Available online at www.sciencedirect.com
ScienceDirect
Scientia Horticulturae 113 (2007) 238–243
SCIENTIA HORTICULTURAE
www.elsevier.com/locate/scihorti

Climatic conditions affect the texture and colour of Cavendish bananas (Grande Naine cultivar)

C. Bugaud [a,*], M.O. Daribo [a], C. Dubois [b]

[a] *Centre de Coopération International en Recherche Agronomique pour le Développement (CIRAD), Pôle de Recherche Agro-Environnementale de Martinique, BP 214, 97285 Lamentin Cedex 2, France*
[b] *CIRAD, Avenue Agropolis, 34398 Montpellier Cedex 5, France*

Received 7 November 2006; received in revised form 21 March 2007; accepted 22 March 2007

Abstract

Relationships between natural production conditions (soil and climate) and physical fruit traits (texture and colour) were studied in Martinique to fuel discussions on creating a label for bananas from the French West Indies. Bananas produced at six sites, under very different conditions, during three different periods of the year, were harvested at the same temperature sum and ripened under identical conditions. The peel of green bananas harvested during the hot humid season was not as hard as that of bananas harvested during the cool dry season. In ripe bananas, an increasing correlation was noted between the rainfall level and fruit firmness ($R = 0.88$) and peel hardness ($R = 0.80$). This correlation could explain why bananas produced during the dry season were less firm and, conversely, those produced in highland areas, where rainfall is highest, were firmer. In ripe bananas, a decreasing correlation was also noted between the mean daily temperature and the fruit yellowness ($R = 0.84$). This interaction could be responsible for the yellower colour of mountain banana pulp and of bananas harvested during the coolest seasons. The green life of bananas harvested during the hot humid season was shorter than that of bananas harvested during the dry and intermediate seasons.

Keywords: Musa; Quality; Physical characteristics; Rainfall; Daily temperature; Soil; Green life

1. Introduction

Banana production is one of the main economic resources of the French West Indies (FWI). Considering the high commercial competition from other banana-exporting regions that benefit from lower production costs, the FWI banana industry should offer a new range of products in order to enhance market loyalty and sustainability. FWI banana producers are thus now proposing a product origin-based segmentation of this market.

A relationship between products such as wines and cheeses and their specific regions of origin has been widely demonstrated, but this is seldom true for fruits, especially bananas. There is very little objective data available to highlight differences in quality associated with geographical factors (soil, climate).

In immature green fruit, physiological differences associated with the altitude of the plantation, the soil type and season have been noted. Lowland bananas are more susceptible to wound anthracnose, caused by *Colletotrichum musae*, than mountain bananas (Chillet et al., 2000). In ripe bananas, studies carried out in FWI have revealed physical and aromatic differences between mountain bananas (>300 m ASL) and lowland bananas (50–100 m ASL) (Brat et al., 2004; Bugaud et al., 2006). At the same harvest stage and under identical ripening conditions, mountain bananas have a firmer texture and a higher concentration of aromatic compounds. Other studies have revealed physicochemical, nutritional and sensorial differences according to the region of origin of the bananas (Hughes and Wainwright, 1994; Cano et al., 1997; Hardisson et al., 2001).

In the light of these results, it is hard to conclude that the production area has a real impact on the fruit traits because of the lack of control of certain production factors (cultivation practices, harvest stage, ripening, storage), the inaccuracy of data on production conditions in the study sites, and the low number of sites studied.

We thus carried out a year-long study in Martinique on a range of sites, highly diversified in terms of soil and climatic conditions, with the aim of determining the impact of soil and

* Corresponding author. Tel.: +33 5 96 42 30 98; fax: +33 5 96 42 30 01.
E-mail address: bugaud@cirad.fr (C. Bugaud).

0304-4238/$ – see front matter
doi:10.1016/j.scienta.2007.03.013

climate factors on the final quality of bananas. The harvest stage and ripening and storage conditions were kept identical throughout the study in order to reduce the impact of these factors on the fruit traits.

2. Materials and methods

2.1. Experimental design

This study was carried out on six banana producers' farms in Martinique (FWI) during three periods of the year, corresponding to three different seasons in the West Indies: hot wet period (WP), cool dry period (DP), and intermediate period (IP). The test sites and meteorological conditions at these sites are described in Tables 1 and 2. The highland AB site was the coolest and rainiest site with the least sunlight. In contrast, the VA site was the hottest and driest site. The climatic data were collected throughout the banana-bunch growth period at each site: July to October 2003 for WP, December 2003 to March 2004 for DP and March to June 2004 for IP. Mean daily temperatures, cumulated rainfall, and daily sunlight were recorded for each farm on the basis of data obtained from meteorological stations (CR10X, Campbell, Courtaboeuf, France).

The fertilizer types and quantities applied were similar at the different sites for the same given period. During the dry season (January–April), fertilizers were applied manually once every 3–4 weeks, whereas they were applied once every 2 weeks during the wet season. All sites except AB were irrigated during the dry season. Depending on the rainfall level, the equivalent of 4–5 mm of water per day was supplied to each site. Drip irrigation was used at the BP and LA sites, sub-canopy sprinkler irrigation was used at the CB and VA sites, and overhead sprinkler irrigation was used at the SJ site. Other cropping practices (suckering, bunch management) were similar throughout the study period.

The banana variety studied was Grande Naine, Cavendish subgroup (AAA). For each site and period, five bunches were randomly chosen at the flowering stage (inflorescence emergence stage) and harvested at a temperature sum of 1000 ± 50 dd for each period (Table 3). This temperature sum represented the mean daily temperature sum (calculated in degree-days) accumulated by the fruit during its growth from flowering to harvest using a baseline temperature of 14 °C (Ganry and Meyer, 1975). The fruit diameter was an additional harvest decision-making factor, which accounted for the natural production conditions. Bananas from the VA site were thus harvested at over 1100 dd for two of the three study periods since they had not reached a minimum diameter of 30 mm at 1000 dd.

The bunches were handled in the same way for all sites and periods. Bunches were bagged during flowering. The male bud and two female hands were removed at the 'last female horizontal hand' stage.

Table 1
Geographical characteristics of the sites

Sites	Municipalities	Altitude (m)	Soil[a]
AB	Ajoupa Bouillon	378	Andosol on ash and pumice
BP	Basse Pointe	55	Immature on ash
CB	Carbet	58	Virgin andosol
LA	Lamentin	16	Continental alluvial
SJ	Saint Joseph	40	Brown rust to halloysite
VA	Vauclin	14	Vertisol

[a] By Colmet-Daage (1970).

Table 2
Climatic conditions for sites and periods during banana bunch growth

	Mean daily temperature (°C)	Rainfall (mm/month)	Sunlight (MJ/m^2)
Sites[a]			
AB	23.4	326	13.7
BP	26.4	258	18.7
CB	26.5	147	18.3
LA	26.2	214	17.3
SJ	25.9	194	16.0
VA	27.3	149	19.4
Periods[b]			
Wet	26.8	230	18.4
Dry	24.9	132	16.9
Intermediate	25.9	238	17.8

[a] Climatic parameters were measured for July 2003 to June 2004.
[b] Hot wet period: July to October 2003, cool dry period: December 2003 to March 2004, intermediate period: March 2004 to June 2004.

2.2. Fruit ripening and storage

The bananas to be analysed were rinsed and dipped in fungicide (thiabendazol, 500 ppm) for 1 min. One banana hand per bunch was placed in plastic bags with 20 μ respiration holes and stored in packed boxes for 10–15 days at 14 °C, thus simulating the storage conditions commonly used during shipment from FWI to European ripeners. Half of the hand was used for green fruit measurements and the other half was stored in a room at 16 °C and used for ripe fruit measurements. After 2 h, the bananas underwent an ethylene treatment (1000 ppm for 24 h at 16 °C) to trigger the ripening process. After 24 h, the room was ventilated. Bananas were maintained at 20 °C for 6 days until the ''yellow'' ripeness stage was reached.

Table 3
Banana fruit age for each site and period

Sites	Wet period		Dry period		Intermediate period	
	FHT (d)	Fruit age (dd)	FHT (d)	Fruit age (dd)	FHT (d)	Fruit age (dd)
AB	95	995	118	1024	110	950
BP	78	1035	91	1030	86	1010
CB	77	1015	88	1000	83	1030
LA	72	970	86	990	82	1025
SJ	77	995	100	1050	89	1000
VA	72	1020	92	1130[a]	87	1120[a]

FHT: flowering-to-harvest time.
[a] Bananas from the VA site were harvested at over 1100 dd for the two last periods because they had not reached the minimum diameter of 30 mm at 1000 dd.