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NOBLE SUGARCANES AND MODERN CULTIVARS IN TAHITI RELATIVE TO ORGANIC RUM PRODUCTION: DESCRIPTION AND KEY CHARACTERISTICS

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ABSTRACT

Since the beginning of the twentieth century, various actions regarding sugarcane improvement were implemented. Researchers and breeders created new varieties for the sugar industry, more resistant to pests and diseases and more productive than noble sugarcanes. Today, modern cultivars are used for both sugar industry and distillery and noble sugarcanes are no more cultivated for this purpose. However, they could be cultivated in some particular contexts such as the organic cultivation, where the production costs are similar for both cane varieties. In Tahiti, a company decided in 2015 to produce organic rum from both noble sugarcanes and modern cultivars. A 2 835 m² experimentation was installed on a machineable land, representative to agriculture requirements. Six noble sugarcanes plus three modern cultivars all found locally (315 m² / variety) were tested. The agronomic yields reached were around 70 tons/ha for the best noble sugarcanes and around 100 tons/ha for the modern cultivars while at small-scale industrial processing, the noble sugarcanes present a greater juice extraction about 10 to 25% more than the modern varieties. In this situation, the organic cultivation of noble sugarcanes could be a valuable improvement regarding the whole agriculture and sugarcane industry in French Polynesia. In the future, we will also study the aromatic contents within the noble sugarcane plants and determine if it can improve the quality of the rum.

Keywords: *Noble sugarcane, sugarcane variety, organic cultivation, French Polynesia, Tahiti.*

INTRODUCTION

Sugarcane (Poaceae family) is considered native to New Guinea between 8 000 to 15 000 before Christ and it is recognized as *Saccharum officinarum* variety groups coming from *Saccharum robustum* (Artschwager & Brandes, 1958). According to these authors, the dispersal was done by human means to proximity islands and it was carried to Tahiti in French Polynesia by Polynesians people during their migrations between 500 and 1 100. At the same time, two groups of natural hybridized canes were observed in India and China as *Saccharum barberi* and *Saccharum sinense*, coming also from New Guinea (D'Hont et al., 2002). During the late 18th century, navigators such as Bougainville, Bligh or Cook contributed to disperse the Otahiti cane variety around the world for the sugar production. It was then worldwide cultivated until the years 1840 to 1890 where it was stopped and replaced by other varieties as the Cheribbon ones (Stevenson, 1965). Both of them were then replaced by the very first new varieties from new research centers in the 1890s because of the crop damages caused by pests and diseases. So the first breeding stations were built in Java, Barbade, Mauritius, Reunion, British Guiana, Queensland and Hawaii (Heinz, 1987). The first commercial intra-specific cross occurred between Otahiti and Cheribbon varieties at the Java station and at the same time, the variety H109 was created with different Otahiti canes (Lahaina) in Hawaii. In 1929, in the Java station, a major turning point was reached with the "nobilization" of some wild species such as *Saccharum spontaneum* crossed with *Saccharum officinarum* to create new varieties (inter-specific) with a new agronomic potential, the POJ 2878 being the first of all. It was the beginning of the expansion of the modern hybrid varieties (contrary to the noble *Saccharum officinarum*) we continue to use nowadays for both sugar and rum industry. For Stevenson (1965) and Heinz (1987), even if the Otahiti cane has never been outstanding as a breeding cane as opposed to the Cheribbon, breeding programs pedigrees show that it is a remote ancestor of POJ 2878 and other famous Javan and Hawaiian hybrids. Such an argument give the Otahiti cane a big interest to produce high value rum but today, in Tahiti, it is very difficult to recognize the varieties, even based on the old bibliography. Cuzent (1860) has made one of the best descriptions of the Tahitian canes but no collection was created and maintained until today (Vitrac *et al*., 2018). Moreover, we didn't found Otahiti canes in the following collection centers: USDA in the United States of America, CIRAD in Montpellier (southern France), CTCS in Guadeloupe (Caribbean's), eRcane (Reunion Island) and HARC (Hawaiian Agricultural Research Center). In 2016, HARC sent us some photos of the Lahaina variety they conserved but without any true identification corresponding to the Tahitian varieties. We decided then to collect study and cultivate them to see: (1) their morphology as nobles or hybrids varieties; (2) their agronomic behavior in terms of sensitivity to bioagressors (weeds, pests and diseases); (3) their industrial potential; and (4) their aromatic potential. The main differences between noble and hybrid sugarcanes of *Saccharum officinarum* being their morphology, yields (biomass and sugar), resistance to bioagressors (Stevenson, 1965) and machinability (Van Dillewijn, 1960). The sugarcane has only been developed from decades regarding sugar production (Fauconnier, 1991). For this reason, the stalks of hybrids are taller, containing a higher sucrose content and they are also thinner with a stronger skin than nobles varieties (Van Dillewijn, 1960). But no aromatic interest has motivated breeders and very few aromatic studies have been published or only in the sense of legislation (Boscolo *et al*., 2000; Cimino Duarte *et al*., 2017). Furthermore, many nonsucrose components like starch, ash, polysaccharides or organic acids are extracted from the canes inside the juice, and the difference in the nonsucrose components are often significantly influenced by the cane variety (Rein, 2017). The organic sugarcane has a strong economic potential in Tahiti and it was decided to establish one distillery in 2015 to produce organic rum. The following questions were then raised: if it is possible to cultivate some Otahiti canes, do they have some special key characteristics which should be valued for the rum industry? Do the hybrid varieties show some particularities? In such a context of a small-scale organic production, expensive hand labor is needed at every stages of the cultivation and transformation process (Vitrac *et al*., 2018). We finally supposed that among noble and hybrid varieties we could find some materials which can fit to biomass production and transformation requirements of such a context.

MATERIAL AND METHODS

Under organic standards, a field of about 1 ha was planted in a machineable context harvesting in private gardens 3,125 tons in 2015. A plot of about 2 835 m² was set up to evaluate seven varieties (315m² each) in 2015, and nine in 2016. Eight varieties were found around the island of Tahiti, and one was located in Taha'a in the same archipelago (Society Islands). The first canes were harvested 12 months later (December 2015) and first ratoon 24 months later (December 2016). A specific design using stripes was organized with one variety per stripe (composed of three rows) perpendicularly to a slope of about 3%. Before planting, original vegetation composed mostly of ferns was cut. Organic fertilization was then applied to correct the desaturated soil by spreading vinasse from the distillery (20t/ha), composted equine manure (5t/ha) and dolomite (2 t/ha). Minimum soil tillage was conducted (15cm deep) before creating furrows. Manual planting was done in paired rows with a distance between the plants of about 50cm and 1,6m (interrows), representing 20 000 cutting stalks / ha. Weed removing was conducted manually in the row and using a 4WD micro-tractor of about 16 horsepower (1,1m width) with a rotative disposer for the inter-row. Yields were estimated on 3 x 100 kg of fresh full hand-harvested canes by stripe, to get a range of data in this agricultural context. These canes were crushed one time (hand feeding three rolls 1t/h crusher), and the amount of juice was weighted for each sample of 100kg (giving us the crushing yield) and also for each whole stripe plot about 315m². We then deducted the production of sugarcane biomass per stripe. Regarding rat control, we counted and weighed the total amount of stalks damaged just after the shooting occurred. Finally, we added the weight of sugarcane produced and the weight of stalks damaged to get the global amount of sugarcane produced per stripe to calculate the total yield in tons/ha. The cultivation calendar for agricultural operations in the years of 2015 and 2016 is shown in table 1.

Table 1. Monthly cultural operations from plantation to the first ratoon.

	jan	feb	march	april	may	june	july	aug	sept	oct	nov
2015	G+H1	G+H1	G+H1		G+H1	R	G+H1		H2+R		H2+S
2016	G+H1		G+H1			B	G+H1 R- B	B	H2+R	H2+S	

G: rotative disposer; R: rat treatment (Brodifacoum 0,005%)
S: straw removing; B: Brix degree during growth
H1: hand hoeing before cane inter-row closure
H2: hand hoeing after cane inter-row closure

Regarding sampling / morphology, 30 canes of each variety were sampled regularly among the stripes one week before harvest in 2015 and 2016. Following UPOV (in french: Union Internationale pour la Protection des Obtentions Végétales) reference (2005), we measured the height (H), the diameter at H/2, the internodes and the tillering. We also measured the Brix degree (at the soil level, H/2 and H) with a portable ATAGO® refractometer. All of these measures being principal components of the aboveground biomass and alcohol amounts. We finally fermented (zymaflores® bio yeast 100 g / 1 000 l; pH = 3,5; 26 – 29 °C) and distillated (100 l pot still copper alambic) the sugarcane juice for each whole 315m² stripe to get the yield in Pure Alcohol hector-Liter (PAhL) / hectare (ha) with no repetition. The maturation and dilution process to get rums at 50° alc/vol. was done in stainless steel tanks as the following: (1) 10 minutes/day of aeration (by pumping and drenching over the rum inside the tank) during 1 month; (2) same aeration and adding of ceramic filtered water (0,1µm) to reduce alc/vol. rate about 5° every two days, 3 times a week. First hedonic sensorial analysis was done by an expert jury.

RESULTS AND DISCUSSION

Among the nine varieties cultivated, aboveground biomass yields ranged from 34,7 to 111,1 ton/ha in 2015, and from 34,9 to 92,8 t/ha in 2016. In the communication "organic sugarcane cultivation in Tahiti" (Vitrac *et al*., 2018) 2 groups were identified based on their yields: the varieties with yields of more than 70 t/ha (3 varieties) and those with less (6 varieties). This result is reinforced regarding Brix degrees and showing the Otahiti canes (the noble *Saccharum officinarum*) to constitute the group with the lower yields and the lower Brix. Moreover, for this group, we observed the highest rat attacks in 2015 while treatments and maintenance of the field was correctly done and also in 2016. It is probably due to the thickness of the cane stalks which might be thinner than those not attacked, which is a characteristic of the noble sugarcanes (Van Dillewijn, 1960). The morphological sampling (Table 2) also showed a lower height, internodes and tillering and a higher diameter for these canes. It is then probable that this sugarcane group is representative to noble varieties. However, we didn't found any information about such measurements to confirm the Otahiti group in the literature (Cuzent, 1860).

Table 2. Morphological characteristics for the nine varieties after plantation and 1st ratoon. *Saccharum officinarum* are: RBV (Rouge à Bandes Vertes); JRP (Jaune à Rayures Pourpres) ; VE (Verte) ; 3C (3 Couleurs) ; PO (Pourpre) ; VBP (Verte à Bandes Pourpres). Modern varieties are : RRV (Rouge à Reflets Verts) ; JR (Jaune Roseau) ; BL (Blanche).

	varieties:		RBV	JRP	VE	3C	PO	VBP	S. off.	RRV	JR	BL	Hyb.
tillering	plant.	av.	5,27	3,03	5,10	6,73	4,07	8,83	4,84	7,07	5,37	13,33	6,22
		s.d.	2,49	1,73	2,14	3,57	2,03	3,21	1,39	4,42	1,69	3,54	1,20
	1st rat.	av.	6,80	2,80	5,00	5,03	4,93		4,91	15,00	7,37		11,18
		s.d.	4,50	1,47	3,09	2,97	3,80		1,42	5,02	3,92		5,40
internode	plant.	av.	7,10	5,89	6,46	5,73	5,10	6,19	6,06	8,56	12,37	10,53	10,46
		s.d.	1,91	1,05	1,30	1,20	1,37	1,43	0,76	1,84	2,52	1,19	2,69
	1st rat.	av.	6,75	7,82	6,44	5,14	5,64		6,36	8,97	9,06		9,02
		s.d.	0,62	0,77	1,28	0,90	1,49		1,04	1,12	1,87		0,07
diameter	plant.	av.	3,44	3,58	2,73	2,83	3,53	2,97	3,22	2,95	2,93	2,76	2,94
		s.d.	0,39	0,29	0,30	0,25	0,34	0,33	0,41	0,23	0,24	0,22	0,02
	1st rat.	av.	3,42	3,61	2,75	2,79	3,22		3,16	2,99	2,61		2,80
		s.d.	0,30	0,42	0,26	0,79	0,36		0,38	0,23	0,23		0,27
height	plant.	av.	1,58	1,88	1,36	1,34	1,13	1,20	1,46	1,94	1,88	1,32	1,91
		s.d.	0,34	0,31	0,21	0,23	0,19	0,32	0,29	0,29	0,29	0,17	0,04
	1st rat.	av.	1,49	1,89	1,21	1,02	1,04		1,33	1,90	1,98		1,94
		s.d.	0,20	0,17	0,32	0,35	0,26		0,37	0,31	0,26		0,05
Brix	plant.	av.	15,76	16,43	14,39	18,26	20,17	19,24	17,00	18,98	19,84	19,61	19,41
		s.d.	1,77	1,24	2,24	1,75	1,57	2,28	2,25	1,27	1,12	1,26	0,61
	1st rat.	av.	15,14	15,42	14,39	18,01	19,82		16,56	20,57	19,53		20,05
		s.d.	2,30	1,35	2,55	2,46	1,72		2,28	0,90	0,88		0,73

av. & s.d. : average and standard deviation relative to 30 canes sampled among each stripe
internode, diameter are in (cm) ; height is in (m) ; Brix is in degree or %age
S. off. & Hyb.: *Saccharum officinarum* and modern Hybrids averages and standard deviat--tion between the varieties. VBP and BL wasn't counted because of their plantation in 2016

Sugarcane has been hybridized to produce more biomass and more sucrose to reach heavy yields in sucrose/ha. Crosses and selections have been made to make the sugarcane cultivars more resistant to diseases (Heinz, 1987) and easier to process (Rein, 2017). It is what we observe for the hybrids in the Table 1: (1) internodes are higher (10,46cm compare to 6,06cm after plantation); (2) diameter are lower (2,94cm vs. 3,22cm). Even if their stalk structure seems to be thicker regarding the low infestation levels by rats (Vitrac *et al.*, 2018), they correspond to sugar industry milling requirements and the fewer internodes they have the higher sucrose amount (Rein, 2017 & Moore, 2014). Finally, we can say that the group with RRV, JR and BL are considered modern varieties even found in Tahiti in 2015 without any information from the immigration or agricultural authorities. The other varieties seem to be pure *Saccharum officinarum* but nothing tells us they correspond to Otahiti canes. The use of molecular markers to compare these nine varieties should definitely allow us to separate these two groups and find or not the Otahiti canes by the introduction of Hawaiian Lahaina DNA from the HARC. Among the modern cultivars described, the JR seems to be the more productive even in cane biomass than in crushing yield and PAhl/ha. But we have to be carefully interpreting such a result because of the 3% of slope included in the plot. What it is interesting is the identification and characterization of two groups we should cultivate and experiment later. If 3C show the highest crushing yield after plantation (Figure 1) and good Brix (Table 2), we understand its attractive effect to rats (Vitrac *et al*., 2018) by the combination of thin skin, high sucrose content and precocity, which is also the case regarding PO and VE. However, in 1st ratoon, all the varieties showed a decrease not only regarding biomass and PAhL/ha and a gap regarding crushing for 3C, VE and PO. We now that no maintenance on the field occurred during 3 months during the grow stage (until June). Also we observed at this period less rains (1330 mm) than in 2015 (2093 mm). Maybe it induced functional biology tissues changes creating a curing of the skin in response of water stress (Lakshmanan & Robinson *In*: Moore, 2014) combined to weeds and rats pressure (Vitrac *et al*., 2018)? Such sensitivity indicated us some important limits for the agricultural use of these noble varieties in such a context, especially regarding 3C, VE and PO.

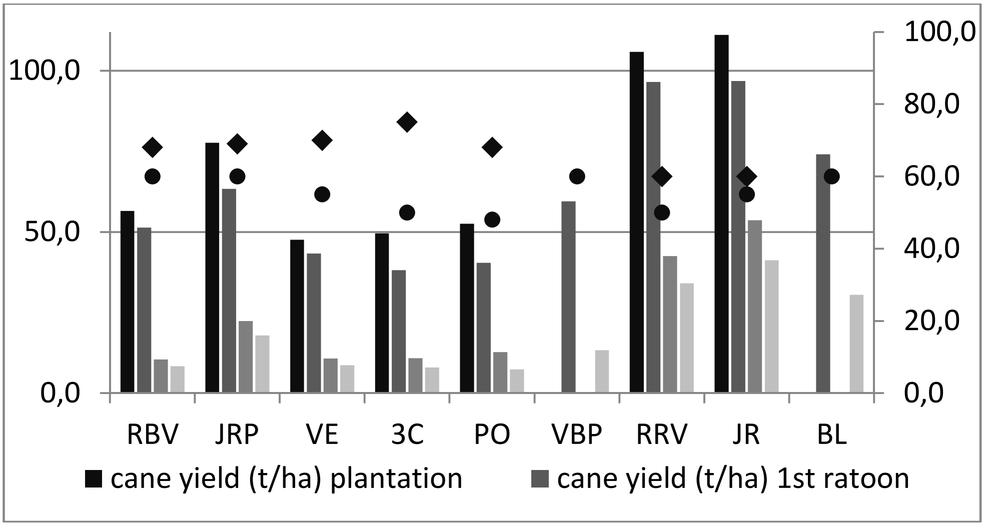

Figure 1. Yield data in cane biomass (t/ha) and Pure Alcohol hecto-Liter (PAhL/ha) (left axis) and crushing milling (%) referred to the axis on the right. All data are representative to the varieties cultivated after plantation and first ratoon.

There are few correlations between the first harvest after plantation and the different ratoons (Paulet & Glaszmann, 1994), the first being generally the most productive (Fauconnier, 1991). It was not the case in our agricultural context. As shown by Jamet (1987), the main cultivable soils are desaturated and ferralitics. But one noble variety, the JRP, showed a good potential for agronomic use with biomass yields of about 70 t/ha and 20 PAhL/ha for rum production. It also had a better crushing capacity (one press crushing) even if its diameter is higher than modern cultivars. It was the same in lesser extent for the RBV. It is thus possible that with innovative agronomic systems and some improved crushing methods, we reach better yields. After distillation (without any repetition), hedonic sensorial analysis gave us neutral results regarding the modern varieties. No acetaldehyde compounds were detected showing the quality of the fermentation process. The noble sugarcanes show a panel of different compounds, especially JRP and RBV with some notes of white truffle (DMS – Dimethyl Sulfide) which are generally observed in winery (Dagan & Schneider, 2013). Among varieties, context, climatic factors, human methods, transformation process and breeding of alcohols, there are too many points to investigate and it is difficult to draw any conclusion about aromatic advantages of noble sugarcanes. However, this study constitutes a first step to search if sugarcanes can be bred not only for sugar production but also for their aromatic qualities.

CONCLUSIONS

We found locally nine different varieties, 3 are modern hybrids cultivars and 6 are noble *Saccharum officinarum* sugarcanes. In our type of soils, the hybrids were productive even under organic standards. The noble canes seem to be very sensitive and difficult to cultivate and no Otahiti cane were found. However, two of them showed a great potential for agricultural purpose associated with aromatic particularities of the processed rum.

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