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Agronomic Evaluation of Some Cassava Varieties (*Manihot Esculenta* Crantz) and Sensory Evaluation of Attieke from These Varieties in Three Agro-Ecological Zones of Cote D'ivoire

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Abstract

Cassava is the fifth most important food crop in the world after maize, rice, wheat and potato. It is used in human and animal food and is an excellent source of calories. Ivorian production is estimated at around 5 million tonnes. The majority of Ivorian dishes are based on cassava, specifically attiéké, which is widely consumed by the population. However, the improved varieties disseminated by research centres are selected mostly on the basis of production and not on the quality of the attiéké they offer. Yet, the criteria for acceptance of the varieties by end-users are based on the quality of the resulting products. This work aims to improve the conditions for selecting improved varieties by taking into account their adaptation to the chosen agro-ecological zones and the quality of the attiéké they offer for their selection. To this end, 16 varieties from the National Agricultural Research Centre and from farmers were evaluated in areas of high cassava and attiéké production. The trials were carried out in stations (Bouaké) and in farmers' areas (Molonoublé, Sakiaré and Okpoyou). The results showed that there is an interaction between locality and variety, as on-station varieties recorded yields ranging from 25.55 to 63.99 t/ha. These yields are much higher than those obtained in the farmers' areas, which range from 11.25 to 29.96 t/ha. The processing of the tuberous roots of the different varieties produced good attiéké, which was appreciated by tasters in each locality. For this purpose, the improved varieties Bocou2, Bocou5, Bocou6 and I083774 can be selected, as they have a good yield and give good quality attiéké.

Keywords*: cassava, agronomic evaluation, sensory evaluation, attiéké, agro-ecological zone, Côte d'Ivoire*

1. INTRODUCTION

Cassava *(Manihot esculenta* Crantz) is a very important crop in the tropics. It is the fifth most important food crop in the world after maize, rice, wheat and potato. Cassava is used in human and animal nutrition. It is an excellent source of calories and is the staple diet of nearly one billion people in the tropics (Macrae et al., 1993). Global production of cassava tuberous roots was estimated at 277 million tonnes in 2018, of which 61.1% was from Africa (FAO, 2020).

In Côte d'Ivoire, cassava is the second most important food crop, after yam, with an estimated production of about 5 million tonnes on an area of 808.671 ha in 2018. This production has enabled the country to rank 14th in the world (FAO, 2020). Due to its adaptation to all types of land, cassava is grown throughout Côte d'Ivoire, but the main production area remains the forest regions where rainfall is high. Also, as one moves southwards, the more cassava cultivation tends to increase, with a concentration around the major urban centres (Abidjan, Yamoussoukro, Bouaké, Daloa, San Pedro, Duekoué) (Mendez del Villar et al., 2017). Regardless of the production area, cassava tuberous roots are intended for sale or for self-consumption. They lend themselves to a range of processing methods, resulting in various food by-products (Segnou, 2002). The few by-products that cassava can provide are: attiéké, foutou, placali, flour, starch and gari (N'Zué,

2007). The majority of Ivorian dishes are based on cassava, in particular, attiéké, which is widely consumed in several forms, including 'garba'. Attiéké is a food made from steamed cassava semolina with a whitish colour and a slightly acidic taste (Assanvo, 2008). According to Aka (2013), attiéké is able to replace other foods (plantain, yam, taro and sweet potato) in case of shortages at certain times of the year in Ivorian markets. It is eaten two to three times a day with meat, fish or raw vegetables, and is the most consumed food in urban centres in Côte d'Ivoire (Kakou, 2000; Djéni et al., 2014). Its popularity is well known in the West African sub-region and even in Europe, where it is exported (Assanvo, 2008).

However, there is a shortage of tuberous cassava roots, which also causes a shortage of attiéké in Côte d'Ivoire. This shortage is due to the decline in production. Indeed, the traditional varieties cultivated by farmers have a long cycle and low production. They are therefore abandoned in favour of improved varieties disseminated by research centres, but most of these varieties were created with the aim of increasing yields and not the quality of the resulting products such as attiéké. It is also possible that the varieties developed do not adapt to all types of soil, hence the poor quality of the attiéké that these varieties produce. To this end, some of the CNRA's improved varieties were subjected to agronomic and organoleptic evaluation of attiéké in three agro-ecological zones. The evaluation consists in detecting and selecting productive varieties that provide good quality attiéké in these zones. The objective of this study was to identify high-performance varieties that are adaptable to the production zones and produce good quality attiéké.

2. MATERIALS AND METHODS

2.1. Experimental sites

2.1.1. *Bouaké (station)*

In Bouaké, the trial was conducted at the Station de Recherche sur les Cultures Vivrières du Centre National de Recherche Agronomique (SRCV/CNRA). The station is located in central Côte d'Ivoire at latitude 7°46' N, longitude 5°06' W and altitude 375 m (Fondio et al., 2003; N'Zi et al., 2010). It lies in the transition zone between the southern forest climate and the northern savannah climate (Traoré et al., 2013). The climate of the study area is humid tropical with four seasons, including a long dry season (November to February), a long rainy season (March to June), a short dry season (July to August) and a short rainy season (September to October). These periods have become less marked in recent years (Brou et al., 2005). The vegetation consists of wooded savannah with several Poaceae species (Séka et al., 2009). The soils are ferralitic gravelly, reworked, shallow and derived from granitic alteration material with a sandy clay texture (N'cho, 1991). The average annual rainfall is 1200 mm (Akassimadou and Yao-Kouamé, 2014), with an average temperature of 25.73 °C (Traoré et al., 2013.

2.1.2. *Didiévi (Molonoublé)*

Didiévi is a department of the Bélier region, the soils of the region are 3 types: ferralitic soils on granitic bedrock in the forest zone; clayey or sandy-humus soils or hydro morphs, near rivers, in the lowlands and in areas near the Bandama. The vegetation of the region is composed of wooded savannahs, grassy savannahs and gallery forests characteristic of the "V Baoulé" (transition zone between the forest of the south and the savannah of the north of the country). The region's climate is similar to that of the tropics. It is characterised by: a long dry season from November to February with a harmattan that is not too severe; a long rainy season from March to July with heavy rainfall; a short dry season from August to September; a short rainy season from September to October. The average annual rainfall varies between 1000 and 1200 mm^3. The average temperature is 30°C (Anonymous, 2013).

2.1.3. Yamoussoukro (Sakiaré)

The Yamoussoukro district, located between 6°15 and 7°35 north latitude and 4°40 and 5°40 west longitude, is part of the large lake region. Yamoussoukro has an equatorial climate with four seasons: A long dry season from mid-November to mid-March, characterised by the presence of the harmattan from December to January, a long rainy season from mid-March to mid-July, a short dry season from mid-July to mid-September and a short rainy season from mid-September to mid-October. Average rainfall amounts vary

from 900 to 1,100 mm per year with a highly variable spatial distribution throughout the year and from one year to the next. The average temperature in the region is around 26°C. Relative humidity varies between 75 and 85% with drops to 40% during harmattan periods and is between 80 and 85% during rainy periods (Anonymous 3, 2018).

2.1.4. Dabou (Okpoyou)

Dabou is a city of the south of Côte d'Ivoire located on the coast 59 km from Abidjan, and is part of the Odjoukrou region. The area benefits from oceanic influence and a transitional equatorial climate with four seasons, including two dry seasons and two rainy seasons. The long dry season, which is more rigorous, runs from December to March and the short dry season, which is less harsh, extends from the end of July to September. These two dry seasons are separated by the rainy seasons, the longest of which runs from early April to mid-July. The average annual rainfall is between 1600 and 2000 mm. The average temperature is 25°C. The vegetation is humid forest type, very dense and evergreen. This forest formation belongs to the Guinean domain, mainly to the ombrophilous forest characterised by the presence of large trees. There are also swamp forests, mangroves and very localised savannah formations. The soils in this area are ferralitic and highly desaturated under high rainfall and are generally formed from sandy-clay detritus deposits (hydromorphic soils). Its relief is made up of a plateau with altitudes varying between 50 and 80 m and a fluviolagunar plain of less than 40 m (Atlas de Côte d'Ivoire, 1976). The main activity is agriculture, which has become much more intensive with the diversification and spread of cash and food crops. However, cassava and industrial crops are the dominant activities in this area (Kangah et al., 2016).

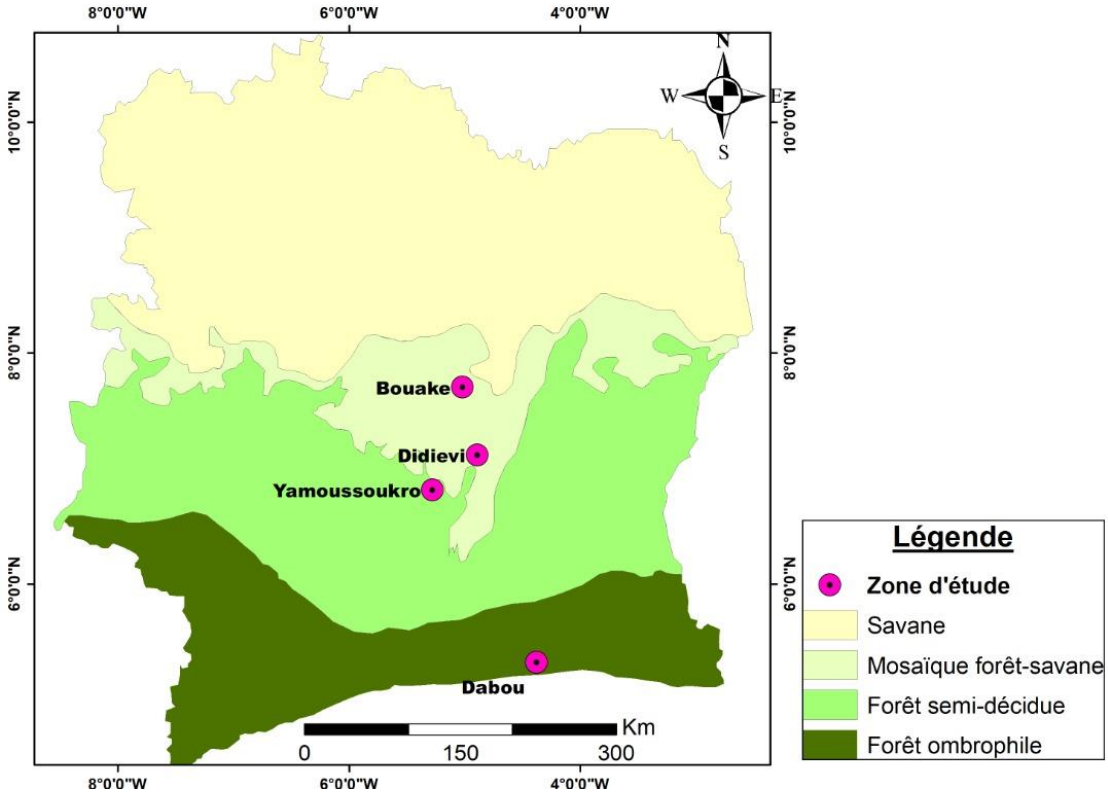

Figure 1: Location of the different study sites

2.2. Material

The plant material consisted of cuttings of 16 cassava varieties. They come from the National Agricultural Research Centre (CNRA): Bocou2, Bocou5, Bocou6, Bocou7, Yacé, Yavo, I090006, I083774, I084157, I083724b; and from the farming environment which are: Agba blé, Rapide, Zoukougbeu (Molonoublé),

Kolou (Sakiaré), Ess-akpl and Agbègrè (Okpoyou). For the CNRA varieties, only the Yacé variety is not improved. It was used as a control for the dry matter rate characteristic (Table I).

Variety	colour of the flesh	Status
Bocou2	Yellow	improved and brought by CNRA
Bocou5	Cream	improved and brought by CNRA
Bocou6	Cream	improved and brought by CNRA
Bocou7	Cream	improved and brought by CNRA
I083724b	Yellow	improved and brought by CNRA
I083774	Yellow	improved and brought by CNRA
I084157	Orange	improved and brought by CNRA
I090006	Yellow	improved and brought by CNRA
Yavo	White	improved and brought by CNRA
Kolou	White	local supplied by producers
Rapide	White	local supplied by producers
Zoukougbeu	White	local supplied by producers
Agba blé	White	local supplied by producers
Ess-akpl	White	local supplied by producers
Agbègrè	White	local supplied by producers
Yacé	White	local supplied by producers

Table I: Origin and colour of varieties

2.3. Method

2.3.1. Setting up the trial at the Bouake research station

The trial in Bouake was carried out at the experimental site of the food crop research station (SRCV), with a 3-repeat Fischer design. The planting was done in July 2018. After clearing the plot with a tractor, it was divided into three blocks separated by 2 m. Each block received the 11 varieties used, one variety constituted an elementary plot composed of 5 lines of 6 feet, i.e. 30 feet per elementary plot. The spacing was 0.8 m between plants and between lines, i.e. a density of 15,625 plants per hectare, the surface area of each elementary plot was 19.2 m2 and the distance between the elementary plots was 1.5 m. Weeding was done on demand. The replacement of non-emerged plants was done one month after planting, i.e. in August 2018. Harvesting took place in August 2019, 13 months after planting.

2.3.2. Setting up the field trials

The Molonoublé trial took place in July 2018. In Okpoyou and Sakiaré, the trials were set up in April and May 2019. The Fisher 2-repeat design was used in these locations with 10 varieties used in Molonoublé and Sakiaré and 11 varieties in Okpoyou. The varieties constituted each an elementary plot of 10 lines of 15 feet on an area of 120 m2. The planting density was 12,500 plants per hectare, i.e. a spacing of 1 m between rows and 0.8 m between plants. The distance between individual plots was 1.5 m on the two blocks, which were 2 m apart. The replacement of non-emerged plants was done one month after planting, weeding was done on demand. Harvesting took place 14 months after planting.

2.3.3. Observations and measurements of agronomic characteristics

Observations were made mainly on the following parameters:

The emergence rate: expressed as in %, it is the number of emerged plants multiplied by 100 on the number of cuttings planted at the beginning.

Emergence rate (%) = number of plants emerged *100/ number of plants initially planted

Incidence and severity of mites, anthracnose, mosaic and mealybugs: concerning the incidence, the number of plants attacked by pests or disease was calculated as a ratio of the total number of plants emerging from each elementary plot. It is expressed in %. The severity was noted on a scale from 1 to 5 according to the severity of the damage caused to the plant. The average severity was calculated as the

number of diseased plants multiplied by their corresponding score in the round divided by the total number of diseased plants.

Average tuberous root weight: expressed in kg/tuberous root, it was determined by taking the ratio of the weight of tuberous roots of a variety to the number of tuberous roots of that variety.

Average tuberous root weight (kg/root) = root weight (kg)/number of roots

Average tuberous root production per plant: expressed in kg/plant, this was determined by taking the ratio of the weight of tuberous roots of a variety to the total number of plants of that variety.

Average tuberous root production per plant (kg/plant) = root weight (kg)/number of plants

Tuberous root yield: expressed in t/ha, at harvest all tuberous roots, small or large, from a given elementary plot (variety) were piled up and weighed with a scale; the weight obtained was reported per hectare.

Yield (t/ha) = production (t)/area (ha)

2.3.4. Method of preparation of attiéké

Attiéké is a traditional cassava couscous made from fresh cassava pulp semolina prepared by steaming. To prepare attiéké, the fresh tuberous cassava roots were peeled, cut into pieces, washed and ground. During grinding, palm oil and ferment (1/10 of the quantity of fresh roots) were added. The ferment was obtained from pieces of prepared or braised tuberous root, depending on the locality, and stored for 2 to 3 days in bags. The paste obtained after grinding was put in bags to be fermented for 15 hours, the fermented paste which still contains water was drained, dewatered and sieved with a 5mm sieve (mesh diameter). The granules were dried in the sun for 30 min to 1 hour, the semolina was cooked directly. The cooking was done in steam for about 30 min at 100°C.

2.3.5. Organoleptic properties

The organoleptic characteristics were assessed by at least 60 tasters who are regular consumers of this product. The assessment criteria on a scale of 1 to 5 were noted by each taster: colour, flavour, grain size, consistency, presence of fibre and aroma. The rating criteria are 1 = very poor, 2 = poor, 3 = acceptable, 4 = good and 5 = very good.

2.3.6. Statistical analysis

A one-way analysis of variance (ANOVA) with an LSD test at the 5% threshold in case of significant difference was performed for agronomic and organoleptic characteristics. Also, a two-factor analysis of variance was performed to detect the effect of locality and variety on the agronomic parameters using STATISTICA software version 7.1.

3. RESULTS

3.1 Agronomic evaluation of cassava varieties tested on station and in the field

3.1.1. In station (Bouaké)

a) Emergence rate

The emergence rate of the varieties varied from 64.44 to 96.66% for the varieties I084157 and Agba blé respectively. For this characteristic, only two (2) varieties had a rate less than 80%. A significant difference was observed in this parameter with a probability of 0.001 (Table II).

b) Incidence and severity of diseases (mosaic and anthracnose)

The incidence of mosaic on the varieties studied varied from 22.44% for the variety Rapide to 87.72% for Yacé. Statistic analysis showed that there was no significant difference in the level of attack between varieties. However, it should be noted that for the variety Yacé, although the level of incidence was not statistically different from the others, it was attacked a lot. As for the severity of this disease, it varied from 1.67 to 3. The variety Agba blé recorded the highest severity (3) followed by the variety Yacé with a severity index of 2.67. The lowest severity index was observed in the varieties Rapide, I090006 and Bocou5 (Table II). The incidence of anthracnose on the cultivated varieties was only observed on the varieties I090006 and Yacé with values of 1.23 and 7.02% respectively. These varieties were attacked by anthracnose with a severity index of 1.33, the other varieties were tolerant to this disease with severity indices of 1, which means no symptoms.

c) Incidence and severity of pests (mite and mealybug)

Cassava varieties were attacked by mites with very high incidences. These incidences ranged from 61.33% (Rapide) to 100% (Yacé). The majority of varieties recorded a mite attack incidence more than 90%. The analysis carried out on the data concerning the incidence of mite attacks showed a significant difference at the variety level with a probability of 0.001 (Table II). The degree of severity ranged from 2 to 2.67 for varieties I084157 and I083774 respectively. Overall, the varieties were less severely attacked by mites, as the severity level was close to 2 for the majority of varieties. A non-significant difference was observed in the incidence of mealybug attack. Only the varieties I090006 and Agba blé were attacked by these pests with incidences of 1.23 and 3.45% respectively. The mealy bug severity index ranged from 1 to 1.33. No significant difference in the severity of mealy bug attacks was observed.

d) Average tuberous root weight, average production per plant and yield

The average tuberous root weight (Pmoyt) of the varieties tested at the station ranged from 0.36 kg/tuberous root for the variety I090006 to 0.85 kg/tuberous root for the variety Yavo. The analysis carried out showed a significant difference between the varieties. The average production per plant ranged from 2.35 to 3.85 kg/plant for variety I083724b and Yavo respectively. A significant difference was observed between the varieties for this characteristic with a probability of 0.004. The yield of the varieties ranged from 25.55 to 63.99 t/ha. The highest yield was observed in the variety Bocou5 followed by the varieties Bocou2 (59.03 t/ha) and Rapide (56.80 t/ha). The lowest value was recorded by the variety I084157. A significant difference was also observed between the varieties for this characteristic (Table II).

e) Dry matter content

The dry matter content of the varieties ranged from 36.10 (I084157) to 42.96% (Agba wheat). Seven (7) varieties had a dry matter rate higher than that of Yacé which recorded a DMR of about 39%. It should be noted here that the Yacé variety is the reference in terms of dry matter rate. The three varieties with a lower DMR than Yacé are yellow and orange. For this characteristic, there was no significant difference between the varieties with a probability of $p > 0.05$.

Table II: Parameters with significant differences for the on-station trial (Bouaké)

Varieties	Lift rate (%)	Incidence of mites (%)	Mosaic Severity Index	Average weight of tuberous roots (kg/tuberous root)	Average production per plant (kg/plant)	Yield (t/ha)
Abga blé	96,67 ± 0 a	96,55 ± 5,98 ab	3 ± 0,00 a	0,63 ± 0,1 c	2,9 ± 0,49 bcd	46,88 ± 8,93 cd
Yacé	74,44 ± 10,18 cd	100 ± 0,00 a	2,67 ± 0,58 ab	0,64 ± 0,07 c	3,63 ± 0,53 abc	48,36 ± 7,77 c
Bocou2	92,22 ± 10,72 ab	94,13 ± 3,59 ab	2,33 ± 0,58 bc	0,61 ± 0,04 c	3,62 ± 0,24 abc	59,03 ± 0,86 ab
I083774	87,78 ± 8,39 ab	96,42 ± 3,46 ab	2 ± 0,00 cd	0,72 ± 0,1 abc	3,13 ± 0,32 abcd	50,35 ± 5,06 bc
Zoukougbeu	95,56 ± 5,09 ab	100 ± 0,00 a	2 ± 0,00 cd	0,66 ± 0,06 bc	2,84 ± 0,45 cd	47,37 ± 2,61 c
I084157	64,44 ± 1,92 d	98,33 ± 2,89 ab	2 ± 0,00 cd	0,81 ± 0,1 ab	2,47 ± 0,36 d	25,55 ± 2,27 f
I090006	91,11 ±1,92 ab	91,36 ± 9,32 ab	1,67 ± 0,58 d	0,36 ± 0,05 d	2,41 ± 0,3 d	36,46 ± 7,55 de
Yavo	87,78 ± 13,47 ab	75,12 ± 17,28 cd	2 ± 0,00 cd	0,85 ± 0,23 a	3,85 ± 1,05 a	55,56 ± 6,75 abc
Rapide	87,78 ± 5,09 ab	61,33 ± 19,63 d	1,67 ± 0,58 d	0,71 ± 0,07 abc	3,76 ± 0,68 ab	56,80 ± 9,57 abc
Bocou5	92,22 ± 5,09 ab	94,17 ± 5,3 ab	1,67 ± 0,58 d	0,64 ± 0,08 c	3,73 ± 0,17 ab	63,99 ± 5,62 a
I083724b	83,33 ± 10 bc	83,95 ± 10,46 bc	2 ± 0,00 cd	0,58 ± 0,02 c	2,35 ± 0,52 d	35,71 ± 5,37 ef
General average	**86,667**	**90,12**	**2,09**	**0,66**	**3,15**	**47,82**
Coefficient of variation (%)	**13,01**	**15,4**	**24,6**	**22,1**	**22,3**	**25,2**
Pr > F	**0,001**	**0,001**	**0,006**	**0,001**	**0,004**	**0,000**

Table III: Parameters with significant differences for the Molonoublé demonstration test

Varieties	Mite severity index	Incidence of mealy bug attack (%)
I083774	2,04 ±0,05 b	0,39 ± 0,55 b
Agba blé	2,03 ± 0,04 b	0,7 ± 0,99 b
Bocou5	2 ± 0,00 b	0 ± 0 b
I084157	1 ± 0,00 c	0 ± 0 b
I090006	2 ± 0,00 b	2,56 ± 0,21 a
Bocou2	2,11 ± 0,03 a	0 ± 0 b
I083724b	2 ± 0,00 b	0 ± 0 b
Yavo	1 ± 0,00 c	0 ± 0 b
General average	**1,76**	**0,49**
Coefficient of variation (%)	**26,96**	**191,5**
Pr > F	**0,000**	**0,007**

3.1.2.2. Okpoyou

a) Emergence rate

The emergence rate of the varieties grown in Okpoyou varied from 51 to 96%. In this locality, only three (3) varieties had an emergence rate below 80%. The variety Ess-akpl had the highest rate. In contrast, the variety Bocou2 had the lowest emergence rate. A significant difference was observed in this parameter with a probability of 0.021 (Table IV).

b) Incidence and severity of diseases (mosaic and anthracnose)

The incidence and severity of mosaic varied from 0 to 27.16% and from 1 to 2 respectively. Significant differences were observed in these two variables. The varieties Yacé (27.16%), Bocou2 (7.77%) and Ess-akpl (1.42%) were the only ones attacked by mosaic in this locality (Table IV). No significant differences were observed in the incidence and severity of anthracnose. However, the values of these parameters fluctuated between 1 and 2.5 for severity and 0 and 39.19% for incidence.

c) Incidence and severity of pests (mite and mealybug)

The varieties grown in Okpoyou were attacked by pests. The incidence and severity of mealybug attack varied from 3.9 (Bocou5) to 51.36% (Ess-akpl) and the severity from 1.5 to 2.5. The incidence of mite attack varied from 0 to 50.36%. The variety Agbègrè had the highest incidence. Five (5) varieties had an incidence of more than 30%: I083774, Bocou2, I084157, I083724b, and Agbègrè. The severity varied from 1 to 2.5, the varieties Yacé and Ess-akpl were not attacked by these pests. No significant difference was observed for all parameters.

d) Average tuberous root weight, average production per plant and yield

The values of average tuberous root weight ranged from 0.19 kg/tuberous root obtained by the variety Ess-akpl to 0.48 kg/tuberous root obtained by the variety I084157 (Table IV). The average production and yield varied from 0.98 (I090006) to 1.90 kg/plant (I083724b) and from 12.81 (I090006) to 25.26 t/ha (Bocou6) respectively. For all three traits studied, a significant difference was observed only in the average weight of tuberous roots.

Varieties	Emergence rate (%)	Mosaic Severity Index	Incidence of mosaic (%)	Average weight of tuberous roots (kg/tuberous root)
Agbègrè	94,33 ± 3,3 a	1 ± 0 c	0 ± 0 b	0,24 ± 0 cd
Bocou6	94 ± 1,89 a	1 ± 0 c	0 ± 0 b	0,32 ± 0,02 bc
Yacé	94 ± 13,2 a	2 ± 0 a	27,16 ± 11,84 a	0,27 ± 0,02 cd

I083724b	72,67 ± 16,03 ab	1 ± 0 c	0 ± 0 b	0,46 ± 0,06 a
Bocou2	51 ± 26,87 b	2 ± 0 a	7,77 ± 9,63 b	0,31 ± 0,01 cd
I084157	63,67 ± 4,24 b	1 ± 0 c	0 ± 0 b	0,48 ± 0,04 a
Bocou7	92,33 ± 3,3 a	1 ± 0 c	0 ± 0 b	0,44 ± 0,09 ab
Ess-akpl	96 ± 2,83 a	1,5 ± 0,7 b	1,42 ± 2 b	0,19 ± 0,06 d
Bocou5	91 ± 4,24 a	1 ± 0 c	0 ± 0 b	0,32 ± 0,02 bc
I083774	88 ± 1,89 a	1 ± 0 c	0 ± 0 b	0,24 ± 0,02 cd
I090006	88 ± 7,54 a	1 ± 0 c	0 ± 0 b	0,23 ± 0,09 cd
General average	**83,72**	**1,23**	**25,15**	**0,32**
Coefficient of variation (%)	**19,53**	**34,95**	**122,64**	**33,68**
Pr > F	**0,021**	**0,001**	**0,003**	**0,003**

Table IV: Parameters with significant differences for the Dabou demonstration test

3.1.2.3. Sakiaré

a) Emergence rate

The emergence rate of the varieties grown in Sakiaré ranged from 80.33 to 99%, recorded respectively by the varieties Bocou2 and Bocou6. Overall, the varieties had a good emergence rate. No significant differences were observed in this parameter.

a) Incidence and severity of diseases (mosaic and anthracnose)

Mosaic was present on most varieties with a severity index ranging from 1 (I083724b, I083774, I090006) to 3.58 (Yacé). The incidence of this disease varied from 0 to 42.79%. The incidence of 0 was obtained in varieties with a severity index of 1. The variety Kolou was the most attacked, followed by the varieties Bocou2 and Yacé with incidences of 20.8 and 19.59% respectively. Significant differences were observed in these two parameters (Table V). The varieties in Sakiaré were tolerant to anthracnose, in fact, the incidence and severity of this disease varied respectively from 0 to 50% and from 1 to 2. However, only 4 varieties out of the 10 grown showed symptoms, these were I084157, I083774, Yacé and Kolou. The variety Kolou had the highest incidence while I084157 had the highest severity index. No significant differences were observed for these parameters.

b) Incidence and severity of pests (mite and* mealybugs *)

The mite attack in Sakiaré on the varieties was not severe enough. The severity index ranged from 1 to 3, while the incidence of attack by these pests ranged from 0 to 52.84%. The variety Bocou5 had no symptoms, giving it an incidence of 0%, while the variety I090006 had the highest incidence with a severity index of 2.5. The variety Bocou2 recorded the highest severity index with an incidence of 50.43%. No significant differences were observed for these two parameters. In this locality, mealybugs were observed on the varieties Bocou2, Bocou6 and I083724b.

c) Average tuberous root weight, average production per plant, yield and tuberous root loss.

The varieties in Sakiaré were heavily attacked by rodents, which made it possible to calculate the tuberous root loss. With the exception of variety I090006, all other varieties were eaten. These varieties had losses ranging from 0.05 to 1.53 t/ha. The variety Bocou5 had the highest loss in tuberous roots (1.53 t/ha). The tuberous roots weighed from 0.33 to 0.77 kg/tuberous root, while production varied from 1.14 to 2.17 kg/plant. The yields of the varieties ranged from 11.25 to 20.96 t/ha. In contrast to the variety I084157 which had the largest tuberous roots and the lowest yield, the variety Bocou2 had the highest production per plant and the highest yield. A significant difference was observed in the average weight of tuberous roots with a probability of 0.025 (Table V).

Table V: Parameters with significant differences for the Sakiaré demonstration test

Varieties	Mosaic Severity Index	Incidence of mosaic (%)	Average weight of tuberous

			roots (kg/tuberous root)
Bocou2	2,74 ± 0,26 ab	20,8 ± 13,57 b	0,48 ± 0,01 bc
Kolou	2,51 ± 0,05 b	42,8 ± 3,76 a	0,50 ± 0,02 bc
Yacé	3,58 ± 0,14 a	19,6 ± 1,91 b	0,43 ± 0,06 bc
I084157	2,56 ± 0,63 b	3,86 ± 3,38 c	0,77 ± 0,20 a
Bocou6	1,5 ± 0,71 cd	3,36 ± 4,75 c	0,49 ± 0,05 bc
Yavo	2,25 ± 0,35 bc	3,29 ± 2,57 c	0,55 ± 0,05 b
I083724b	1 ± 0 d	0 ± 0 c	0,55 ± 0,13 b
Bocou5	1,5 ± 0,71 cd	0,37 ± 0,53 c	0,46 ± 0,08 bc
I083774	1 ± 0 d	0 ± 0 c	0,42 ± 0,01 bc
I090006	1 ± 0 d	0 ± 0 c	0,33 ± 0,02 c
General average	**1,96**	**9,41**	**0,5**
Coefficient of variation (%)	**46,62**	**151,19**	**26,22**
Pr > F	**0,001**	**0,000**	**0,025**

3.2 Effect of locality on agronomic parameters

3.2.1. Emergence rate of varieties

The emergence rate of the varieties in the localities ranged from 74 to 89.55%. The lowest rate was observed in Molonoublé and the highest in Sakiaré. In Okpoyou and Bouaké, emergence rates were 75.72 and 87.22% respectively. For this parameter, a significant difference was observed with a probability of 0.033 (Table VI).

3.2.2 Incidence and severity of mites

The severity indices of mite attacks varied from 1.83 to 2.28 in Okpouyou and Sakiaré respectively. The average severity indices observed in the other two localities were: 1.84 for Molonoublé and 2.16 for Bouaké. The varieties showed a statistically similar severity index in all localities. The incidence of mite attack ranged from 10.26 (Molonoublé) to 90.27% (Bouaké). A significant difference was observed in this parameter with a probability of 0.000008.

3.2.3. Average tuberous root weight, average production per plant and yield.

The average weight of tuberous roots in the different localities varied from 0.34 (Okpoyou) to 0.72 kg/tuberous root (Molonoublé). This weight was 0.50 kg/tuber root in Sakiaré and 0.62 kg/tuber root in Bouaké. The average production per plant ranged from 1.42 kg (Sakiaré) to 2.83 kg/plant (Bouaké). The other two localities obtained average productions of 1.49 kg/plant in Okpoyou and 2.53 kg/plant in Molonoublé. The yield of the varieties in the localities varied from 13.99 to 44.33. The highest yield was recorded in Bouaké (Table VI).

Table VI: Variation in agronomic parameters according to locality

locality	Emergence rate (%)	Incidence of mite attack (%)	Average tuberous root weight (kg/root)	Average production per plant (kg/plant)	Yield (t/ha)
Molonoublé	74 b	10,26 b	0,72 a	2,53 a	21,02 b
Okpoyou	75,72 b	31,72 b	0,34 d	1,49 b	17,51 bc
Bouaké	87,22 ab	90,27 a	0,62 b	2,83 a	44,33 a
Sakiaré	89,55 a	21,09 b	0,50 c	1,42 b	13,99 c
p	**0,033**	**0,000008**	**0,000001**	**0,00000**	**0,00000**

3.3 Effect of variety on agronomic parameters

3.3.1. Emergence rate of varieties

The emergence rate of the varieties varied from 71.67 to 92.58%. The varieties Bocou2 and Bocou5 had the lowest and highest emergence rates respectively. The statistical analysis carried out showed that there was no significant difference in this parameter with a probability of 0.06.

3.3.2 Incidence and severity of mites

The incidence of mite attack varied between 24.92 and 53.19%. The variety Bocou2 was the most attacked by mites while Bocou5 was the least attacked. No significant difference was observed in this parameter with a probability of 0.62. The mite severity index ranged from 1.62 to 2.4. The highest severity index was observed on the variety Bocou2 and the lowest on the variety Bocou5. The statistical analysis carried out showed a significant difference in this parameter with a probability of 0.023 (Table VII).

3.3.3. Average tuberous root weight, average production per plant and yield.

The average tuberous root weights of the varieties ranged from 0.34 to 0.79 kg/tuberous root. Variety I090006 gave the smallest tuberous roots and variety I083774 gave the largest. The average production per plant of the tested varieties ranged from 1.64 to 2.39 kg/plant. The variety I090006 (1.64 kg/plant) had the lowest average production per plant. The varieties Bocou2 (2.39 kg/plant) and Bocou5 (2.35 kg/plant) had the highest average production per plant. The yield of the varieties ranged from 19.49 to 32.78 t/ha. The varieties I084157 and Bocou5 had the lowest and highest yields respectively. Statistical analysis showed a significant difference in the three parameters (Table VII).

Table VII: Variation of agronomic parameters according to varieties

Varieties	Mite Severity Index	Average tuberous root weight (kg/root)	Average production per plant (kg/plant)	Yield (t/ha)
Bocou5	1,63 b	0,55 b	2,35 ab	32,78 a
I084157	1,77 b	0,79 a	2 bcd	19,49 c
I090006	2 ab	0,34 c	1,65 d	19,66 c
I083724b	2,03 ab	0,57 b	1,91 cd	20,82 c
I083774	2,38 a	0,53 b	2,02 bc	24,93 bc
Bocou2	2,40 a	0,48 b	2,39 a	27,57 ab
P	**0,023**	**0,00001**	**0,004**	**0,0001**

3.4. Combined effects of localities and varieties on agronomic parameters

3.4.1. Emergence rate of varieties

The emergence rate of the varieties varied from 50 to 98.33%. Molonoublé recorded the lowest emergence rate with the variety I083724b and Bouaké recorded the highest emergence rate with the variety Bocou2. The variety x locality interaction had no significant effect on the parameter with a probability of 0.49.

3.4.2. Incidence and severity of mites

The incidence of mites ranged from 0 to 97.5%. The lowest incidence was obtained by the varieties Bocou5 and I084157 respectively in Sakiaré and Molonoublé and the highest incidence was recorded in Bouaké by the variety I084157. The severity of the mites ranged from 1 (Bocou5 and I084157) to 3 (I083774). As for incidence, the lowest and highest severity indices were observed in the same localities. The variety x location interaction had no significant effect on the two parameters with probabilities of 0.87 and 0.15 for incidence and mite severity index respectively.

3.4.3. Average tuberous root weight, average production per plant and yield.

The average tuberous root weight of the varieties ranged from 0.23 to 1.13 kg/tuberous root. The average production per plant of the varieties ranged from 0.98 to 3.71 kg/plant. The smallest tuberous root weight was obtained by variety I090006 in Okpoyou and the largest roots were recorded by variety I084157 in Molonoublé. The variety x locality interaction had no significant effect on this parameter with a probability

of 0.29. The smallest production was obtained by variety I090006 in Okpoyou and the largest production was obtained by variety Bocou5 in Bouaké. Yields ranged from 11.25 to 63.62 t/ha. Variety I084157 had the lowest yield and varieties Bocou5 and Bocou2 had the highest yields. The variety x locality interaction had a significant effect on the latter two parameters with probabilities of 0.0006 and 0.0156 for average production per plant and yield respectively.

Table VIII: Variation of agronomic parameters according to localities

Localité	Variété	Production moyenne (kg/plant)	Rendement (t/ha)
Bouaké	Bocou2	3,48 ab	59,52 a
	Bocou5	3,71 a	63,62 a
	I083724b	2,05 efghij	32,74 cd
	I083774	2,95 bc	48,36 b
	I084157	2,27 cdefgh	24,55 def
	I090006	2,54 cdef	37,20 c
Molonoublé	Bocou2	2,49 cdefg	13,33 gh
	Bocou5	2,69 cde	29,96 cde
	I083724b	2,52 cdefgh	14,92 fgh
	I083774	2,73 cde	23,36 defg
	I084157	2,81 bcd	24,96 def
	I090006	1,91 fghijk	16,54 fgh
Okpoyou	Bocou2	1,44 ijklmn	16,46 fgh
	Bocou5	1,65 hijklmn	23,18 defg
	I083724b	1,9 fghijkl	19,58 efgh
	I083774	1,21 klmn	15,83 fgh
	I084157	1,76 ghijklm	17,19 fgh
	I090006	0,98 n	12,81 gh
Sakiaré	Bocou2	2,17 defghi	20,96 efgh
	Bocou5	1,34 jklmn	14,36 fgh
	I083724b	1,49 ijklmn	13,08 gh
	I083774	1,19 klmn	12,17 h
	I084157	1,15 mn	11,25 h
	I090006	1,17 lmn	12,08 h
	Localité*variété	0,0006	0,0156

3.5. Evaluation of the organoleptic parameters of the varieties tested on the farm

3.5.1. Okpoyou

The tasting test carried out on the varieties grown in Okpoyou showed that for all the descriptive characteristics used, the Yacé variety was the best in attiéké with scores between 4 and 5. In contrast to Yacé, the variety I084157 was the least appreciated by consumers, as it scored between 3.33 and 3.69 on the descriptors. Overall, white-fleshed varieties were more appreciated than yellow-fleshed varieties. This depreciation was mainly due to the colour of the attiéké and the presence of fibre. However, the sensory profile of the different varieties showed that no variety was poor (Figure 4). For all descriptors, significant differences were observed with a probability of $p = 0.0001$.

3.5.2. Molonoublé

The sensory profile carried out showed that the Molonoublé tasters appreciated all the processed varieties. The scores for the different assessment parameters ranged from 3.96 for aroma (variety I083774) to 4.87 for fibre and aroma (variety Yavo). For all parameters combined, the Yavo variety was the best, with scores between 4.73 and 4.87. In this locality, variety I084157 was most appreciated among the coloured flesh varieties (Figure 5). Overall, the coloured flesh varieties were the least liked by consumers. For all descriptors, significant differences were observed with a probability of $p = 0.0001$.

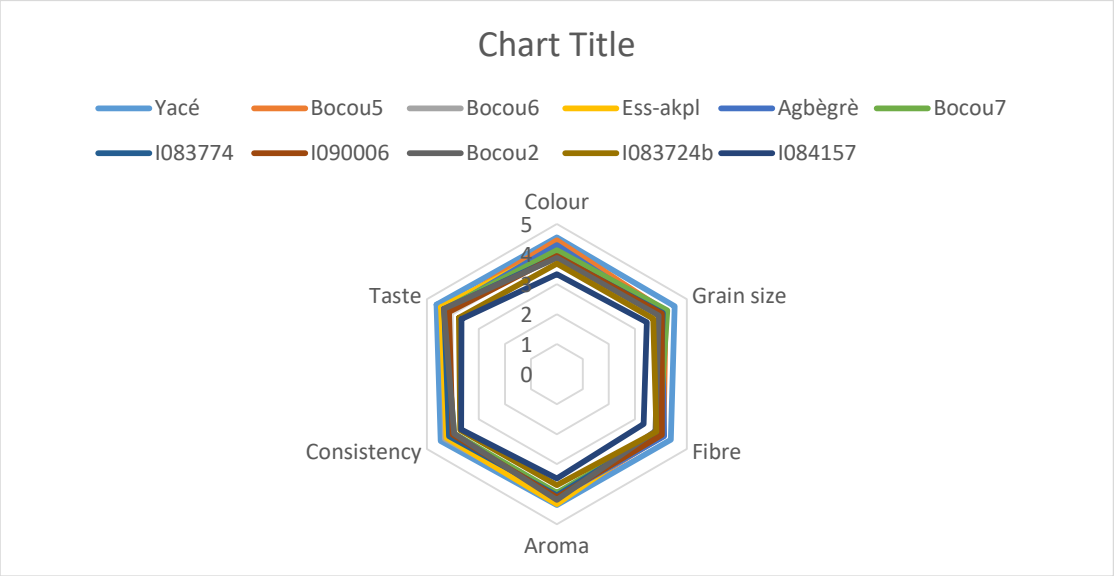

Figure 4: Sensory profile of different varieties in Okpoyou

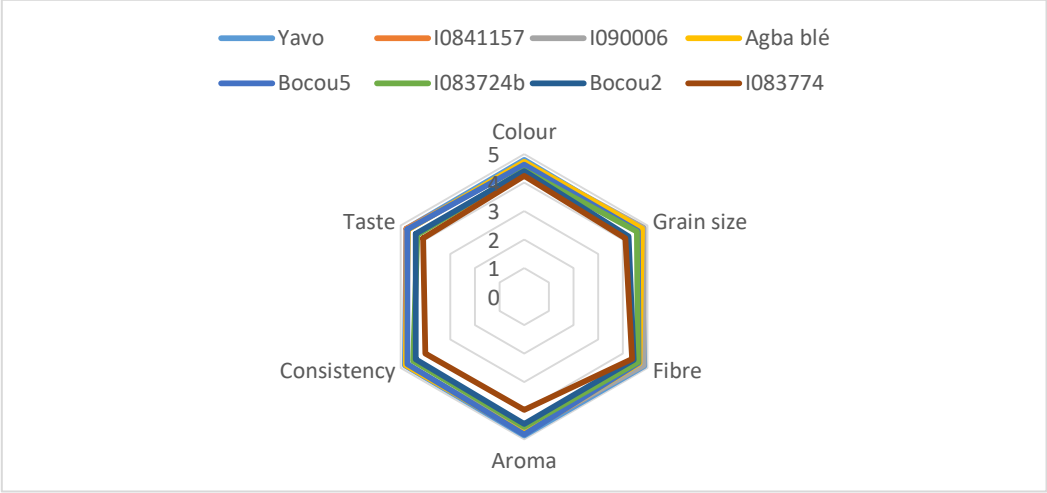

Figure 5: Sensory profile of the different varieties in Molonoublé

3.5.3. Sakiaré

Scores for attiéké quality parameters ranged from 3.27 to 4.58. These scores reflect that the attiéké of the varieties ranged from acceptable to good. These scores indicate that the attiéké of the varieties range from acceptable to good. The sensory profile shows that among the varieties, Yacé was good for all quality traits. In contrast to Yacé, the variety Kolou had the lowest scores for almost all the traits that reflect the quality of the attiéké. The Bocou5 variety was the most fibrous with 3.69. In contrast to the other localities, yellow-fleshed varieties are appreciated in Sakiaré, such as I090006 and Bocou2 (Figure 6). For all descriptors, significant differences were observed with a probability of p = 0.0001.

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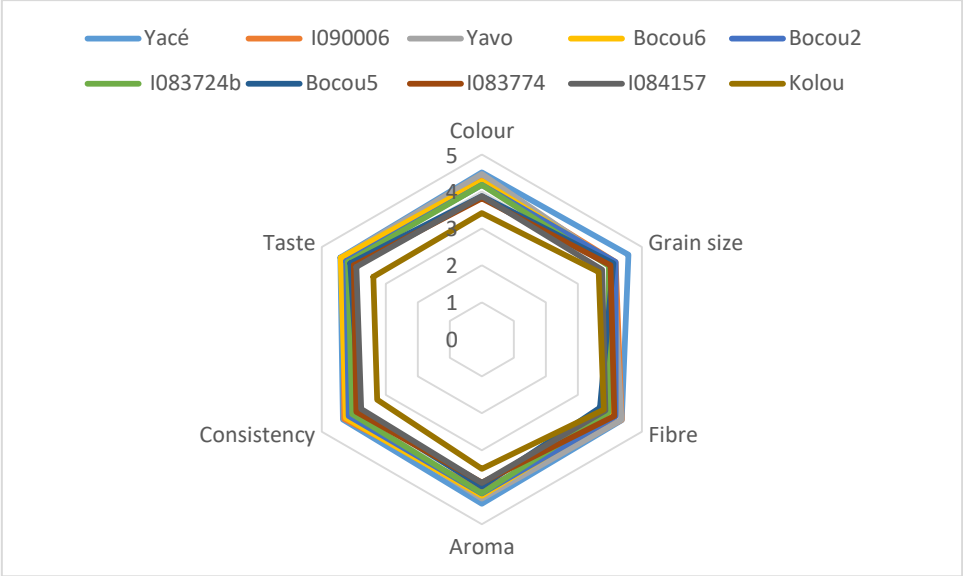

Figure 6: Sensory profile of different varieties in Sakiaré

4. DISCUSSION

In Bouaké, all cassava varieties were attacked by cassava mosaic disease and by mites. However, this disease and the attack of these pests were not severe enough on the varieties, but had a high impact on them. The low severity of the attack of these diseases and pests did not affect the yield of the varieties, as the varieties recorded a yield of more than 30 t/ha. Indeed, according to Zinga et al (2008) high mosaic severity is likely to cause the loss of half the yield of cassava tuberous roots in areas of high attack. The presence of cassava mosaic symptoms on all varieties in Bouaké (SRCV) could be explained by the presence of vegetable crops on the station. Indeed, several research studies have shown that Bemisia tabaci is the causal agent of certain diseases on several vegetable crops such as tomato (Soro et al. 2007; N'zi et al. 2010). The presence of these crops favours the movement of whiteflies on cassava. This displacement of whiteflies lead to an increase in the whiteflies population on cassava varieties and the transmission of the virus. In contrast to Bouaké, some varieties grown on the farm (Molonoublé, Okpoyou and Sakiaré) showed no symptoms of mosaic and mite attack. Mealybugs are pests that have almost disappeared from cassava fields, hence the low incidence of mealybug attack on varieties in each locality. Studies have shown that natural enemies exist against these pests, such as the wasp *Epidinocarsis lopezi* (CTA, 2008).

The yield obtained in the station is largely superior (more than double) to the yields obtained in the farming environment. There are several reasons for this difference. Indeed, the varieties planted on the station benefited from several weeding operations on demand and recorded high emergence rates. Also, on the station, the experimental plots are used extensively for rotational crops. Some of these crops (e.g. maize) benefit from fertiliser inputs. The fertiliser residues applied to the previous crop could increase the yield of cassava varieties. This observation is in line with that made by N'Zué (2007) in his work evaluating varieties on several sites. The author obtained a high yield in Man where there is also a research station. Akanvou et al (2009) also recorded a higher yield of maize at the station than in the field. According to these authors, the lack of labour on the farm for food crops could explain the yield gap. Most of the improved varieties had higher yields than the local varieties chosen as controls in each locality. Indeed, the improved varieties used were selected based on their production. Kouadio et al (2014) and Djinadou et al (2018) also showed that improved varieties yielded more than local varieties in their research work. The yield of the varieties in Sakiàré was lower than in the other zones in the farming environment because of the loss caused by rodents on the tuberous roots. The dry matter content of the coloured flesh varieties was lower than that of the white flesh varieties. In general, coloured flesh varieties have a very high water content due to the presence of sufficient carotenoid (Njenga et al., 2014). Several research studies such as those of Cissé (20 15) and N'Zué et al. (2021) have confirmed the low dry matter content of coloured flesh varieties. However, the

varieties I090006 and I084157 had the lowest yields (less than 20t/ha) in all localities combined. I090006 has small tuberous roots, while I084157 has large tuberous roots but a low emergence rate.

The varieties grown, processed and tasted by the producers were appreciated by them. With the exception of Sakiaré, where most of the coloured-flesh varieties were appreciated in the same way as the white-flesh varieties, they were less accepted in the other two localities. Despite the food habit of the Adjoukrous (Okpoyou population) who mix attiéké with red palm oil, attiéké of the coloured flesh varieties was not appreciated enough by this people. The rejection of attiéké from these varieties could be explained by the fact that the varieties in question give the desired colour, but not the taste of the oil. The work of Aboua et al (1989) showed that the evaluation of the quality of Attiéké could often be done by the appreciation of its colour. The attiéké of the improved varieties brought by the CNRA to sakiaré was more appreciated by consumers than the local variety (Kolou). Indeed, the Kolou variety is the one most used by women processors to make attiéké. However, the attiéké of this variety is depreciated the day after preparation because it turns black. In all localities, attiéké from these varieties scored from acceptable to good, i.e. none of the varieties produced poor quality attiéké.

5. CONCLUSION

The varieties used for the evaluation of agronomic and organoleptic parameters of attiéké are made up of improved and local varieties. They were tested on station (Bouaké) and in the field (Molonoublé, Okpoyou and Sakiaré). The majority of the improved varieties recorded higher yields than the local varieties in all environments and also produced good attiéké after processing the tuberous roots. The scores for the different assessment criteria ranged from 3 to 4, reflecting the acceptability of the varieties' attiéké to consumers. The varieties Bocou6, Bocou5, Bocou2, I090006 and Yavo produced attiéké of comparable quality to Yacé, which is the reference. These varieties can be selected for this purpose. However, the varieties I090006 and I084157 had lower yields in all localities.

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