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Research Article

New Drought Tolerant Sugarcane Varieties (*Saccharum officinarum*) to be Developed on Ferké Sugar Plantations in Northern Ivory Coast

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Abstract

The study was motivated by lower cane yields observed often on non-irrigated industrial plantations as well as village plantations in Ivory Coast. Its objective was to determine high performing drought tolerant cane varieties. Each of the tree field trials carried out on Ferké 1 as well as Ferké 2 commercial plantations in northern Ivory Coast was set up following a randomized complete block design involving 10 varieties in 6 replications. All experiments were conducted over three consecutive harvest cycles, i.e. a plant crop followed by two ratoons, cane yield and crop tolerance to endemic diseases being the main screening criteria. The performance of varieties M1176/77, M1246/84, M2593/92, M1565/87 and N21 were significantly higher compared to that of control varieties R579 and SP70/1143. Varieties RB80/6043 and SP81/3250 were equivalent to the best control variety, namely R579. Among all seven drought tolerant varieties selected as drought tolerant, the high-yielding ones to undergo pre-commercial tests were M1176/77 and N21 with on average 82 and 85t of cane/ha, respectively, over three consecutive cropping cycles starting from plant cane.

Keywords: Cane yield; Drought tolerance; Disease resistance; Ratooning ability; Green harvesting; Double-row planting

Introduction

Sugar production in Ivory Coast is made from irrigated industrial plantations which cover nearly 25000ha involving four sugar mill plantations located in central and northern parts of the country. Nevertheless, about 1500ha of village plantations under rainfed conditions were set up in early 1980 when the Zuénoula sugar mill was created in central western Ivory Coast where the evapotranspiration seemed to be moderate compared with that of northern sugar mill plantations of Ferké 1&2, and Borotou-Koro. Rainfed plantations have substantially increased on industrial blocks of Ferké sugar mill areas, with about 2500ha reached in 2015-16, due to a rapid degradation or the obsolescence of certain irrigations systems such as full covering sprinkler irrigation, drip irrigation and rolling gun [1-3]. The purpose of village plantation development program in sugarcane which has been started since 1988 in Borotou-Koro sugar mill areas under favorable climate and soil conditions, was to contribute in the reduction sugar production costs in Ivory Coast. That program was eventually extended to the other three Ivorian sugar complexes, both Ferké 1 and 2 sites being included in late 1990. The development of sugarcane village plantations was strengthened by a new dynamic with a land surface extension project implemented by the European Union aiming to promote the Ivorian sugar sector. As far as Ferké 1 and 2 sugar mill plantations were concerned, that project allowed to increase village plantations by 25%, i.e. from 2000ha in 2015 to 2500ha in 2017. Nevertheless, not only industrial plantations under rainfed conditions but also and much more village plantations where technical recommendations used to be hardly followed by growers are facing very lower yields [4-6]. This tends to jeopardize village plantations which contribute by about 10% to sugar production in Ivory Coast. The objective of the study was to determine high performing drought tolerant cane varieties for non-irrigated industrial plantations as well as village plantations in order to increase their economic viability in the Ferké agro-ecology.

Material and Methods

Study site

Each of the three experiments was carried out on a non-irrigated commercial sugarcane plantation. The plantations concerned were B2-09 in Ferké 1, on the one hand, and V4-51 and V4-52 in Ferké 2, on the other hand. Soil type in these plantations, as a sandy-loam feralsol, was marked by a compaction at 70-75 cm depth. That soil texture was predominant on both Ferké 1 and 2 sugar mill plantations. The available soil moisture gave 90mm on average with about 60mm of readily available moisture [4]. Soils were mainly poor in organic matter (1.5% on average) with a pH highly or moderately acidic (5.5-6.5) and a low cation exchange capacity (8meq/100g). Climate of the Ferké-Tafiré region in northern Ivory Coast is tropical dry type with two seasons: one

being dry, from November to April, the other being wet, from May to October. Rainfall pattern is unimodal and centered on August and September which cumulates almost half of the annual amount of 1200mm/ann. Water deficit to be fulfilled by irrigation to meet sugarcane crop water requirements is around 700mm/ann [7]. The dry season is marked by a favorable short period for cane ripening, namely the harmattan which take place from mid-November to late January, with higher daily temperature magnitudes (20 °C) and 30-35% of relative humidity. Biotic constraints of sugarcane in Ivory Coast were related to smut and leaf scald as endemic diseases caused respectively by *Sporiserium scitamineum* and *Xanthomonas albilineans*, on the on hand, and stalk borers *Sesamia calamistis* and *Eldana saccharina W*, on the other hand, which cause damage on young shoots and adult cane stalks respectively [7,8].

Crop material

Three lots of crop material each comprising about 10 sugarcane varieties of diversified origin, were tested over three consecutive years as plant cane followed by two ratoons. Two commercial varieties mostly grown on Ferké sugar mill areas, namely SP70-1143 and R579, were used as check respectively for early and late season trials.

Experimental design

Each of the three experiments was laid out following a randomized complete block design with ten cane varieties as single factor investigated in six replications. A single plot within each experiment comprised 8 cane rows of 10m (120m^2), with 7200m^2 in total. Both selection criteria considered in rainfed sugarcane were cane yield and tolerance to endemic diseases and pests.

Cropping conditions

Sugarcane cuttings were planted manually during the rainy season following simple rows with 1.5m of row spacing. Except for the crop material used, the cropping sequence practiced was the following: glyphosate treatment of stools regarding previous sugarcane crop, organic fertilization based on filter cake (20t/ha) and molasses (8t/ha), soil tillage within previous stools more provided with organic matter practiced after natural drainage of soil following irrigation application or rainfall, furrowing, mechanized fertilization of N-P-K within rows, planting, pre-emergence herbicide treatment, manual weeding at 4-5 months, manual harvesting after cool burning of sugarcane at 16 months in plant cane and 11-12 months in ratoons (Table 1).

Table 1: Dates of planting and harvest depending on lots of varieties tested under rainfed conditions and Ferké sugar mill sites.

Variety Trials and Sites	Planting Dates	Harvest Dates		
		Plant cane	Ratoon 1	Ratoon 2
Lot 1 (Ferké 1)	Aug. 21, 2010	Jan. 09, 2012	Dec. 06, 2012	Nov. 07, 2013
Lot 2 (Ferké 2)	Aug. 23, 2010	Jan. 14, 2012	Jan. 09, 2013	Dec. 06, 2013
Lot 3 (Ferké 2)	Aug. 06, 2011	Jan. 09, 2013	Dec. 06, 2013	Dec. 27, 2014

Agronomic observations during vegetation and at harvest

Smut and leaf scald infections on cane varieties tested were observed at four and half months, while flowering rates were collected in November at early dry season where the photoperiod intensity was maximum. At harvest, five millable cane stalks were sampled within each plot after the counting of all millable cane stalks on two central rows for measurements of morphological traits followed by separate sucrose analyses. Cane stalks from six central rows within each plot (90m^2 net) were separately weighed to determine the cane yield. Thereafter, fifty cane stalks were sampled per plot to determine stem borer damage levels in terms of percentage of internodes bored (INB).

Results

Rainfall patterns

In Ferké 1, 2011 and 2012 were in rainfall deficit over the period of study compared to the 10-year average (2004-2014) and the Nicholson variability index, as opposed to 2013 and 2014 with rainfall excess (Table 2). In Ferké 2, 2011 as a year of rainfall excess with 1537mm in total was followed by a 3-year period of deficit (2012-2014).

Table 2: Rainfall patterns over the period of study in both Ferké sugar mill plantations.

Sugar Mill Plantations	Rainfall Over Study Period (mm)				10-Year Rainfall Average (mm)
	2011	2012	2013	2014	
Ferké 1	1183.5	1288.3	1242.1	1290.4	1228±141
Ferké 2	1536.7	1318.1	1155.2	1158.3	1257±165

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Varieties of lot 1 tested in Ferké 1

Biometrical characteristics

As far as the first lot of varieties were concerned, smut and stalk borer infestations observed in second ratoon were quiet low with 0-20 whips/ha and 0-2.5% INB, respectively. Except for varieties M1334/84, VMC93-341 and VMC95-105, the flowering rate in second ratoon varied from 28 to 67%. The average stalk length regarding varieties SP80-1816 and M2593/92 was higher in second ratoon with 233 and 234cm, respectively.

Agronomic performance at harvest

Varieties M1176/77 and M2593/92 were significantly higher yielding compared to the check, with 82 and 80t/ha i.e. 5 and 2% additional yields, respectively. Their sugar yields and fiber contents were quiet acceptable with about 8 t/ha and 13%, respectively.

Varieties from lot 2 tested in Ferké 2

Biometrical characteristics

As far as varieties from lot 2 were concerned, smut infections observed in second ratoon were lower than the threshold limit of 5000 whips/ha. Stem borer infestations were also lower than the threshold limit of 5% INB. All varieties from this lot flowered moderately (12-24%) in second ratoon. Due to lower rainfall patterns occurred in 2013 with 1155 mm in total compared to 1320mm in 2012, lower cane stalk lengths were observed (105-134cm).

Agronomic performances at harvest

Varieties M1176/77, M1246/84 and M1565/87 were significantly higher yielding than the check with an average yield of 70t/ha, i.e. 23% additional yield. Their sugar yields and fiber contents were quiet acceptable with about 7t/ha and 14-16%, respectively.

Varieties from lot 3 tested in Ferké 2

Biometrical traits

Except for varieties RB73-454 and SP83-2847 with 6500 and 21700 whips/ha, respectively, recorded in second ratoon, smut infection levels were lower than the threshold. Stem borer infestations recorded were similarly lower than 5% INB (threshold). All varieties from this lot flowered poorly (0-15%) in second ratoon. Due to lower rainfall patterns occurred in 2014 and 2013 (1160 compared to 1320mm in 2012), lower cane stalk lengths were observed for all varieties except for variety N21 with 239cm on average. This suggests its good adaptation under rainfed conditions.

Table 3: Means of technological quality traits and yields of tested varieties under rainfed conditions in Ferké 2 (plant cane and two ratoons on aggregate).

Varieties (lot 3)	Technological Quality Traits (%Cane)			Yields	
	Purity	Pol	Fiber	Cane (t/ha)	Sugar (t/ha)
R581	81.1 ab	13.0 b	16.3 c	56.2 b	4.8 a
SP80/3280	82.9 bc	13.3 b	14.2 ab	63.0 c	5.8 b
RB80/6043	83.9 bc	13.5 b	14.5 b	71.6 e	6.7 bc
SP81/3250	81.3 ab	12.9 b	16.1 c	73.2 e	6.2 bc
SP83/2847	84.9 bc	13.7 b	14.6 b	65.4 d	6.2 bc
SP71/1081	85.4 c	14.9 c	16.0 c	58.9 bc	6.1 bc
RB73/454	84.8 bc	13.9 b	14.8 b	51.2 a	5.0 a
N21	78.4 a	12.0 a	15.8 c	85.7 f	6.6 bc
R579 (T)	83.1 bc	13.5 b	13.5 a	75.0 e	7.0 c
Average	82.9	13.4	15.1	66.7	6.1
CV (%)	3.7	6.9	7.5	8	12.3
STD	3.1	0.9	1.1	5.3	0.7
Blocking effect	ns	ns	ns	**	ns
Variety effect	**	**	**	**	**
Year effect	**	**	**	**	**

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Only the variety N21 was significantly higher yielding than the check with 86t/ha on average, i.e. 15% additional yield (Table 3). Two varieties (RB80-6043 and SP81-3250) equivalent to the check gave 72 and 73t/ha respectively. Sugar yields of these varieties were equivalent to that of the check, i.e. 6-7t/ha. The three promising varieties performed significantly higher fiber contents compared to the check with 15.8, 14.5 and 16%, respectively. This could partly explain their moderate sucrose content under rainfed conditions.

Discussion

Cane varieties selected under rainfed conditions

This study showed that varieties M1176/77, M2593/92, M1246/84, M1565/87 and N21 were higher yielding than check varieties SP70-1143 and R579 used. However, varieties RB80/6043 and SP81-3250 were equivalent to the best performing check (R579) which is under cultivation in rainfed conditions not only in industrial plantations but also in village plantations [9]. Among these selected varieties, the best yielding ones were M1176/77 and N21, with 82 and 85t/ha, respectively, as average yields obtained over 3 consecutives cropping seasons (plant cane and two ratoons). These good performances suggest a good ratooning ability of both varieties. They are characterized by a low leaf area index which is among the most relevant criteria for varietal tolerance to drought [10-15]. The above results have motivated the development of varieties M1176/77 and N21 on village plantations since 2012-13 and 2014-15 harvest seasons, respectively. Their smooth development over the coming years should be achieved to the expense of areas under varieties R579 and NCo376. Nursery sanitation proceedures based hot water treatment might keep disease infection levels of M1176/77 below the threshold limits as it is a susceptible variety to smut and leaf scald under rainfed conditions.

Weeding

The above drought tolerant varieties selected presenting a lower LAI, they should be planted in double rows to enhance a rapid soil covering which therefore contributes to weeding at lower cost. That one, together with rainwater, soil depth and fertilizers are the top yield limiting factors in rainfed sugarcane in the context of Ferké where soils are poor in organic matter.

Method of harvest

In contrast of R579, varieties M1176/77, N21 and NCo376 do not have self-defoliating leaves and therefore are less adapted to manual green harvesting. That one, in contrast with burned cane harvesting currently practiced on village plantations in Ivory Coast, allows trash blanketing which enhances soil water conservation and provides organic matter to soil while limiting weeds [16,17]. The selection of self-defoliating varieties adapted to rainfed conditions should promote the adoption of that harvesting practice by farmers on village plantations as it significantly contributes to soil fertility and the reduction of sugar production costs. The new varietal selection project from sugarcane hybrid seeds under way in Ferké sugar mill plantations since November 2014 should allow in the long run the development of varieties truly drought tolerant through a selection process starting much earlier, i.e. at the first advanced two-year screening stage.

Conclusion

The performance of varieties M1176/77, M1246/84, M2593/92, M1565/87 and N21 were significantly higher compared to that of control varieties R579 and SP70/1143. Varieties RB80/6043 and SP81/3250 were equivalent to the best control variety, namely R579. Among all seven drought tolerant varieties, the best-yielding ones to undergo pre-commercial tests were M1176/77 and N21 with on average 82 and 85t of cane/ha, respectively, over three consecutive cropping cycles starting from plant cane.

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