Original Research Article

EVALUATION OF THE AGRO-TECHNOLOGICAL AND HEALTH CHARACTERISTICS OF SUGAR CANE VARIETIES (*Saccharum officinarum* L.) IN RAINFALL CONDITIONS

Abstract

Sugar cane *Saccharum officinarum* (Poaceae) is an important industrial crop in the Ivory Coast. Cane production involves two types of culture. The irrigated cultivation of sugar cane which is that practiced by industrialists and the cultivation in rainy conditions which is that of village producers The study aimed to improve agricultural productivity in village sugar cane plantations by selecting varieties adapted to rain conditions. The trials carried out at the CNRA research station in Ferké (north of the Ivory Coast) in experimental plots were arranged in complete randomized blocks with 7 varieties, including two controls, repeated 6 times. These experiments were carried out on two consecutive harvest cycles, a virgin and a regrowth, with cane yield, extractable sugar content and tolerance to bio-aggressors as the main selection criteria. The varieties Co 997, M 1176/77 and M 2238/89 were found to be significantly superior to controls R 570 and SP 711406. As for the variety KnH 80412, it appeared equivalent to the best control R 570. Among these 5 varieties tested under rainy conditions, the most productive was Co 997 with 60.5 t of cane / ha after 2 consecutive harvest cycles since the new plantation. These varieties are drought tolerant and can therefore replace obsolete varieties that have become too sensitive to the major enemies of sugar cane in village cultivation in the Ferkessédougou region.

Keywords: cane yield, drought tolerance, extractable sugar content, Ferkessédougou

1. INTRODUCTION

Sugar cane (*Saccharum officinarum* L.), is part of the Poaceae family and the S*accharum* genus. Originally from Papua New Guinea, it is cultivated for its stem rich in sucrose. It is cultivated in all tropical and subtropical regions of the world, up to approximately 35°N and 35°S [1]. It has a global production of 1.9 billion tonnes of sugar cane. Sugar produced from sugar cane represents 65 to 80% of global production, with the remainder coming from sugar beets. Sugar cane is used in several areas, including food, the production of biofuels, energy and paper. It plays an important role in the global economy and in environmental protection through its capacity to fix a large quantity of CO_2 [2]. In Ivory Coast, sugar cane plays an important role in the economy. In terms of surface area, it occupies 25,400 ha out of a land area of 61,400 ha exploited by the sugar industries.

Ivory Coast is ranked 53rd globally and 16th in Africa in terms of sugar production [3]. Within the UEMOA area, sugar production amounts to 214,000 t of finished sugar. This plant is mainly cultivated in the North and Center-West of Côte d'Ivoire. The contribution of sugarcane production to GDP is approximately 1% and 3.3% of the agricultural sector, thus generating more than 10,000 jobs [4].

The Ivorian sugar sector includes a sub-sector of irrigated industrial cultivation practiced by sugar companies and a sub-sector of rain-fed village cultivation practiced by farmers. The share of village sugar cane covers an area of approximately 5,000 hectares. The average yield in village cultivation is around 40 tonnes/ha compared to 80 tonnes/ha for industrial cultivation [5].

This poor performance is generally due to the use of varieties that are not very productive and are most often unsuitable for rainfed cultivation, which is the condition for growing village sugar cane. In addition, these varieties are susceptible to pests such as smut caused by *Sporisorium scitaminea*, leaf scald, nematodes and stem borer (*Eldana saccharina*) which cause significant damage in Africa causing yield losses in crop cultivation. sugar cane.

Despite its importance, these numerous biological constraints contribute to limiting sugar cane production. In order to provide village sugar cane producers with more efficient varieties (high sugar yield, tolerant to pests) and meeting the requirements of industrialists, the National Agronomic Research Center (CNRA) has undertaken a study varietal evaluation and selection. It is in this context that this study is located, the general objective of which is to contribute to the improvement of sugar cane production in rainfed conditions in the north of Côte d'Ivoire.

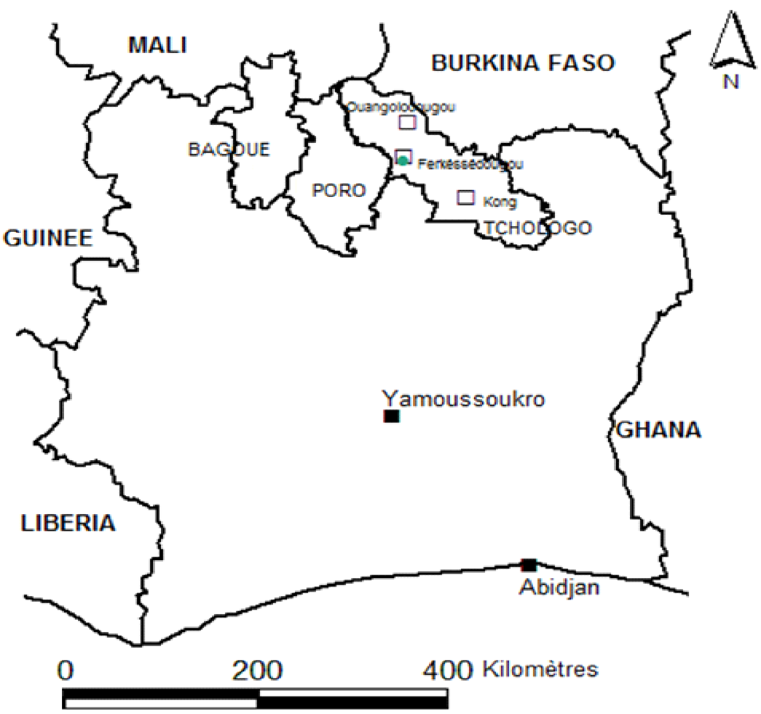
Specifically, this involved:

- evaluate the agronomic parameters of five varieties of sugar cane,
- determine the technological parameters of these five varieties of sugar cane in rainfed conditions in comparison with those of two known controls
- analyze the phytosanitary characteristics of these varieties

2. MATERIAL AND METHODS

2.1. Site Features

The study was carried out on the experimental site of the research station of the National Agronomic Research Center (CNRA) in Ferkessédougou, in the north of Ivory Coast. The geographic coordinates of the region are: 9°35' 54'' N, 5°13' 30'' W and 323 m above sea level. The ferralitic type soil has an ocher-colored loamy-sandy texture which is dominant throughout the perimeter of the station. It is marked by a lateritic induration at medium depth (50-70 cm). The soil is mainly poor in organic matter (1.5% on average) with a strongly or weakly acidic pH (6 to 6.5) and a low cation exchange capacity (8 meq/100 g) [6]. [7].   The climate is subhumid tropical or transitional sub-Sudanian [8]. with two seasons including a dry season from November to March and a rainy season from April to October. The average annual rainfall reaches 1200 mm with relatively large daily thermal amplitudes (32.5 and 21 °C) with an annual average of 26 °C [9]. The duration of insolation is around 2610 h.year^{-1}. The vegetation of the Ferké region is a wooded Guinean (or sub-Sudanese) savannah, with variable levels containing small strips of detached forest.



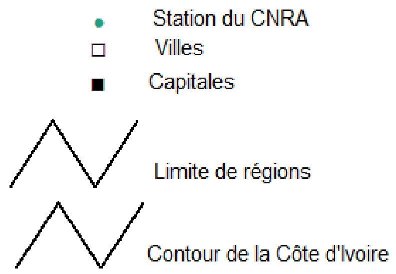


Figure 1 Map of Côte d'Ivoire presenting the study area

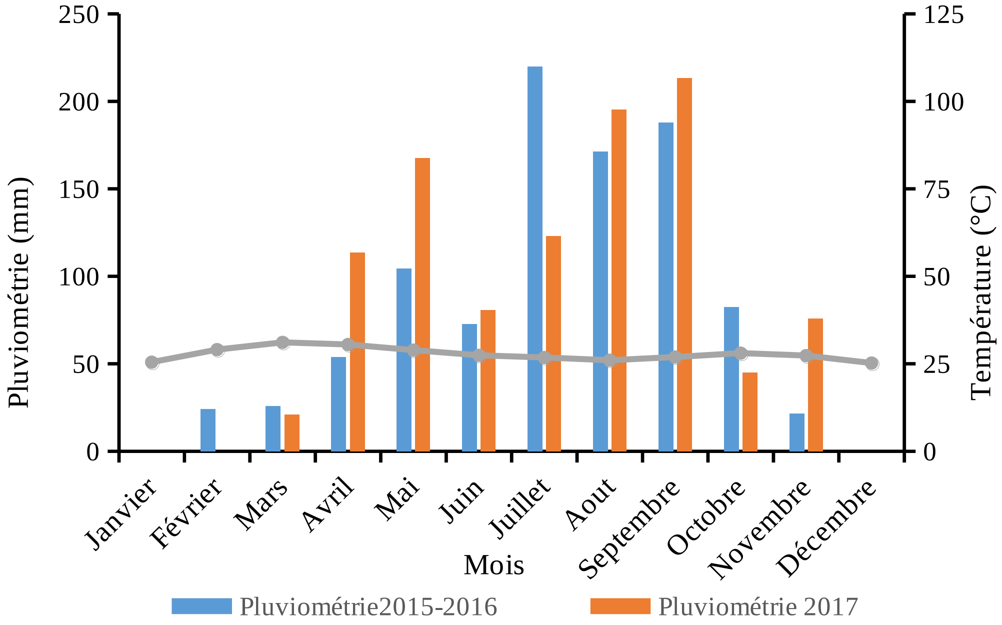


Figure 2 Ombro-thermal diagram of Ferkessédougou showing rainfall average of three years (2015-2016 and 2017) and the temperature of the year 2017 (Source: Sucaf CI meteorological service)

2.2 Plant material

The plant material used consisted of 5 commercial varieties of sugar cane which are Co 997; B 98653; M 1176/77; M 2238/89; KnH 80412, introduced in Ivory Coast in 2012 as part of the CFC/ISO 32 Project on sugar cane. The varieties R 570 and SP 711406 were chosen as the controls in this experiment.

2.3. Méthodes

2.3.1. Dispositif expérimental

The experimental design consists of completely randomized blocks with 7 treatments (the varieties) and 6 repetitions (the blocks), i.e. 42 micro-plots. The factor studied is the variety of sugar cane: Co 997; B 98 653; M 1176/77; M 2238/89; KnH 80 412, R 570 and SP 711406. The varieties R 570 and SP 711406 were used as controls in this experiment.

Each micro-plot consisted of 3 rows of 5 m long canes spaced 1.5 m apart from each other, i.e. an area of 2.5 m² (5m x 1.5m x 3lines). For each variety of sugar cane, the total surface area of the useful plot is 135 m². The total surface area of the useful plot of the experiment is 945 m^2.

The study was carried out over two production cycles (a virgin crop cycle and a regrowth cycle) to take into account interannual variations and varietal performance. Setting In order to highlight the variety effect, all factors of production, land preparation, manuring, manual weeding or use of herbicides were kept uniform and at their optimum.

2.3.2. Evaluation of agronomic parameters

• Emergence rate (% Germination)

The emergence rate was estimated by counting the cuttings that actually emerged on each of the six (6) useful experimental plots per sugarcane variety. Counting of raised eyes was carried out 14, 21 and 42 days after planting. The lifting rate was determined from the following formula:

Lifting rate (%) = n/N X 10

with **n**: number of eyes raised ; **N**: total number of eyes planted

- **Tillering**

The evaluation of tillering was made by counting the primary and secondary stems per sugarcane plant. Thus, from the 3rd to the 10th month after planting the stems were counted on each planting line. The day after the burning preceding the harvest, the cane stems were systematically counted on the useful lines. The number of stems per hectare was determined according to the following formula:

$$\textbf{Tilling (number of stems/hectare)} = \frac{\textbf{total number of stems x 6667}}{\textbf{number of useful lines x length of 1 line}}$$

- **Plant height and diameter**

In each micro-plot, 10 plants, 3 per row, were chosen randomly and then identified using an indelible marker. The height of the plants was measured using a tape measure, from the collar to the V base formed by the last leaves. On these same plants, the diameter of the stem was measured using a caliper. These measurements were made at the tenth month after planting the cuttings.

2.3.3. Assessment of performance metrics

The yield parameters evaluated were the mass of the sugar canes, the cane yield then the extractable sugar level, saccharin richness, brix refractometry, fiber content and purity.

• Average stem mass and cane yield

In each micro-plot, 10 stems were chosen at random then cut and weighed to determine the average mass of a stem. The stems were harvested from the 3 useful lines of each elementary plot, then weighed using a scale. The cane yield was evaluated according to the following formula:

Cane yield (t/ha) = mass of canes x 10.000 / useful surface area

2.3.4. Saccharimetric analyzes

A sample of 9 sugar cane stalks was taken from each of the useful micro-plots of the trial andbrought back to the laboratory. Each cane was cut into three pieces, retaining a base, a middle and a top or end to constitute a secondary sample. This sample was reduced to a pulp by an electric grinder. The pulp was subjected to a hydraulic press then technological qualities were determined for each sample:

• Extractable sugar level (SE%): this is the level of sugar that can be extracted from a cane

• Saccharin richness (Rich%) or pol: this is the level of sucrose in the juice of a sample of 9 canes per variety, measured using a polarimeter.

• Refractometric Brix (%): this is the rate of dry matter dissolved in the juice of a sample of 9 canes per variety, measured using a manual refractometer.

• Fiber content (%): determined after pressing a sample of 500 g of cane pulp per variety using a hydraulic press.

• Purity (%): it corresponds to the level of sucrose in the dissolved dry matter determined according to the formula Pol% / Brix.

2.3.5. Evaluation of phytosanitary parameters

Surveys were carried out in the experimental plot from 3 months after planting and harvesting to assess any disease attacks on the different varieties. Thus, tolerances to diseases such as smut, scald as well as stem borer attack were determined by counting the plants showing disease symptoms on the useful stems of each micro-plot.

For “smut”, the smut whips that appeared were counted from three and a half months after the previous planting or cutting (start of stem and whip formation) on each useful line. The number of whips per hectare was calculated according to the following formula:

$$\textbf{Number of whisks.ha}^{-1} = \frac{\textbf{total number of whisks x 10 000}}{\textbf{useful or harvestable surface area}}$$

For leaf scald (*Xanthomonas albilineans*), the infested strains were counted in each useful plot. The number of these strains was reduced per hectare to determine the disease attack rate for each variety.

As for the stem borer, the rate of attacked internodes was determined at harvest on a sample of 30 stems taken from the useful plot of each block, at a rate of at least 10 canes per line. These canes were cut longitudinally and the internodes were observed to detect possible borer attack (annular hole and reddish coloring of the pulp). The number of internodes attacked was compared to the total number of internodes on each stem in order to calculate the attack rate (ENA%) according to the following formula:

$$\textbf{ENA \%} = \frac{\boldsymbol{\Sigma}\textbf{ (Internodes attacked on the 30 stems)}}{\boldsymbol{\Sigma}\textbf{ (Internodes of the 30 stems)}} \textbf{ X 100}$$

2.4. Statistical analysis

The collected data were subjected to a one-way analysis of variance for classification (treatment) and the comparison of means was carried out according to the LSD test (ANOVA post-hoc test) at the 5% significance level using the STATISTICA 7.5.3 software. A principal component analysis (PCA) was carried out to characterize the varieties. The different variables which made it possible to characterize the varieties are the sugar and cane yields, the saccharin richness, the purity, the brix rate, the fiber content, the rate of internodes attacked by Eldanna saccharina, the length stem average, average cane weight, flowering rate, emergence rate, stem height and number of stems per hectare. These initial quantitative variables, correlated or not, are transformed into uncorrelated variables (principal components). Which leads to the calculation of a diagonal matrix of eigenvalues representing the variances of the individuals on the two main axes which contribute largely to the total variance of the individuals. These axes made it possible to better visualize individuals in relation to each other.

3. RESULTS

3.1. Agronomic parameters during vegetation

3.1.1. Emergence rate (%) and number of regrowths

The emergence rate, 21 days after planting, and the number of stems per hectare, 21 days after regrowth, vary depending on the different varieties of sugar cane used. Thus, the analysis of variance revealed a significant difference between the varieties both for the emergence rate and for the number of stems per hectare (Table 1). In virgin cultivation, the controls R 570 and SP 711406 obtained the highest emergence rates which are respectively 46% and 44%, values which are statistically identical but different from the results of the other varieties. The lowest emergence percentage of 12% was recorded in the variety KnH 80412. Intermediate emergence rate values of 30 %, 21 %, 30 % 33 % were noted in the varieties B98653, Co 997, M 1176/ 77 and M 2238/89 respectively. At regrowth, the number of stems/ha evolved from one variety to another with the highest recovery rate, 76,659 stems/ha, presented by the variety M 1176/77.

Table 1: Germination rate, 21 DAP, and number of stems per hectare, 21 DAH, of sugar cane varieties

Varieties	Germination rate (%)	Stems/ha
	V	R1
B 98653	32 bc	14 073 e
Co 997	21 d	34 885 c
KnH 80412	12 e	31 219 cd
M 1176/77	30 c	76 659 a
M 2238/89	35 b	47 625 b
R 570 (T)	**46 a**	**21 035 de**

SP 711406 (T)	**44 a**	**36 148 bc**
Average	**31**	**37 378**

In each column, the values assigned the same letter do not differ significantly at the 5% threshold (Newman-Keuls).

V : virgin culture cycle — R1: 1st cycle of regrowth cultivation

DAP: day after plantation — DAH: day after harvest

3.1.2. Height and tallering

Table 2 presents the height and the average tillering (stems/ha), 3 months after planting and harvest of the sugar cane varieties in rainfed conditions, during the virgin crop cycle and the first regrowth crop cycle.

a- Plant height

The results showed significant differences between sugarcane varieties. During the virgin crop cycle, stem heights varied between 36.3 cm and 79.7 cm. The control variety SP 711406 had an average stem height of 79.7 cm, significantly higher than those of the other varieties.

The variety M 1176/77 had stems 36.3 cm long which were the shortest. Intermediate values were obtained by the variety KnH 80412 followed by the variety B 98653 and the control variety R570. During the 1st cycle of regrowth cultivation the lowest height was obtained with the variety B 98653 with 11.4 cm. The other varieties showed stem heights significantly lower than those observed during the virgin crop cycle, with values ranging from 15.5 to 20.3 cm. Over all 2 cultivation cycles, the control variety SP 711406 presented the best growth.

b- Tillering

The results showed that there is a significant difference ($p<0.05$) observed between the different varieties for this parameter. These varieties have on average a high tillering. During the virgin crop cycle, the control variety SP 711406 produced the highest number of stems with 173094 stems/ha. This value is statistically identical to that obtained by the variety B 98 653 with 165817 stems/ha. On the other hand, in the first cycle of regrowth cultivation, the variety B 98 653 produced the lowest number of stems/ha which went from 165817 to 7152 stems/ha. It was the Co 997 variety which presented the greatest tillering (62556 stems/ha), clearly higher than that of the controls which nevertheless had the best tillering in the virgin cultivation cycle. Over the two (2) development cycles, the control SP 711406 presented the best tillering.

Table 2: Height and number of stems per hectare of sugar cane varieties 3 months after planting (V) and harvest (R1) in rainfed conditions

Variétés	**Average stem height (cm)**			**Stems/ha**		
	V	R1	V+R1	V	R1	V+R1
B 98653	54,6 c	11,4 c	33,0 b	165 817 a	7 152 e	86 485 b
Co 997	41,2 d	20,0 a	30,6 b	67 919 d	62 556 a	65 238 c
KnH 80412	61,9 b	19,2 a	40,6 a	116 766 b	22 000 d	69 383 c
M 1176/77	36,3 e	20,3 a	28,3 b	100 434 bc	60 741 a	80 588 b
M 2238/89	43,1 d	19,5 a	31,3 b	69 549 d	46 667 b	58 108 d
R 570 (T)	**50,6 c**	**15,5 b**	**33,05 b**	**92 583 c**	**39 378 e**	**65 981c**
SP 711406 (T)	**79,7 a**	**17,9 a**	**48,8 a**	**173 094 a**	**35 524 c**	**104 301 a**
Average	**52**	**16**	**34**	**111 243**	**39 145**	**53 460**

In each column, the values assigned the same letter do not differ significantly at the 5% threshold (Newman-Keuls).

V : virgin culture cycle R1: 1st cycle of regrowth cultivation

3.2. Biometric characteristics of agronomic parameters at harvest

3.2.1. Flowering rate

The flowering rates obtained over the 2 development cycles are presented in Table 3. In virgin cultivation cycle, the KnH 80412 variety with a flowering rate of 45.5% had the highest flowering rate. The variety Co 997 and the control R 570 presented the rates of floraison the lowest of 0% and 0.3 %. In regrowth crop cycle, variety KnH 80412 showed the highest flowering rate of 19 % while control R 570 and variety B 98653 showed zero flowering rates.

3.2.2. Number of machinable stems per hectare (tillering)

Statistical analysis showed significant differences between the average numbers of machinable stems per hectare during the virgin crop cycle and the first regrowth crop cycle. During the virgin cultivation cycle, the control varieties R 570 and SP 711406 showed stem counts statistically similar to that of the variety KnH 80412 with 75778 machinable stems. This number of stems is statistically lower than those of the varieties B 98653, M 1176/77 and M 2238/89 which do not differ statistically. The Co 997 variety had the best tillering with 121630 stems/hectare. In the first cycle of regrowth cultivation, the analysis revealed significant differences between sugarcane varieties. The Co 997 variety presented the highest number of stems. Over both cultivation cycles, the Co 997 variety had the best tillering with 105 726 stems/ha. This number of stems is significantly higher than those of the varieties R 570 and SP 711406 which produced 61574 and 64945 stems/ha respectively. The numbers of stems of other varieties are between 61 555 and 80796 stems/ha (Table 3).

Table 3. Flowering rate and number of machinable stems (tillering) per hectare of sugar cane varieties observed at harvest

Varieties	Flowering rate (%)			Machinable stems/ha		
	V	**R1**	**V+R1**	**V**	**R1**	**V+R1**
B 98653	7,5 bc	-	-	103 259 b	-	-
Co 997	0	0,8 d	0,4 d	121 630 a	89 822 a	105 726 a
KnH 80412	45,5 a	19,0 a	32,3 a	75 778 d	47 333 c	61 555 c
M 1176/77	13,5 b	6,4 bc	10 b	95 111 b	58 704 bc	76 907 c
M 2238/89	8,5 bc	9,3 b	8,9 b	92 148 c	69 444 b	80 796 b
R 570 (T)	**0,3 d**	**0 d**	**1,5 d**	**77 926 d**	**45 222 c**	**61 574 c**
SP 711406 (T)	**1,0 d**	**2,8 cd**	**1,9 d**	**80 148 cd**	**49 741 c**	**64 945 c**
Average	**10,9**	**5,4**	**8,2**	**77481**	**60 044**	**68 763**

In each column, the values assigned the same letter do not differ significantly at the 5% threshold (Newman-Keuls).

V : virgin culture cycle R1: 1st cycle of regrowth cultivation

3.2.3. Average weight of machinable rods

The average cane weights of the sugarcane varieties are shown in Table 4. Statistical analysis revealed significant differences between varieties. During the virgin cultivation cycle, varieties KnH 80412 and M 2238/89 produced stems of 1176 g and 919 g respectively. These stem weights are statistically similar to those of the control varieties. The latter produced canes that were heavier than those of the Co 997 and M 2238/89 varieties. Variety B 98653 produced the lightest canes averaging 606g. During the first cycle of regrowth cultivation, the control variety SP 711406 had the lowest average cane weight which was statistically similar to that of the variety KnH 80412. Over both cultivation cycles, the variety B 98653, had obtained an average stem weight of 303 g, lower than the stem weight of all the varieties which was 782.14 g.

3.2.4. Average length of sugarcane stems

The average stem lengths of the sugarcane varieties were significantly different. The KnH 80412 variety had a cane length of 305 cm, greater than that of the control varieties R 570 and SP 711406 which were 240 and 271 cm respectively. The other sugar cane varieties studied, on the other hand, had shorter stems than those of the control varieties (Table 4). Apart from the B98653 variety whose plants did not regrow after the first harvest, the other varieties presented stem lengths varying from 125 to 150 cm in the first cycle of regrowth cultivation

Table 4. Average weight (g) and average length of machinable stems (tillering) per hectare of sugar cane varieties observed at harvest

Varieties	Average stem weight (g)			Average stem length (cm)		
	V	R1	V+R1	V	R1	V+R1
B 98653	606 c	-		209 d	-	
Co 997	831 bc	800 a	816 bc	187 d	125 b	156 c
KnH 80412	1 176 a	669 c	923 a	255 a	150 a	203 a
M 1176/77	881 b	686 bc	784 c	205 d	148 a	177 b
M 2238/89	919 ab	781 ab	850 bc	203 d	140 ab	177 b
R 570 (T)	**1 050 ab**	**704 b**	**877 bc**	**240 c**	**140 ab**	**190 b**
SP 711406 (T)	**1 087 a**	**660 c**	**874 bc**	**271 b**	**120 ab**	**176 b**
Average	**936**	**717**	**826**	**219**	**137**	**178**

In each column, the values assigned the same letter do not differ significantly at the 5% threshold (Newman-Keuls).

V : virgin culture cycle R1: 1st cycle of regrowth cultivation

3.2.5. Average stem diameter

Statistical analysis revealed significant differences between the stem diameters of sugarcane varieties in the virgin crop cycle. Variety B98653 had a stem diameter of 23 mm, smaller than those of other varieties, varying from 27 to 29 m and statistically similar. In the first cycle of regrowth cultivation, the Co 997 variety had the largest stem diameter (28 mm), statistically similar to that of the M 2238/89 variety (27 mm) and greater than those of the other varieties (Table 5).

3.2.6. Average number of stem internodes

The average numbers of internodes carried by the stems of the sugarcane varieties are presented in Table 5. The statistical analysis revealed significant differences between the varieties over the two cultivation cycles. The variety M 1176/77 had 20 internodes per stem, significantly higher than those of the control varieties which each had 16 internodes/stem. During the first cycle of regrowth cultivation, the variety M 1176/77 still had 20 internodes per stem. However, the control varieties had 13 internodes/stem, lower than those of the other varieties which were 14 and 16.

Table 5: Diameter and number of average stem internodes observed at harvest in rainfed conditions

Variétés	**average stem diameter (mm)**			**Number of internodes per stem**		
	V	**R1**	**V+R1**	**V**	**R1**	**V+R1**
B 98653	23 b	-	-	16 b	-	-
Co 997	27 a	28 a	27,5 b	17 b	16 b	17 c
KnH 80412	29 a	24 bc	26,5 b	17 b	15 bc	16 b
M 1176/77	28 a	26 ab	27 ab	20 a	20 a	20 a
M 2238/89	29 a	27 a	28 a	17 b	14 cd	16 b
R 570 (T)	**28 a**	**24 bc**	**26 b**	**16 b**	**13 cd**	**15 b**
SP 711406 (T)	**28 a**	**23 c**	**25,5 b**	**16 b**	**13 cd**	**15 b**
Average	**27**	**25**	**27**	**17**	**15**	**16**

In each column, the values assigned the same letter do not differ significantly at the 5% threshold (Newman-Keuls).

V : virgin culture cycle R1: 1st cycle of regrowth cultivation

3.3. Technological qualities of the varieties

Tables 6 present the average values of the sucrose level in the dissolved dry matter (purity), the fiber content of the cane pulp, the saccharin richness and the Brix (sugar content) of the sugar cane varieties. For data obtained during the virgin crop cycle, statistical analysis revealed significant differences between sugarcane varieties with respect to fiber content and Brix (%). On the other hand, no significant difference was observed between the average values of the varieties for the purity of cane juice and the saccharin or Pol richness. All varieties studied had high levels of purity and average saccharin richness of 85.4 % and 14.0 % respectively.

The KnH 80412 variety had an average fiber content of 15.2 %, statistically higher than that of other varieties whose fiber contents did not differ. The control variety R570 had the lowest fiber content (12.4 %). The sugar content (Brix) is very high for all varieties with an average of 20.2%. The varieties B 98653 and Co 997 obtained a brix (19.2 %) lower than that of the control varieties which amounted to 20%. The highest Brix was obtained in the varieties KnH 80412 (21.1 %) and M 2238/89 (21 %).

Regarding the data collected during the first cycle of regrowth cultivation, no significant difference was noted between the sugar cane varieties either for saccharin richness or for the percentage of brix (Table 7). However, significant differences are observed between the other varieties for purity and fiber content.

Table 6. Sucrose rate in dissolved dry matter (purity) and fiber content of the stem pulp of sugar cane varieties

Variétés	Purity (%)			Fiber content (%)		
	V	R1	V+R1	V	R1	V+R1
B 98653	84,6 a	-	-	13,5 bc	-	-
Co 997	84,6 a	82,6 b	83,6a	13,4 bc	12,2 ab	12,8 c
KnH 80412	85,6 a	83,9 ab	84,8 a	15,2 a	13,9 a	14,6 a
M 1176/77	85,4 a	85,6 a	85,5 a	13,9 b	12,8 ab	13,4 bc
M 2238/89	85,9 a	83,9ab	84,9 a	13,5 bc	14,1 a	13,8 bc
R 570 (T)	**86,4 a**	**82,7b**	**84,6 a**	**12,4 c**	**11,4 b**	**11,9 c**
SP 711406 (T)	**85,4 a**	**84,7ab**	**85,1 a**	**13,9 b**	**14,2a**	**14,1 a**
Average	**85,4**	**71 ,9**	**78,7**	**13,68**	**11,22**	**12,5**

In each column, the values assigned the same letter do not differ significantly at the 5% threshold (Newman-Keuls).

V : virgin culture cycle R1: 1st cycle of regrowth cultivation

Table 7. Saccharin richness (Pol) or rate of sucrose and refractometric Brix or rate of dry matter dissolved in the juice of sugar cane varieties

Variétés	Richesse saccharine (%)	Brix (%)

	V	R1	V+R1	V	R1	V+R1
B 98653	13,3 a	-	-	19,3 c	-	-
Co 997	13,3 a	13,8 a	13,6 a	19,3 c	20,0 a	19,7a
KnH 80412	14,3 a	14,3 a	14,3 a	21,1 a	21,0 a	21,0 a
M 1176/77	13,9 a	14,8 a	14,4 a	20,2 ab	21,0 a	20,6 a
M 2238/89	14,7 a	13,9 a	14,3 a	21 ab	20,5 a	20,8 a
R 570 (T)	**14,6 a**	**13,7 a**	**14,2 a**	**20,3 ab**	**19,6 a**	**20,0 a**
SP 711406 (T)	**13,8 a**	**13,7 a**	**13,8 a**	**20 ab**	**20,1 a**	**20,0 a**
Average	**14**	**12,0**	**13,0**	**20,2**	**20,3**	**20,3**

In each column, the values assigned the same letter do not differ significantly at the 5% threshold (Newman-Keuls).

V : virgin culture cycle R1: 1st cycle of regrowth cultivation

3.4 Variety yield

The yield parameters of sugarcane varieties are shown in Table 8. Statistical analysis showed significant differences between the tested varieties for cane and extractable sugar yields during the virgin crop cycle and the first volunteer crop cycle. The average yields of cane and sugar for all varieties combined were respectively 52 tc/ha-1 and 5.1 t.s.e. ha-1 in virgin cultivation cycle and 37.71 tc.ha-1 and 3.71 t.s.e. ha-1 in the first cycle of regrowth cultivation. The Co 997 varieties, with 61 tc. Ha-1 and 5.8 t.s.e. ha-1, M 1176/77, with 56 tc.ha-1, and 5.5 t.s.e.ha-1 and M 2238/89 with 52 tc.ha-1 and 5.4 t.s.e.ha-1 were more efficient than the control varieties R 570 and SP 711406. The control varieties outperform the variety B 98653 while the variety KnH 80412 and the variety R 570 have the same cane yield which is 49 Tc/ha in a virgin cultivation cycle. In the regrowth cycle we see that the results are the same, namely that the varieties Co 997, M 1176/77 and M 2238/89 perform better than the control varieties.

Table 8. Yield of cane (Tc/ha) and extractable sugar (T.S.E/ha) of sugar cane varieties grown in rainfed conditions

	Tc/ha			T.S.E/Ha		
Variétés	**V**	**R1**	**V+R1**	**V**	**R1**	**V+R1**
B 98653	46 c	-	-	4,3 c	-	-
Co 997	61 a	60 a	60,5 a	5,8 a	6 a	5,9 a
KnH 80412	49 bc	32 c	40,5 b	4,7 bc	3c	3,9 c
M 1176/77	56 ab	48 b	52 ab	5,5 ab	5 b	5,3 a
M 2238/89	52 bc	54 ab	53 ab	5,4 ab	5 b	5,2 a
R 570 (T)	**49 bc**	**38 bc**	**43,5 b**	**5,1 bc**	**4 c**	**4,6 b**
SP 711406 (T)	**51bc**	**33 c**	**42 b**	**5 bc**	**3 c**	**4 b**
Moyenne	**52**	**37,7**	**44,4**	**5,1**	**3,7**	**4,4**

In each column, the values assigned the same letter do not differ significantly at the 5% threshold (Newman-Keuls).

Tc/ha: tonnes of cane per hectare T.S.E/ha: tonnes of extractable sugar per hectare

V : virgin culture cycle R1: 1st regrowth crop cycle

3.5. Health status of the varieties

Varieties B 98653 and R 570 showed rust symptoms with rates of 2.5 % and 9.5 % respectively. The infestation levels for each variety tested against the stem borer (Eldana saccharina) were below the tolerable threshold which is 6%. The statistical analysis showed no significant difference between the different varieties tested for this parameter both during the virgin cultivation cycle and the first regrowth cultivation cycle. (Table 9).

Table 9. Rate of attacked internodes of sugar cane varieties

	ENA (%)

Varieties	V	R1	V+R1
B 98653	2,9 a	-	-
Co 997	6,8 a	0 b	3,4 c
KnH 80412	6,3 a	10,8 a	8,6 a
M 1176/77	7,5 a	2,7 ab	5,1 b
M 2238/89	7,2 a	1,2 b	4,2 b
R 570 (T)	**9,5 a**	**2,3 ab**	**5,9 b**
SP711406 (T)	**4,6 a**	**5,4 ab**	**5 b**
Average	**6,4 a**	**3,2**	**4,8**

In each column, the values assigned the same letter do not differ significantly at the 5% threshold (Newman-Keuls).

V : virgin culture cycle R1: 1st cycle of regrowth cultivation

ENA (%) : rate of attacked internodes

3.6. Screening of sugarcane varieties

3.6.1. Characterization of variety groups

Figure 3 presents the arrangement of the variables in the factorial plan formed by axes 1 and 2 of the principal component analysis carried out with the data collected during the virgin crop cycle. This representation shows that the axes F1 (Fact1) and F2 (Fact2) alone explain 65.55%.

The F1 axis (Fact1) which expresses 38.97% of the variability of sugar cane varieties is positively correlated with the number of internodes (NEN), cane yield (Tc/Ha), sugar yield extractable (t.s.e) and the number of stems per hectare (NT/ha). On the other hand, it is negatively correlated with the flowering rate (FLO), the fiber content of the cane pulp, and the average length and diameter of the stem.

This discrimination shows that the varieties Co 997 and M 1176/77 have similar agrotechnological qualities which differ from those of the control varieties R 570 and SP 711406 and the other varieties tested in virgin.

Figure 4 presents the arrangement of the variables in the factorial plan formed by axes 1 and 2 of the principal component analysis carried out with the data collected during the first cycle of regrowth cultivation. The F1 and F2 axes alone explain 80.61% of the dispersion of sugar cane varieties.

The F1 axis (Fact1) which expresses 48.69% of the dispersion of sugar cane varieties is positively correlated with the number of internodes (NEN), extractable sugar rate (tse), stem length and the number of stems per hectare (NT/ha), the average diameter (DM), the average weight (PM) of the canes and the cane yield (Tc/Ha).

The F2 axis (Fact2) which represents 31.91% of the variability of sugar cane varieties is positively correlated with the saccharin richness (Pol), the fiber content of the cane pulp, the Brix, the purity, flowering rate (Flo), average cane length (LM) and rate of internodes attacked (ENA). On the other hand, it is negatively correlated with the average weight of the canes (PM).

The projection of sugar cane varieties in the factorial plan reveals three groups of individuals:

- the group consisting of the varieties M 1176/77, M 2238/89 and Co 997,

- the group of control varieties SP 711406 and R 570

- the group of variety KnH 80412.

This discrimination shows that the varieties M 1176/77, M 2238/89 and Co 997 have similar agro-technological qualities and yields which differ from those of the control varieties SP 711406 and R 570 and the variety KnH 80412 in the first cycle of cultivation of regrowths.

Over the two years of the test, the PCA shows that F1 (Fact1) and F2 (Fact2) alone explain 78.29% of the dispersion of sugar cane varieties (figure 5).

Factor 1 which contributes to 59.10% of the total variance of individuals is positively correlated with all parameters except lifting with which it is negatively correlated. While factor 2 which contributes to 19.19% of this variability is positively correlated with the parameters flowering, elongation, ENA, average length, average weight, fiber and brix. The ACP individual dispersal plan for this trial therefore highlights three groups of varieties:

- the varieties constituting the first group are characterized by moderately good agro-technological qualities, but are very resistant to the stem borer;

- the varieties of the second group are very sensitive to the stem borer, with average yields and technological qualities;

- variety B 98653 of the third group is characterized by poor agronomic yield and technological qualities. From a phytosanitary point of view, it is tolerant to the stem borer.

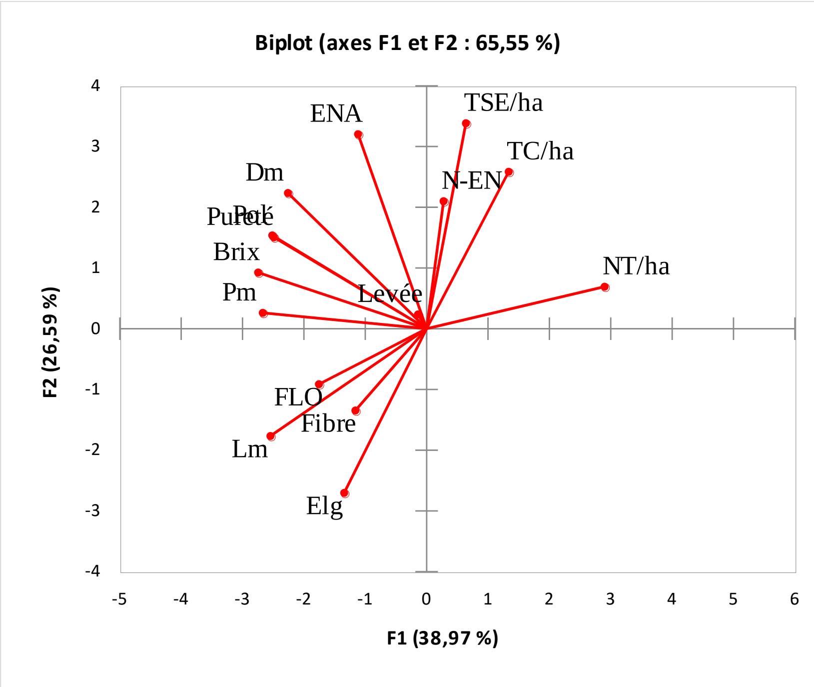


Figure 3. Projection of agro-technological parameters of virgin sugar cane varieties (V) in the plane formed by factorial axes 1 and 2

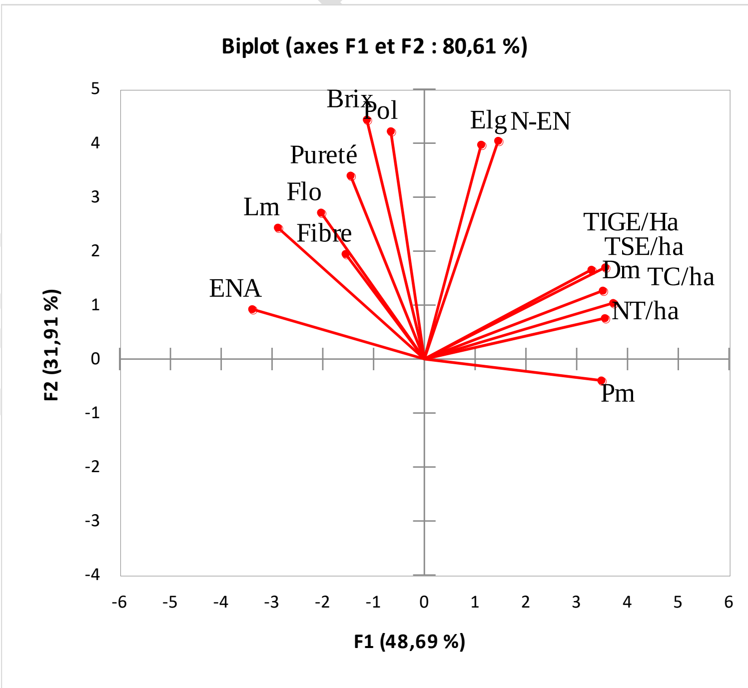


Figure 4. Projection of agro-technological parameters of sugar cane varieties in regrowth 1 (R1) in the plane formed by factorial axes 1 and 2

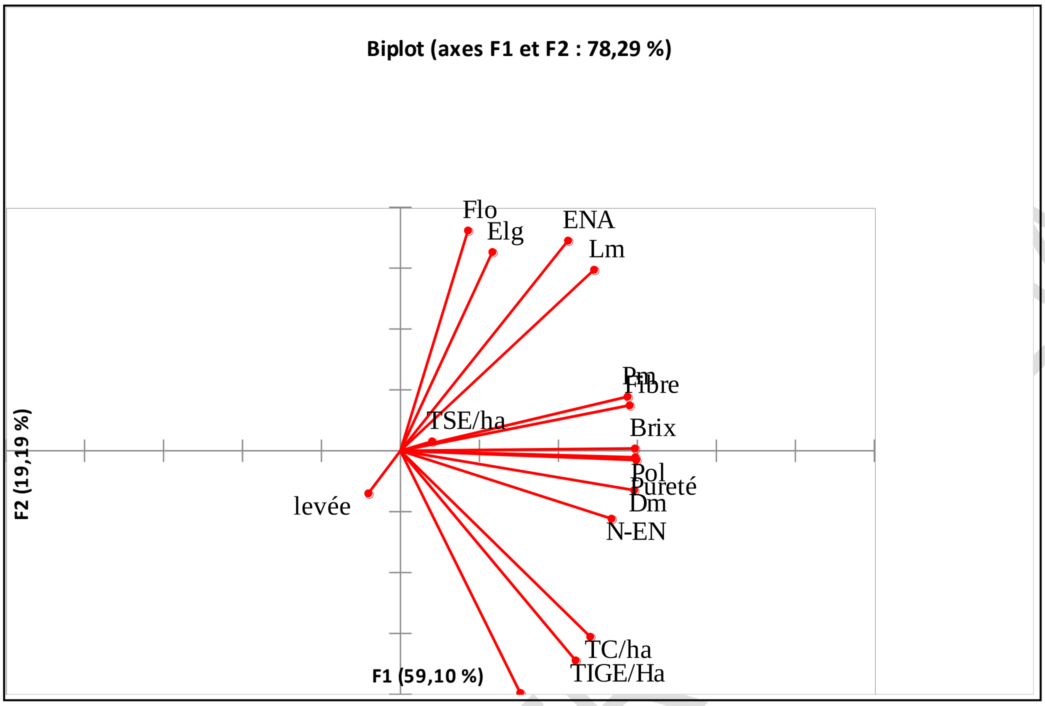


Figure 5. Projection of agro-technological parameters of sugarcane varieties in virgin + regrowth 1 (V+R1) in the plane formed by factorial axes 1 and 2

4. DISCUSSION

The analysis of the results obtained during this experiment made it possible to determine the agro-technological and phytosanitary characteristics of different varieties of sugar cane under rainfed conditions in the Ferkessédougou area.

During vegetation, the controls (SP711406 and R570) showed the best growth during the virgin crop cycle. However, in the first cycle of regrowth cultivation (R1) there was a drop in growth in these two controls compared to the varieties M 1176/77, M 2238/89, and Co 997 which presented better growth in the first cycle of regrowth. regrowth cultivation. The variety B 98653, which during the virgin cultivation cycle showed good growth, did not resist drought in the first cycle of regrowth cultivation (R1) and a few months after harvest it ended up dying. This variety is not suitable for growing sugar cane in rainfed conditions. This study showed that the varieties M 1176/77, M 2238/89, and Co 997 showed better growth than the control varieties SP711406 and R570. However, the KnH 80412 variety proved to be equivalent to the controls SP711406 and R570 which are fairly well cultivated in rainfed conditions in both industrial and village plantations [7].

At the end of the 2-year selection cycle, the Co 997 variety significantly outperforms the controls and the other varieties in its extractable sugar yield which is 5.9 tonnes/ha. This variety is the richest in sugar and has the best cane yield of 60.5 tc/ha. It has good tillering with 105,726 stems/ha as average yields achieved over two consecutive harvest cycles.

Concerning the varieties M 1176/77 and M 2238/89, their extractable sugar content is slightly higher than that of the controls with respectively 5.3 t.s.e/ha and 5.2 t.s.e/ha while their cane yield is significantly higher than that of the controls with respectively 52 tc/ha and 53 tc/ha. These two varieties also have ood tillering compared to the controls with 76907.5 t/ha for the variety M 1176/77 and 80796 t/ha for the variety M 2238/89. These results can be compared to those obtained by [6].

Regrowth resistance being the ability of a variety to maintain its production potential for as long as possible, these good performances obtained therefore suggest good regrowth resistance of these three varieties tested [6].. In fact, from one cycle to the next, they were able to maintain their production of cane and extractable sugar while the control varieties SP711406 and R570 recorded a considerable drop for the parameters studied. These three varieties are also distinguished by a low leaf area index which is one of the relevant criteria for varietal drought tolerance [10,11,12,13] because it turns out that the best varieties adapted to the conditions have a low leaf area index, hence the need to plant them in twin rows in order to promote rapid soil coverage and thus contribute to the control of grass cover at lower cost . This is, along with rainwater, soil depth and fertilizers, the first factors limiting yields in rainfed sugar cane cultivation in the context of Ferké, marked by the poverty of the soil in organic matter [14].

The Co 997 variety has proven to be very resistant to the major sugar cane pest *Eldana. saccharina*, compared to the best control R570.

As for the KnH 80412 variety, although it has vegetation behavior equivalent to that of the controls, it has a cane yield and an extractable sugar content significantly lower than those of the controls with 40.5 tc/ha and 3.85 t.s.e/ha .

These promising results obtained with these three varieties tested (Co 997, M 1176/77 and M 2238/89) make it possible to envisage the improvement of agricultural productivity in rainfed sugar cane cultivation by the selection of varieties adapted to this type. of exploitation in order to make it economically viable for village producers and meeting the requirements of industrialists.

5. CONCLUSION AND PERSPECTIVES

At the end of this study, the objective of which was to contribute to the improvement of sugar cane production through the selection of five varieties of sugar cane for their agronomic, technological and phytosanitary performances in rainfed conditions, we can say that the evaluation of the five (5) varieties (Co 997, B 98653, M 1176/77, M 2238/89 and KnH 80412) introduced in the north of Côte d'Ivoire precisely in Ferkessédougou was a success. This evaluation made it possible to characterize these varieties in rainfed conditions and to be able to determine the most efficient varieties. The choice of varieties is made taking into account the cane yield ($Tc.ha^{-1}$), and sugar yield ($T.S.E.ha^{-1}$), the percentage of Brix (% Brix) and the percentage of internodes attacked (% ENA). Thus, according to these characteristics, the varieties which showed promise are Co 977, M 1176/77 and M 2238/89. They can therefore replace obsolete varieties that have become too sensitive to the major enemies of sugar cane in village cultivation in the Ferkessédougou region.

One of the beneficial effects of growing sugarcane is being able to grow more than one regrowth crop. Therefore, it would be interesting to follow the performance of these varieties in second growth cultivation.

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