values alone in predicting the effects of selecting best genotypes. Chaudhary [34] also reported high heritability and genetic gain for single cane weight followed by number of millable cane in a study of 36 clones indicating substantial scope for cane yield improvement. On the other hand, sucrose content recorded low heritability and genetic gain suggesting little scope for improvement in this character [56]. Patel et al [57] also reported high heritability estimates for single cane weight, number of internodes, tiller number, hand refractrometer brix, cane diameter and millable cane length, which were associated with moderate to high genetic advance (23-190%). Findings indicated that these characters might be improved through selection. From the literature, findings on heritability, genetic gain, PCV and GCV for the same traits look sometimes controversial depending on locations, crop cycle (plant cane or ratoon), soil types, water regime (rainfed or irrigated), etc. [6, 22, 41, 58]. But still, this is all about the scope of experimentation in agronomy, findings being mostly site-specific.

Table 6: Variability and heritability among sugarcane genotypes tested in Ferké 2, Ivory Coast (aggregate data of both plant and first ratoon crops)

Agronomictraits	Mean	Variance			Coefficient of variation (%)		H^2 (%)	GA (-)	GAM (%)
		σ^2g	σ^2e	σ^2p	GCV	PCV			
Pol juice	16.1	5.79	1.02	6.71	15.0	16.1	86.3	4.6	28.7
Purity	86.8	14.88	2.85	17.28	4.4	4.8	86.1	7.4	8.5
Pol%C	13.2	3.96	0.66	4.56	15.1	16.2	86.8	3.8	29.0
Fiber%	13.1	1.80	0.28	2.07	10.3	11.0	87.1	2.6	19.8
CYield	135.5	1778.00	398.00	2219.33	31.1	34.8	80.1	77.9	57.5
RSucrose	9.4	3.35	0.54	3.84	19.4	20.8	87.1	3.5	37.3
SYield	12.8	21.06	3.85	25.35	36.0	39.5	83.1	8.6	67.7
$SNbx10^3$	116.3	1139.90	265.80	1461.90	29.0	32.9	78.0	61.5	52.9
AvWeight	1.3	0.14	0.07	0.25	29.6	39.3	56.8	0.6	46.1
AvHeight	260.7	2468.00	510.00	2848.50	19.1	20.5	86.6	95.4	36.6
AvDiam	21.9	13.05	2.63	15.47	16.5	17.9	84.4	6.8	31.2
NbInternode	22.6	10.35	3.61	13.93	14.2	16.5	74.3	5.7	25.3
BIN%	3.8	9.35	3.44	11.43	80.5	89.0	81.8	5.7	150.1

IV. Conclusion

The present study showed that most relevant traits in genotype clustering were associated to juice quality (recoverable sucrose, sucrose content, purity), yields and their components like single stalk height, and single stalk weight. Based on sugar yields, three high yielding genotypes compared to the check variety (R579), namely RCI14/128, RCI11/112, and RCI11/190, were determined for the late selection stage, with 16.4, 15.8 and 15.0 t sugar/ha, respectively. Their cane yieldsreached 151.5, 164.2 and 132.6 t/ha, respectively, compared to 146.1 t/ha for the check, and they belong to two clusters genotypes over six determined. Except for juice purity and cane fiber content, all agro-morphological traits investigated have explained the genetic variation of sugarcane genotypes tested, with stem borer infestation rate, cane and sugar yields, and number of tillers/ha as the most important traits in this regard.

References Références Referencias

1. FAO, 2014. FAO STAT, FAO statistical databases. Available at: http://faostat3.fao.org/(Last accessed June 07, 2016.
2. Jackson, P.A. (2005). Breeding for improved sugar content in sugarcane. Field Crops Res. 92(2-3): 277-90.
3. Péné CB, Béhou YM, 2019a. Evaluation of sugarcane genotypes under irrigation based on genetic variations and heritability for agronomic traits at early selection stage in Ferké, Ivory Coast. Am. J. Biosci. Bioeng. 7(6): 82-92.

© 2021 Global Journals

4. Tyagi S.D. and D.N. Singh (1998). Studies on genetic variability for stalk characters in sugarcane. Indian Sugar XL VIII: 259-62.
5. Chaudhary, R.R. (2001). Genetic variability and heritability in sugarcane. Nepal Agric Res. 4 & 5: 56-8.
6. Béhou, Y.Y.M. and C.B. Péné (2019). Genetic variability and heritability among sugarcane genotypes in plant crop for some agronomic traits under tropical dry climate of Ferké, Ivory Coast. J. Exp. Agric. Int. 38(1): 1-14.
7. Péné, C.B., K.D. Kouamé, H. Dove and B.M. Boua (2016). Incidence des infestations du foreur de tiges *Eldanasaccharina* W (Lepidoptera:Pyralidae) en culture irriguée de canne à sucre selon la variété et la période de récolte en Côte d'Ivoire. J. Appl. Biosci. 102: 9687-9698.
8. Bakhsh, A., M. Arshad and A.M. Haqqan (2006). Effect of GxE interaction on relationship between grain yield and its components in chickpea (*Cicer arietinum* L). Pakistan J. Bot. 38: 683-90.
9. Da Silva, F.F., M.G. Pereira, H.C.C. Ramos, Jr. Damasceno, N.S. Pereira and C.D. Ide (2007). Genotypic correlations of morpho-agronomic traits in papayas and implications for genetic breeding. Crop Breed. Appl. Biotech 7: 345-52.
10. Tena, E., A. Ayana and F. Mekbib (2016). Heritability and correlation among sugarcane (*Saccharum* spp.) yields and some agronomic and sugar quality traits in Ethiopia. Am. J. Pant Sci. 7(10): 1453-77.
11. Jackson, P. (1994). Genetic relationships between attributes in sugarcane clones closely related to *Saccharum spontaneum*. Euphytica 79: 101-8.
12. Tyagi S.D., M.H. Khan (2010). Studies on genetic variability and interrelationships among different traits in Microsperma Lentil (*Lens culinaris*Medik). J. Agric Biotech Sust. Dev 2: 15-20.
13. De Sousa-Vierra O. and S.B. Milligan (2005). Interrelationships of cane yield components and their utility in sugarcane family selection: path coefficient analysis. Intersciencia 30: 93-9.
14. Milligan, S.B., K.A. Gravois, K.P. Bischoff and F.A. Martin (1990). Crop effects on broad-sense heritability and genetic variances of sugarcane yield components. Crop Sci. 30: 344-49.
15. Gravois, K.A., S.B. Milligan and F.A. Martin (1991). Additive genetic effects for sugarcane yield components and implications for hybridization. Trop. Agric. (Trinidad) 68: 376-80.
16. Tyagi, A.P. and P. Lal (2007). Correlation and path coefficient analysis in sugarcane. South Pacific J. Nat. Sci. 25: 1-9.
17. Péné, C.B., H.M. Ouattara and G.S. Koulibaly (2012). Late season sugarcane performance as affected by soil water regime at the yield formation stage on commercial farms in northern Ivory Coast. J Life Sci. 6(6): 644-651.
18. Konan, E.A., C.B. Péné, E. Dick (2017a). Caractérisation agro-climatique du périmètre sucrier de Ferké 2 au Nord de la Côte d'Ivoire. J Appl. Biosci. 116: 11532-11545.
19. Konan, E.A., C.B. Péné and E. Dick (2017b). Main factors determining the yield of sugarcane plantations on Ferralsols in Ferké 2 sugar complex, Northern Ivory Coast. J. Emerg. Trends Engin. Appl. Sci. JETEAS 8(6): 244-256.
20. M. Hoarau. La canne à sucre. Le technicien d'agriculture tropicale. Maisonneuve et Larose (eds), 1970, 165 p.
21. E. Hugot. Sucrerie de canne. Paris, Collection Tech & Doc, Lavoisier (eds), 1999, 1018 p.
22. Burton, G.W., E.H. Devane (1953). Estimating heritability in tall Fescue (*Festuca arundinacea*) from replicated clonal materials. Agron. J.: 45: 487-88.
23. Shitahum, A., T. Feyissa and D. Abera (2018). Performances evaluation of advanced sugarcane genotypes (Cirad 2013) at Metahara sugar estate, Ethiopia. Int. J Adv. Res. Biol. Sci.: 5(1): 91-104.
24. R.K. Singh and B.D. Chaundary. Biometrical methods in quantitative genetics analysis. New Delhi, Kalyani Publishers, 1977: 57-8.
25. Shivasubramanian, S. and M. Menon (1973). Heterosis and inbreeding depression in rice. Madras Agric. J. 60: 1139.
26. D.S. Falconer, T.F.C. Mackay. Introduction to quantitative genetics. 4th eds. Harmlow: Longman, 1996.
27. Mancini, M.C., D.C. Leite, D. Perecin (2012). Characterization of the genetic variability of a sugarcane commercial cross through yield components and quality parameters. Sugar Tech. 14(2): 119-25.
28. Li, C. (2017). Genotypic variations in transpiration efficiency, due to differences in photosynthetic capacity among sugarcane-related clones. J. Exper. Bot. 68(6): 2377-85.
29. Jackson, P., J. Basnayake, G. Inman-Bamber, P. Lakshmanan, S. Natarajan and C. Stokes (2015). Genetic variation in transpiration efficiency and relationships between whole plant and leaf gas exchange measurements in *Saccharum* spp. And related germplasm. J. Exper. Bot.: 67(3): 861-71.
30. Robinson H F (1966). Quantitative genetics in relation to breeding of the centennial of mendalism. Indian J. Gen. 26: 171-87.
31. Tadesse, F., T. Negi, A. Getaneh, Z. Dilnesaw, N. Ayele and Y. Teferi (2014). Genetic variability and heritability of ten exotic sugarcane genotypes at Wonji sugar estate of Ethiopia. Global Adv. Res. J. Phys. Appl. Sci. 3(4): 1-4.
32. Rebettzke, G.J., A.G. Condon, R.A. Richards and G.D. Farquhar (2002). Selection of carbon isotope discrimination increases aerial biomass and grain

© 2021 Global Journals

yield of rainfed bread wheat. Crop Sci.: 42(3): 739-45.
33. Ram, B., G. Hemaprabha (1992). Genetic variability in interspecific progenies in sugarcane (*Saccharuim* spp.). Ind. J. Genet: 52(2): 192-98.
34. Chaudhary, R.R. (2001). Genetic variability and heritability in sugarcane. Nepal Agric. Res. J: 4: 56-9.
35. Kang, M.S., J.D. Miller and P.Y.P. Tai (1983). Genotypic and phenotypic path analyses and heritability in sugarcane. Crop Sci: 23: 643-47.
36. R.C. Parfitt. Genotype x environment interaction among secondary variety trials in the northern region of the South African sugar industry. Proc. S. Afr. Sug. Technol. Assoc, 2000: 74: 245-58.
37. Glaz, B. and M.S. Kang (2008). Location contributions determined via GGE biplot analysis of multi-environment sugarcane genotype-performance trials. Crop Sci. 48: 941-50.
38. Péné CB, Béhou YM, 2020a. GxE interactions in sugarcane under irrigation for agronomic traits at advanced screening stage in Ferké, Northern Ivory Coast. J. Exper. Agric. Inter. (JEAI) 42(2): 97-115.
39. K.A. Gomez and A.A. Gomez. Statistical procedure for agricultural research (2nd ed). John Wiley and Sons Inc, New York. 1984.
40. Gravois, K.A. and S.B. Milligan (1992). Genetic relationship between fiber and sugarcane yield components. Crop Sci. 32(1): 62-7.
41. Dumont, T., A. Thong-Chane, L. Barau, B. Siegmund and J.Y. Hoarau (2019). Genetic variability and genetic gains for yield components in regional sugarcane breeding program on Reunion Island. Sugar Tech. Available online http://doi.org/10.1007/s12355-019-00718-9.
42. Péné CB, Béhou M, 2019b. Screening of fifteen sugarcane genotypes under irrigation based on genetic variations and heritability for agro-morphological traits at early selection stage in Ferké, Ivory Coast. Am. J. Biomed. Sci. Res. 4(5): 362-71.
43. Péné, C.B., B.M. Boua, Y. Coulibaly-Ouattara and F.R. Goebel (2018). Stem borer (*Eldanasaccharina* W) infestation outbreak in Sugarcane plantations of northern Ivory Coast: Management strategies under implementation. Amer. J Biosci. Bioeng. 6(4): 27-35.
44. Ram, B. (2005). Estimation of genetic parameters in different environments and their implications in sugarcane breeding. In. J. Genet. 52(2): 192-98.
45. Dos Santos Silva, PP, M. Soussa and E.J. De Oliveira (2019). Prediction models and selection of agronomic and physiological traits for tolerance to water deficit in cassava. Euphytica 215(4):73.
46. Ebid, M.H.M., H.A. Khalil, A.M. Abd-ElAal and M.A. Fergany (2015). Heritability and genotypic and phenotypic correlations among sugarcane yield and some agronomic traits. Egypt L Plant Breed: 19(1): 159-71.
47. Fartek, B., S. Nibouche, T. Atiama-Nurbel, B. Reynaud and L. Costet (2014). Genotypic variability of sugarcane resistance to aphid *Melana-phissacchari*, vector of the Sugarcane Yellow Leaf Virus. Plant Breed. 133(6): 771-6.
48. Teklu, D.H., S.A. Kebede and D.E. Gebremichael (2014). Assessment of genetic variability, genetic advance, correlation and path analysis for morphological traits in sesame genotypes. As. J. Agric. Res. 8(4): 181-94.
49. Nair, N.V., K.G. Somarajan and Baasundaram (1980). Genetic variability, heritability and genetic advance in *Saccharum officinarum*. Int. Sugar J. 82(981): 275-6.
50. Singh, G.P., K.R. Maurya, B. Prasad and A.K. Singh (1994). Genetic variability in *Capsicum annum* L. J. Appl. Biol. 4: 19-22.
51. Vidya, KL, S.K. Oommen and K. Vijayaraghava (2002). Genetic variability and heritability of yield and related characters in yard-long bean. J. Trop. Agric. 40: 11-3.
52. Butterfield, M.K. and K.J. Nuss (2002). Prospects for new varieties in the medium to long term: The effects of current and future breeding strategy on variety characteristics. In: Proceed. S. Afric. Sugar Ind. Agron. Assoc., Kwa-Shukela: 41-8.
53. Shoba, D., N. Manivannan, P. Vindhiyavarman (2009). studies on variability, heritability and genetic advance in groundnut (*Arachis hypogea* L). Electron. J. Plant Breed. 1(1): 74-7.
54. Bakshi, R. (2005). Estimation of genetic parameters in different environments and their implications in sugarcane breeding. Indian J. Gen. 65(3): 219-20.
55. Béhou YM, Péné CB, 2020b. Genetic variability and heritability among sugarcane genotypes observed at early stage of the advanced selection for some agronomic traits in Ferké, Northern Ivory Coast. Agric. Sci. 2(1): 83-94.
56. Pandey, R.A. (1989). Variability study in the hybrid progenies of sugarcane (*Saccharumcomplex*). Bharatiya Sugar: 49-51.
57. Patel, MM, H.S. Patel, A.D. Patel and M.P. Patel (2008). Correlation and path analysis in sugarcane. Ind. Sugar 31: 911-14.
58. Tefera, A, A. Sentayehu, T. Leta (2017). Genetic variability, heritability and genetic advance for yield and its related traits in rainfed lowland rice (*Oriza sativa* L) genotypes at Fogera and Pawe, Ethiopia. Adv. Crop Sci. Technol. 5(2): 1000272.

© 2021 Global Journals