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Screening of sugarcane new varieties for agro-technological characters and resistance to *Eldana saccharina* W in Burkina Faso

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Abstract

Burkinabè sugar industry has a low production level, capped at 30,000 tones. The aim of this study was to investigate new sugarcane varieties for agro-technological performance and susceptibility to *Eldana saccharina*. Experimentation was carried out following a Fischer block design with six replications. A total of 14 varieties were evaluated, including 5 check varietiesand 09 new varieties. Data were collected to assess agronomic traits (stem diameter, stem length, flowering to maturity rate, cane and sugar yields), technological traits (brix, purity rate, fiber rate and extractable sugar) and the rate of internodes attacked by *Eldana saccharina*. The new variety BR04005 recorded a flowering to maturity rate of 38.83%. As for susceptibility to*Eldana saccharina,* the check variety CO997 recorded a low attack rate of 1.94%, followed by new variety BR04005 with 2.72%. In terms of technological quality, the new R580 variety achieved the best Brix levels at 23.06%, juice purity at 91.67%, extractable sugar at 14.36% and fiber content at 12.27%. This variety can be used to increase sugarcane production.

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Introduction

Sugar cane is a tropical and subtropical herbaceous sacchariferous plant of *Saccharum* genus belonging to Poaceae family. It is one of the few grasses cultivated for its stalk (Debibakas, 2012). It plays a key economic role as the world's main source of sugar and alcohol production (Thiago *et al.*, 2011). Global production is estimated at 1.1 billion tones. Brazil is world's leading producer of cane sugar, accounting for 62% of global production, with some 715,659,212 tones. In Africa, South Africa ranks first with over 17,991,000 tones, followed by Egypt with 12,360,553 tones (FAO, 2021). In Burkina Faso, sugar cane is produced by the Nouvelle Société Sucrière de la Comoé (SN-SOSUCO), which covers an area of 10,000 ha in Cascades region. Since 1965, SN-SOSUCO has been intensively growing sugarcane on around 5,000 ha under rain-fed irrigation.

The company produces an average of 270,000 tons of cane and 29,000 tons of sugar per year (SN-SOSUCO, 2022). This production represents around 20% of the national annual sugar requirement, which was 135,000 tons in 2012 (OIS, 2013).

Despite economic and industrial importance of sugarcane, its cultivation is subject to numerous biotic and abiotic constraints that can lead to the abandonment and disappearance of certain cultivars (Bradshaw, 2010). The crop is affected by several diseases and pests, causing significant yield losses for growers. Over 120 diseases have been recorded on sugarcane, 66 of which cause significant damage to the crop (Root *et al.,* 2000). Among these diseases, smut is one of main destructive diseases in climatic zones with long dry seasons (Wada *et al,* 2001).

As far as pests are concerned, stem borers are the main culprits, with highly variable yield losses. In Asia and Africa, *Eldana saccharina* is one of most damaging Lepidoptera on sugarcane. It causes significant sugar losses by attacking mature sugarcane plants (Yoseph *et al.,* 2008). Sugar losses caused by this pest are estimated at 40% to 70% of the rate of internodes attacked by the borer (Betbeder-Matibet, 1985).

Sugar cane disease and pest control can be summed up as the use of resistant varieties and plants production of good sanitary quality for planting (Walker, 1971; Flynn and Anderlini, 1990). On Banfora sugar estate, cane varieties such as R570, CO997 and R579 were introduced in 1981, 1982 and 1995 respectively. These varieties alone account for three quarters of SN-SOSUCO's cane acreage, with 80% of the total area. Their average cane yields are relatively low. To cope with the lower productivity of sugarcane in Burkina Faso, new cultivars are necessary. In this way, Burkinabe sugar industry could avoid being sidelined by the genetic progress underway in other countries, where new improved varieties have already been deployed (Domaingue *et al.*, 2008). This is the background to our study, which focused on evaluation of new sugarcane varieties for their agronomic performance and resistance to *Eldana saccharina*. The general objective of this study was to investigate new sugarcane varieties for their agro-technological performance and their behavior towards the insect pest *Eldana saccharina*. Specifically, the aim was to (i) evaluate the behavior of different sugarcane varieties for *Eldana saccharina* resistance, (ii) identify varieties with the best agro-technological characteristics and (iii) identify promising varieties on the basis of cane and sugar yield.

Materials and methods

Study site

Our study was carried out within SN-SOSUCO sugar perimeter located in the south-west of Burkina Faso in the Cascades region. It covers an area of 10,000 ha, of which only 5,000 ha are cultivated with sugarcane due to the site's rather uneven topography and the high proportion of marshy soils. Average altitude on the perimeter is 270 m, located between 10°40 and 10°50 latitude North and 4°35 to 4°40 longitude West (Tou, 2018).

Plant material

The plant material consisted of three-eyed cuttings of 14 sugarcane varieties, including 9 new varieties and 05 control varieties (Table 1).

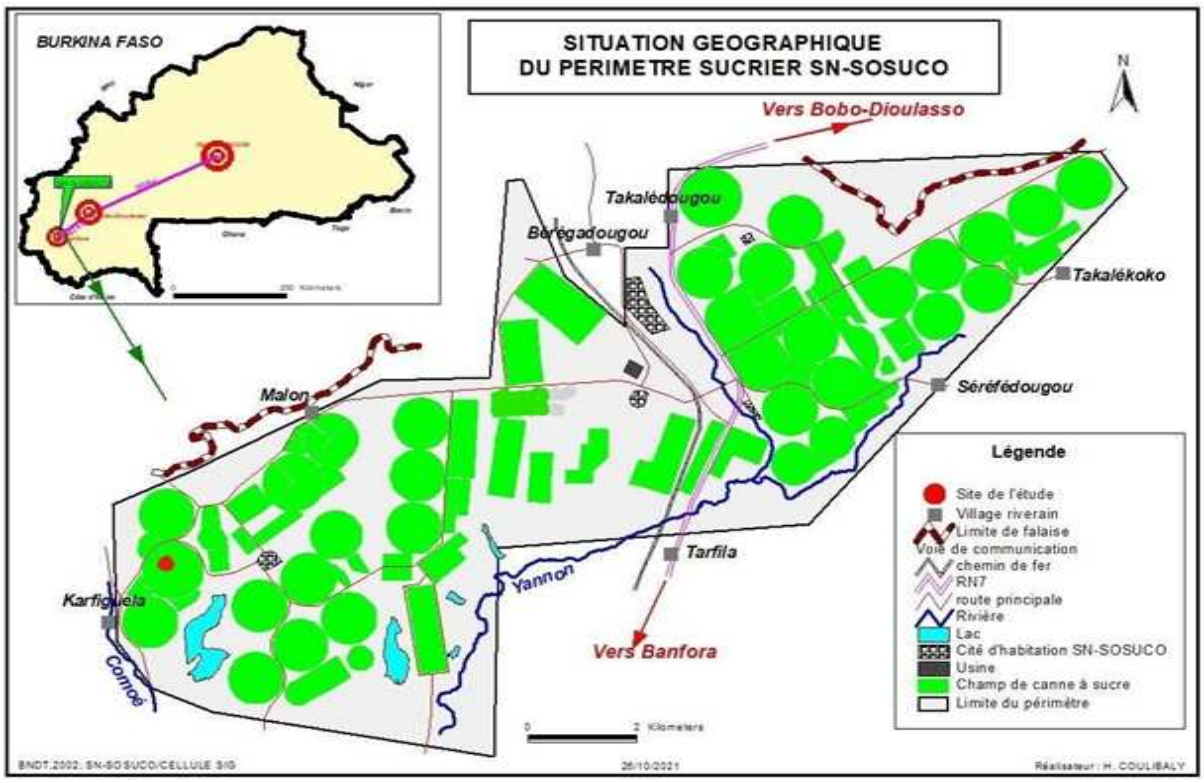

Fig. 1. Geographical location of Banfora sugar perimeter.

Method

Experiments

The experimental set-up used was a completely randomized Fischer block with 6 replicates. Factor studied was the sugarcane variety. Each replication comprised 14elementary plots corresponding to each variety. Each elementary plot consisted of 6 cane rows 12.82 m long with 1.3 m between rows, i.e. 100 m².

The spacing between the individual plots was 2.5 m, forming the rows. The useful plot consisted of 4 central rows, each 12.82 m long (66.66 m²). The total trial area was 9920.66 m², or 0.99 ha.

The experiment was conducted and maintained according to requirements of sugarcane production.

Parameters assessed

Plant length and diameter

Measured from 4ème to 10ème months of age on a sample of 10variable canes tagged with a blue collar on the two central lines of the elementary plot. Lengthwas measured between a stake planted on the ground serving as base 0 and the last visible node of selected stem. Diameter was measured on the second node from the base ofstem, using a caliper.

Flowering to maturity

This consisted in counting the number of sugar canes flowering on the plot and bringing it to 100. The flowering percentage was used to classify varieties according to their crop cycle.

Brix

Rate of dissolved dry matter in the juice of a sample of 10 canes per variety, measuredusing a refractometer.

Cane fiber content (%F)

This is the rate of fibrous matter obtained by weighing the cake obtained after pressing the juice at 100 bar, in relation to the weight of sample; determined after pressing a 500 g sample of cane pulp using a hydraulic press.

Purity of cane juice (Pu)

Which is the percentage of Pol (sucrose) in Brix (dry matter) or the weight of sugar (in%) contained in 100g of a product's dry matter. This rate of sucrose in

dissolved dry matter is determined according to the formula Pol% / Brix. Pol % being thesucrose content of the cane;

$$Pu = \frac{POL\%C}{Brix} \times 100$$

Extractable sugar content (SE%)

Fraction of sugar that can theoretically be extracted from cane.

Cane yield (TC/ha)

This is the weight of cane harvested in each elementary plot, per hectare.

Extractable sugar yield (TSE/ha)

Based on the cane yield and the extractable sugar percentage, the quantity of sugar that can be extracted from the cane is calculated as follows:

$$TSE.ha^{-1} \frac{SE\% \times TC.ha^{-1}}{100}$$

Impact of Eldana saccharina attack on sugarcane varieties (ENA%)

The rate of attacked internodes was determined on a sample of 30 canes from ch treatment. These canes were cut longitudinally and the internodes observed for possible attack by *Eldana saccharina*, an insect borer of sugarcane stalks. The number of attacked internodes was related to the total number of internodes to calculate the attack rate (ENA%) as

follows:

$$ENA\% = \frac{? \text{ (attacked internodes of 30 sugarcane plants)}}{? \text{ (total number of internodes of 30 sugarcane plants)}} \times 100$$

Data analysis

Data were entered using Microsoft Excel 2019. Analysis of variance followed by means comparison using TUKEY test at the 5% threshold was performed using XLStat 2023 software.

Hierarchical ascending classification (HAC) using Ward's aggregation method based on the means of quantitative traits was performed with the same software.

Results and discussion

Results

Average stem diameter and length

Results of analysis of variance for stem diameter and length of the different sugarcane varieties are presented in Table 2.

Table 1. Characteristics of the new varieties tested.

Variétés	Origine	Cycle
PR1007 (témoin)	1977	Début
CO997 (témoin)	1982	Fin
R570 (témoin)	1981	Milieu
CR87339 (témoin)	1999	Début
R579 (témoin)	1995	Milieu
R580	eRcane	Début
		Milieu-Fin
ECU01	CINCAE	Début
		Milieu-Fin
BR04005	Romana	Début
		Milieu-Fin
FG05414	Cirad	Début
R97/2225	eRcane	Début
		Milieu-Fin
R97/0391	eRcane	Début
		Milieu-Fin
R95/2087	eRcane	Début
		Milieu-Fin
R95/2202	eRcane	Milieu-Fin
R95/4216	eRcane	Début
		Milieu-Fin

The analysis shows a highly significant difference ($p < 0.0001$) between varieties for both traits. The check variety CR87339 recorded the highest mean diameter (27.67 mm), followed by R580 with 25.66 mm. The lowestmean diameter was obtained with check variety CO997 at 19 mm. Average stem length ranged from 316.83 cm to 234.5 cm, obtained respectively by varieties R95/4216 and R95/2202.

Table 2. Results of analysis of variance for mean diameter and mean length of sugarcane stalks.

N° Varieties	Stem diameter (mm)	Stem length (cm)
BR04005	25.5 abcd	262.5 bcd
R580	25.67 abc	261.17 bcd
R97/2225	21,83 f	265.83 bcd
FG05414	23 def	282.17 abc
R97/0391	22.83 ef	294.67 ab
CR87339	27,67 a	285 abc
R95/4216	21,67 f	316,83 a
R95/2087	24.83 bcde	286 abc
CO997	19 g	259.33 bcd
ECU01	23.5 cdef	294.17 ab
R570	25.17 abcde	292.33 ab
R579	27.33 ab	252.5 cd
R95/2202	23.33 cdef	234,5 d
PR1007	21.33 fg	265.17 bcd
Average	23,76	275,15
C.V	11,06	9,85
Probability	<0,0001***	<0,0001***

*** *: very highly significant;* C.V=coefficient *of variation*; mm =*millimeter;* cm=centimeter.

Flowering to maturity

Results of analysis of variance of rate flowering at maturity varieties are shown in Table 3. These results show that there is a highly significant difference ($p<0.0001$) between the different varieties. The highest flowering rates were obtained by BR04005 varieties, followed by CR87339 and PR1007 ranging from 26 to50%.

These varieties scored 3, and were classified as early-mid harvest varieties. The new varieties ECU01, R97/2225, R95/4216 and the check R570 recorded intermediate flowering rates of between 11 and 25%, corresponding to grade 2, and were classified as mid-crop varieties. Varieties R97/0391, FG05414, R580, R95/2087 and check CO997 obtained a score of 1 with a flowering rate between 1 and 10% and were classified as mid-late season varieties. Check variety R579 and the new variety R95/2202 recorded low flowering rates (<1%) corresponding to score 0 and were considered as late season varieties.

Analysis of cane and extractable sugar yields per hectare

The results for average yields of cane and extractable sugar are shown in Table 4. Analysis of variance shows a highly significant difference ($p<0.0001$) between the different varieties.

The highest cane yields per hectare were obtained by the varieties R95/4216, FG05414, the CO997 control, R97/0391, R580 and BR04005, with respective cane tonnages per hectare of 110.03; 104.84; 99.45; 98.89; 98.43 and 95.44 t/ha.

In terms of extractable sugar yield, the highest yields were obtained by the varieties R580, FG05414, the CO997 control, R95/4216, R97/0391 and BR04005, with respective sugar tonnages of 14.14; 13.02; 12.91; 12.83; 12.66 and 12.6 t/ha.

Table 3. Rate of flowering at maturity.

Varieties	%Flowering	Score	Cycle
BR04005	38,83 a	3	midearly
CR87339	34.83 ab	3	midearly
PR1007	25.83 abc	3	midearly
ECU01	19 bcd	2	Mid
R95/4216	14.5 cde	2	Mid
R97/2225	12.67 cde	2	Mid
R570	11.17 cde	2	Mid
R97/0391	8.33 of	1	Midlate
FG05414	6.33 of	1	Midlate
R580	3.3 of	1	Midlate
R95/2087	2.33 of	1	Midlate
CO997	1,17 e	1	Midlate
R579	0,5 e	0	Late
R95/2202	0,17 e	0	Late
Average	12,79	-	-
C.V	65,63	-	-
Probability	<0,0001***	-	-

***: *very highly significant;* **C.**V=coefficient *of variation*; %Flowering=percentage *of flowering*.

Resistance of sugarcane varieties to Eldana saccharina

Results of analysis of variance of sugarcane varieties resistance to *Eldana saccharina* stalk borers are presented in Table 5. The analysis shows that there is a highly significant difference between the different varieties ($p<0.0001$). Varieties have been classified into three orders according to the extent of attack: the first order is made up of varieties with an attack rate of over 10%. This order includes the check variety R570 and the new variety R95/2087. The second order is made up of varieties with attack rates above 5% threshold but below 10%. This order is made up of moderately-susceptible varieties and includes check varieties CR87339 and R579 and the new varieties R95/4216 and R580. The lest order is characterized by a low attack rate below the 5% nuisance threshold. It is characterized by resistant varieties and includes R97/0391, FG05414, R97/2225, 95/2202, ECU01, BR04005 and check varieties CO997 and PR1007.

Table 4. Yield analysis results for different varieties.

Varieties	Yields	
	TC (t/ha)	TSE (t/ha)
R580	98.43 ab	14,14 a
ECU01	87.04 abc	11.80 abcd
BR04005	95.44 abc	12.6 abc
CO997	99.45 ab	12.91 ab
PR1007	71.77 c	9,14 d
R95/2202	71.57 c	9.34 cd
R97/2225	89.52 abc	11.21 abcd
R97/0391	98.89 ab	12.66 ab
FG05414	104.84 ab	13.02 ab
CR87339	84.91 bc	10.38 bcd
R579	82.74 bc	9.92 bcd
R95/4216	110,03 a	12.82 ab
R95/2087	88.51 abc	10.54 bcd
R570	87.86 abc	10.64 bcd
Average	90.78	11.51
C.V	17.04	18.41
Probability	<0.0001***	<0.0001***

***: *very highly significant;* C.V=coefficient *of variation*; TC(t/ha)= yield of *cane per hectare;* TSE(t/ha)= yield *extractable sugar per hectare.*

Analysis of technological qualities

Analysis of variance for technological qualities traits are presented in Table 6. The analysis shows a highly significant difference ($p<0.0001$) betweenvarieties for all technological quality's traits. New variety R580 performed best in terms of Brix (23.06%), purity (91.67%), sugar content (15.20%) and extractable sugar content (14.36%), followed by ECU01, with Brix at 22.45%, purity at 90.77%, sugar content in cane at 14.52% and extractable sugar at 13.59% respectively. The lowest fiber content in cane was 11.67% obtained with check variety R579, followed by new varieties R95/2202 and R580, which recorded 11.75 and 12.27% fiber content in cane respectively.

Table 5. Classification of varieties according to the percentage of internodes attacked.

Varieties	ENA%
R570	13,41 a
R95/2087	10.61 ab
CR87339	8.74 abc
R95/4216	6.72 bcd
R580	5.69 bcd
R579	5.11 cd
R97/0391	4.64 cd
FG05414	4.23 cd
PR1007	4.05 cd
R97/2225	4.04 cd
95/2202	3.98 cd
ECU01	3.46 cd
BR04005	2,72 d
CO997	1,94 d
Average	5.68
C.V	70.064
Probability	<0.0001***

***: *very highly significant;* C.V=coefficient *of variation*; ENA%= rate of *internodes attacked by Eldana saccharina*

Classification of varieties according to agro-technological characteristics and resistance to Eldana saccharina

Hierarchical ascending classification (HAC) carried out on basis of quantitative variables enabled us to group the varieties into 02 major distinct groups (Figure 6).

Group 1 comprised nine (09) varieties divided into three subgroups. The first subgroup was essentially made up of three varieties (R580, FG05414 and BR04005) characterized by very good technological qualities traits, high cane yields and sugar content, and an average rate of internodes attacked by *Eldana saccharina*. The second subgroup was made up of four varieties (R95/2202, R579, R97/2087 and PR1007) characterized by average technological qualities, low cane yields and sugar content, and a fairly high rate of internodes attacked by *Eldana saccharina*. The third subgroup was made up of two varieties (R97/2225 and CO997) characterized by average technological qualities, very high cane yields and sugar content, and a low rate of internodes attacked by *Eldana saccharina*.

Group 2 comprised five (05) varieties divided into two (02) subgroups. The first subgroup wasmade up of two new varieties (R95/4216 and R97/0391) characterized by average technological qualities, good yields and a low rate of internodes attacked by *Eldana saccharina*. The second subgroup is made up of two control varieties (R570 and CR87339) and a one new

variety (ECU01) characterized by low technological qualities, low yields and a high rate of internodes attacked by *Eldana saccharina*.

Discussion

A high degree of variation was noted in stem diameter and length. This could be due, on one hand, to the favorable hydric growing conditions and, on the other, to genotypic diversity of varieties. These findings are in accordance with those of Péné and Déa, (2000) and Péné *et al,* (2012) in their studies which indicated that varietal selection appears to be an essential component in increasing sugarcane productivity in same way as irrigation.

Table 6. Results of the analysis of the technological qualities of the different varieties.

Varieties	Technological qualities				
	Brix	Purity	%F	S%C	SE%
V6 R580	23,06 a	91,67 a	12.27 bcd	15,20 a	14,36 a
ECU01	22.45 ab	90.77 ab	12,817 bc	14.52 ab	13.59 ab
BR04005	22.15 abc	90.77 ab	14,15 a	14.09 bc	13.22 abc
CO997	21.87 abcd	90.62 ab	14,27 a	13.86 bcd	12.98 bcd
PR1007	21.47 bcde	89.57 abcd	12.73 bcd	13.74 bcde	12.76 bcde
R95/2202	21.39 bcde	90.35 abc	11.75 cd	13.99 bcd	13.08 cde
R97/2225	21.22 bcde	88.92 bcd	12.45 bcd	13.53 bcde	12.5 bcde
R97/0391	21.18 bcde	90.43 abc	12.47 bcd	13.69 bcde	12.80 bcde
FG05414	21.13 bcde	87,22 d	12.43 bcd	13.46 bcde	12.41 cde
CR87339	20.92 cde	88.78 bcd	12,88 b	13.26 cde	12.24 cde
R579	20.73 cde	87,48 d	11,67 d	13.11 cde	11.96 of
R95/4216	20.71 of	87.77 cd	14,33 a	12,72 e	11,65 e
R95/2087	20.58 of	88.67 bcd	13.35 ab	12.93 of	11.92 of
R570	20,23 e	89.65 abcd	12.31 bcd	13.03 cde	12.11 cde
Average	21,36	89,48	12,85	13,65	12,68
C.V	4,75	2,06	7,8	5,97	6,99
Probability	<0,0001***	<0,0001***	<0,0001***	<0,0001***	<0,0001***

****: very highly significant; C.V=coefficient of variation; %F = percentage of cane fiber; S%C=percentage of cane sugar; SE%=percentage of cane extractable sugar.*

Our results show that flowering of sugarcane varieties tested varies from variety to variety. Based on flowering dates, we were able to classify the varieties tested as early-mid season, mid-season and mid-late season. Our results are in accordance with those of Farias, (1987) and Castro, (2001) who have shown in their study that sugarcane flowering is intrinsic to variety but also controlled by photoperiod, temperature, humidity and solar radiation. However, from an agro-industrial point of view, sugarcane flowering is undesirable because it drastically halts stalk development (Steduto *et al*., 2012). Results of analysis of variance showed a highly significant difference between varieties IN terms of technological quality, cane yield and sugar content. New variety R580 obtained best technological qualities with a low fiber content of 12.27%, good cane yield (98.43t/ha) and sugar yield (14.14t/ha). These results are in accordance with those of Tech (2015), who had shown that this variety is very productive with high cane and sugar yields. As such, it could be adopted by SN-SOSUCO to raise its production level. New variety ECU01 recorded average technological qualities, with a yield of 87.04t/ha. These results are similar to those of Péné and Béhou (in 2019) in Côte d'Ivoire, with exception of yield. However, we note a difference in

yield between varieties evaluated in general. On the one hand, these yield differences could be due to interaction between genetic potential of variety and environment (Péné *et al.*, 2019). On the other hand, the yield of ECU01 variety depends on soil type and fertilization formula (Salazar *et al.,* 2010). The new varieties R95/4216, FG05414, R97/0391, BR04005 and R580 were best performers in terms of sugar yield during this first year of selection. Results of analysis of variance of resistance to *Eldana saccharina* showed a highly significant difference. The results showed that varieties react differently to stem borer attacks. The extent of attacks is thought to be largely linked to the intrinsic resistance of varieties to the pest (Kouamé *et al.,* 2010). Varieties R570 (check) and R95/2087 recorded highest susceptibility rates of over 10%, followed by CR87339 (ccheck), R95/4216, R580 and R579 with susceptibility rates of over 5%. These rates are well above the tolerance threshold of 5%. This could be explained by their low fiber content, ranging from 12 to 13% (Kouamé *et al.,* 2010).

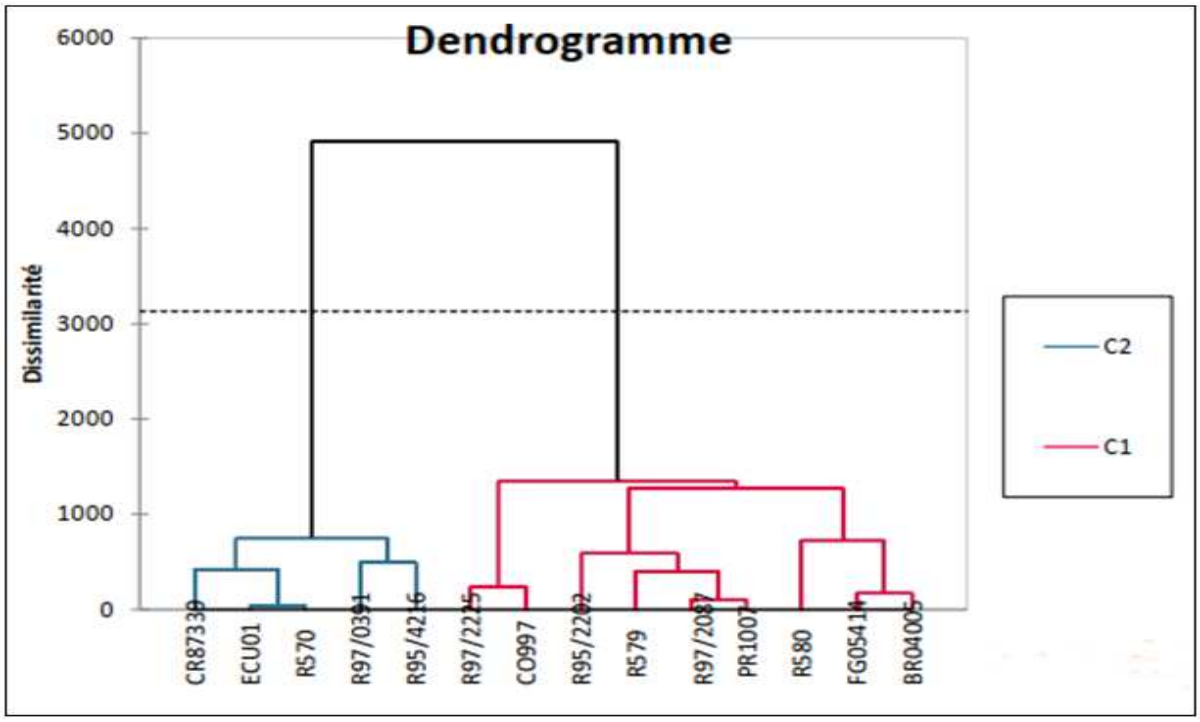

Fig. 1. Dendrogram showing the grouping by class of sugarcane varieties studied.

The high stem borer infestations observed on some varieties would be linked to nitrogen applications (46% N at 140kg/ha) beyond the optimum 100kg/ha.

These results are in accordance with those of Péné *et al,* (2016), who indicated that nitrogen application beyond 100kg/ha would cause a sharp increase in stem borer attacks, as nitrogen is a factor in the development of sugarcane borer larvae. New variety BR04005 and the check CO997 recorded a low susceptibility rate to *Eldana saccharina* stem borers of less than 3%. This could be explained by their high fiber content of 14%, which makes it difficult for the borer to perforate the stalks(Keeping *et al.*, 2009).

Conclusion

The aim of this study was to contribute to improving sugarcane productivity in Burkina Faso, by evaluating agronomic performance of new sugarcane varieties. The aim was to diversify the varietal range by introducing new varieties after subjecting them to a selection process that took into account both their resistance to *E. saccharina* and agronomical traits required to meet the production challenge. From an agronomic point of view, new varieties showed better results compared with checks. Varieties R580, FG05414, R95/2202 and R97/2087 had a flowering rate of between 1 and 10% and were classified as late varieties (end of season). BR04005 was an early

variety, with a flowering rate ranging from 26 to 50%. All varieties studied showed varying susceptibility to *E. saccharina* stem borers. Variety CO997 performed very well against stem borers, with an attack rate of 1.94%, followed by BR04005 with an attack rate of 2.72%.

In terms of technological quality, R580 showed good comparative qualities, with a sugar content of 15.20% and a fiber content of 12.27%. It is a variety with high sugar production potential. New varieties R95/4216, BR04005 and the CO997 control also recorded quite appreciable fiber contents of around 14%, and could be used for energy production in addition to sugar. Overall, cane yields exceeded 70t/ha. The varieties R95/4216 and FG05414 recorded highest cane yields of 110.03t/ha and 104.84t/ha respectively, compared with CO997 (check) with a yield of 99.45t/ha. As for sugar yields, new varieties R580 and FG05414 recorded best sugar yields of 14.14t/ha and 13.02t/ha respectively.

In view of the results obtained, we recommend that the trial be repeated over three (03) years of regrowth in accordance with the current selection scheme, in order to draw a reliable conclusion, as the response of different sugarcane varieties may vary in regrowth. Also to assess the incidence of diseases such as smut and leaf scald on these varieties.

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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