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RESEARCH ARTICLE

IMPACT OF CULTURAL AND STORAGE PRACTICES ON THE SHEL LIFE OF THE YAM OF '*KPONAN*' VARIETY *(Dioscorea cayenensis-rotundata)*

Yapo Hypolithe KOUADIO[1], Kouakou Nestor KOUASSI [1,2], Yao KONAN[2,3], Yao Denis N'DRI[1] and N'Guessan Georges AMANI[1]

[1]Laboratory of Food Biochemistry and Technology of Tropical Products, Department of Food Science and Technology, Nangui Abrogoua University, BP 801, Abidjan 02, Côte d'Ivoire.
[2]Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS-CI), 01 BP 1303 Abidjan 03, Côte d'Ivoire
[3]Laboratory of Systematics Herbarium and Botanical Museum, National Center of Floristics, Félix Houphouet-Boigny University, 22 BP 582 Abidjan 22, Côte d'Ivoire

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ABSTRACT

Yam *Kponan* is an important and strategic foodstuff for many people in Côte d'Ivoire. Its losses due to rotting on storage do not ensure a regular market supply. This study was undertaken to determine the impacts of traditional cultivation and storage practices on *Kponan* (*Dioscorea cayenensis-rotundata*) rotting among producers in the departments of Bondoukou, Bouna, and Kouassi-Kouassikro. Results showed that herbicides were frequently use in the department of Kouassi-Kouassikro (88.90%) than those of Bouna (49.60%) and Bondoukou (37.00%). The methods commonly used for *KPONAN* conservation are straw huts (Bondoukou), burial or straw huts (Bouna) and shade (Kouassi-Kouassikro).. Wounding and heat remain the main factors in rotting. In addition, animals and chemicals cause rotting respectively in Bondoukou and Kouassi-Kouassikro. In field, *Kponan* shelf life varies between 1 and 6 months in Bondoukou and Bouna whereas the majority of producers in Kouassi-Kouassikro (58.52%) do not store their yams beyond one month. The length of time that *Kponan* yam is kept is influenced by the rate of herbicide use during clearing and weeding, the conservation techniques used, the experience of producers and the length of the fallow period.

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INTRODUCTION

Yam is a staple of many tropical countries particularly in West Africa, South Pacific and Asia, Central and Southern America and Caribbean (IITA, 2018). Yam is one of the most important dietary sources of energy composed mainly of starch, with some proteins, lipids, vitamins and minerals (Bhandari *et al*., 2003; Polycarp *et al*., 2012) The bulk of edible yam is produced in the *yam belt* of West and Central Africa, which accounts for approximately 97.2% world production with 73.02 million tons produced in 2017 (FAOSTAT, 2019). Côte d'Ivoire, ranked 3rd yam producing country in the world after Nigeria and Ghana, produced 7.25 million tons in 2018 on an area of 1,313,213 ha (FAOSTAT, 2020). Côte d'Ivoire leads consumption in West Africa at 331 kcal per capita per day behind Benin (395 kcal) (Laly *et al*., 2019). Yam is the main food crop in Côte d'Ivoire in terms of production (Ettien et Tschannen, 2019). Due to traditions, yam plays a vital role in feeding the population, despite the strong expansion of cassava, bananas and rice (Amani *et al*., 2008; Koné *et al*., 2016).

Despite its strong contribution to the nutritional well-being and economic of populations, yam tubers are perishable and seasonal products. The loss is however higher in early tubers (Kouamé *et al*., 2017). The storage of fresh tubers causes weight losses ranging from 65 to 85% (Chu and et Figueiredo-Ribeiro, 2002). Losses are due to rots caused by bacteria, fungi, damage during harvesting, transport, germination, dehydration, injuries during harvesting, parasites and predators (Treche, 1989; Foua- Bi, 1994; Gérardin, 1996). These losses greatly reduce yields and, consequently, the quantity of seed tubers and sometimes cause the disappearance of certain varieties. Among yams, *Kponan* variety (*Dioscorea cayenensis-rotundata*) is the most prized by consumers. *Kponan* yam sold on wholesale markets in Abidjan comes from 6 geographical origins, the main ones being Bondoukou (60%), Bouna (33.3%) and Kouassi-Kouassikro with 6.7% (Kouakou *et al*., 2019). The tubers are characterized by a high post-harvest losses rate during storage. Nevertheless, the risk of losses due to rotting is reduced in *Kponan* yam from Bondoukou.

Accordingly, some consumers are only attached to *Kponan* yam from Bondoukou (Kouakou *et al*., 2019). Moreover, *Kponan* from Zanzan, specifically from Bondoukou, are available in quantity over a long period, sometimes even throughout the year. This is due to the production strength of the region and the mastery of traditional preservation techniques (Kouakou et Anoh, 2019). According to CIDT (1987), depending on the producer's objectives, yam conservation is done using several methods: conservation in mounds, in the shade of abundant foliage, in pits, in mulches and on a vertical braid. In Bouna and Bondoukou areas, the method of storage in pits, which consists of placing the tubers vertically on top of each other with the head facing upwards, is widely practiced (CIDT,1987). This method is applied to the first harvest of early yams and is based on a market delivery strategy (CIDT, 1987). Unfortunately, only few data exist for Bouna and Bondoukou (Kouakou et Anoh, 2019; CIDT,1987) cultivation practices and no data for Kouassi- Kouassikro cultivation and storage practices. In order to understand the preference of *Kponan* from Bondoukou, the aim of this study was to identify the impacts of Bondoukou *Kponan* producers' traditional cultivation and conservation practices on *Kponan* quality compared to those of Bouna and Kouassi-Kouassikro.

MATERIALS AND METHODS

Biological material: The biological material were yams of *Kponan* variety (*Dioscorea cayenensis-rotundata*) produced in the departments of Bouna, Bondoukou and Kouassi-Kouassikro (Côte d'Ivoire).

Technical material: The technical material was consisted of a questionnaire and an interview guide. The questionnaire included questions about respondent, varieties of yams grown and cultivation techniques, and conservation practices in field.

Study area: The investigation areas for this study were the departments of Bouna, Bondoukou and Kouassi-Kouassikro which produced at least 97% of *Kponan* in Côte d'Ivoire and 100% of *Kponan* sold in Abidjan (Doumbia *et al*., 2006; Kouakou *et al*., 2019).

Target population and sampling: Preliminary investigations in the departments of Bondoukou, Bouna and Kouassi-Kouassikro focused on identifying villages that play an important role in *Kponan* yam production. Based on interviews in Agence Nationaled' Appui au Développement Rural (ANADER) of Bondoukou and Bouna, Office d'aide à la Commercialisation des Produits Vivriers (OCPV) of Bondoukou, and with the chief of the department of Kouassi-Kouassikro, 9 villages were selected, 3 villages per production area. The villages selected were no more than 45 km from their respective sub-prefectures. The villages selected in the department of Bondoukou are Flakièdougou, Sorobango, and Tambi. The villages selected in the department of Bouna are Koutouba, Gbrombiré, and Ondéfidouo. In Kouassi-Kouassikro department, the villages of Boua Kouadiokro, Guimbo N'dolikro, and Mékro were surveyed. The sample size of *Kponan* producers was obtained using a non-exhaustive independent sample formula (FAO, 1992).

$$n = \frac{t^2 \times p(1-p)}{e^2}$$

n = minimum desired sample size;
t= 95% confidence level (standard value of 1.96);

p = estimated prevalence of *Kponan* producers in the study area, p estimated at 50% since the total number of people growing *Kponan* is not known;

e = margin of error at 5% (value of 0.05).

Application: The minimum sample size required:

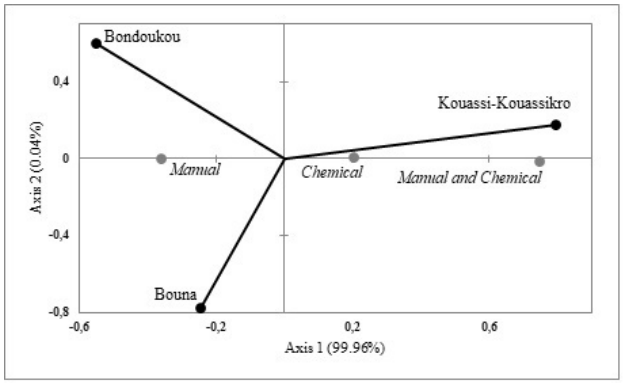
$$n = \frac{1{,}96^2 \times 0{,}5(1-0{,}5)}{0{,}05^2} \approx 385 \text{producers}$$

$n = ([1.96]^2 \times 0.5(1\text{-}0.5))/\ [0.05]^2 \approx 385$ producers

The selection of producers was made using the snowball technique. The criteria used was the representativeness of the producers by department. Twenty (20) individuals were added to compensate for the errors in the items that were poorly completed. Thus, 405 producers were surveyed, including 135 per department.

The questionnaire survey: The survey was conducted to collect quantitative and qualitative data in the three villages of each department.

A questionnaire was drawn up using SPHINX Plus^2 (V5) software (Version 4.5.0.19) in order to understand the existing relationships between storage conditions, growing conditions and the types of damage during yam storage. The questionnaire included basic questions about the respondent, the varieties of yams grown and cultivation techniques, and conservation practices in field.



Manual: Manual clearing; Chemical: Used herbicide to clear. Manual and Chemical: used the both techniques to clear

Figure 1. Land clearing by yam producers according to departments

Data analysis: The collected data were entered using SPHINX Plus² (V5) software and transferred to Excel for database setup. Statistical analyses were performed using XLSTAT 2016 software.

Comparisons between dependent variables were determined by the Chi-square test and completed by Marascuilo procedure (Marascuilo et Serlin, 1988). Descriptive statistics were used to summarize the data into graphs, box plots, means and standard deviations. Statistical significance was defined at the 5% level.

RESULTS

Socio-demographic characteristics of yam producers: The male/female ratio of yam producers in all departments surveyed was 405/0 (Table 1). Their age varied between 15 and 70 years. Those of 25 to 45 are the most important, representing 67.41% of the farmers. The smallest percentage of farmers (3.21%) are those aged 65 and over. The uneducated farmers are the most numerous (63.46%). The producers have between 1 and more than 40 years of professional experience with 6.67% of most experienced (>40 years). This group (>40 years) includes only farmers from Bondoukou (11.1%) and Bouna (8.9%).

Yam production: Cultivation practices involve several activities ranging from clearing to harvesting. Producers of Kouassi-Kouassikro (88.9%) and Bouna (49.6%) use greater quantity of herbicides for land clearing and/or weeding than those in Bondoukou (37%). The use of insecticides (16.3% in Bondoukou, 17.8% in Bouna and 20.7 in Kouassi-Kouassikro) to treat fresh tubers before planting is not significantly different (P= 0.629). The producers (Table 2) use little fertilizers with a proportion of 2.2% (Bondoukou and Kouassi-Kouassikro) and 4.4% (Bouna). Multi-crop is significantly more practiced (P< 0.01) in the department of Bouna (99.3%) than those of Bondoukou (93.3%) and Kouassi-Kouassikro (91.1%).

Table 1. Socio-demographic characteristics of *Kponan* producers

Producer characteristics	**Bondoukou**	**Bouna**	**Kouassi-Kouassikro**	**Total**
Sex ratio (M/F)	135/0	135/0	135/0	405/0
Level of education (%)				
No instruction	62.2	70.4	57.8	63.46
Primary	17.8	17.8	29.6	21.73
Koranic	2.2	0.7	0.7	1.23
Secondary	17.0	9.6	11.1	12.59
Superior	0.7	1.5	0.7	0.99
Age class (%)				
[15-24 years]	6.7	7.4	7.4	7.16
[25-45 years]	67.4	60.7	74.1	67.41
[46-54 years]	9.6	16.3	13.3	13.09
[55-64 years]	9.6	12.6	5.2	9.14
>64 years	6.7	3.0	0.0	3.21
Experiences (Years) (%)				
[1-10 years]	36.3	30.4	55.6	40.74
[11-20 years]	32.6	28.1	34.1	31.60
[21-30 years]	14.1	17.0	8.9	13.33
[31-40 years]	5.9	15.6	1.5	7.65
>40 years	11.1	8.9	0.0	6.67

Table 2. Crop characteristics of *Kponan* yam

Crop parameters	Bondoukou	Bouna	Kouassi-Kouassikro	dl	χ^2	P
Fertilizers	2.2^{a}	4.4^{a}	2.2^{a}	2	1.205	0.547
Herbicide (%)	37.00^{c}	49.6^{bc}	88.9^{a}	2	81.354	< 0.001
Insecticide (%)	16.3^{a}	17.8^{a}	20.7^{a}	2	0.926	0.629
Staking (%)	95.6^{a}	97.00^{a}	100^{a}	2	5.742	0.057
Multi-crop (%)	93.3^{b}	99.3^{a}	91.1^{b}	2	9.325	< 0.01

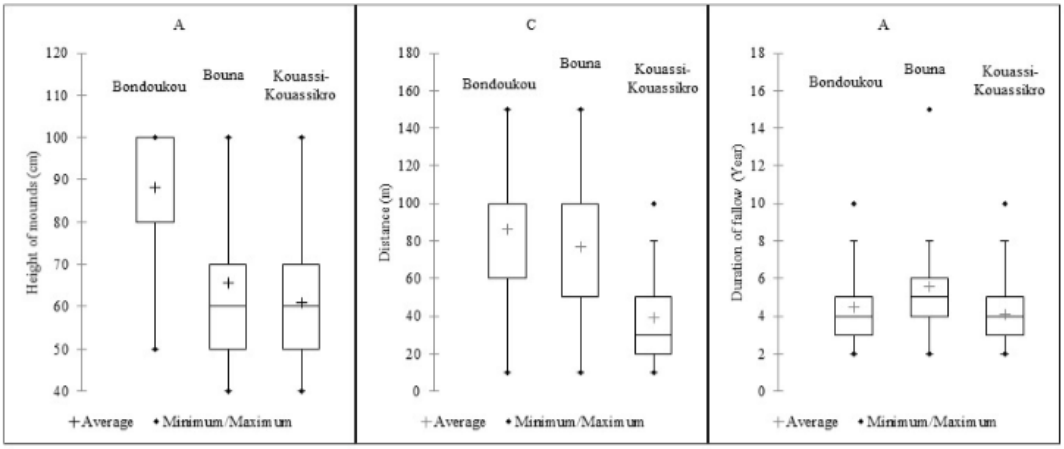


Figure 2. Height of mounds (A), distance between ridges (B) and duration of fallow (C)

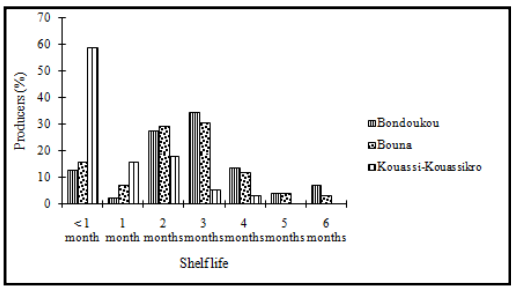


Figure 3: Shelf life of the yam *Kponan* during post-harvest storage in field

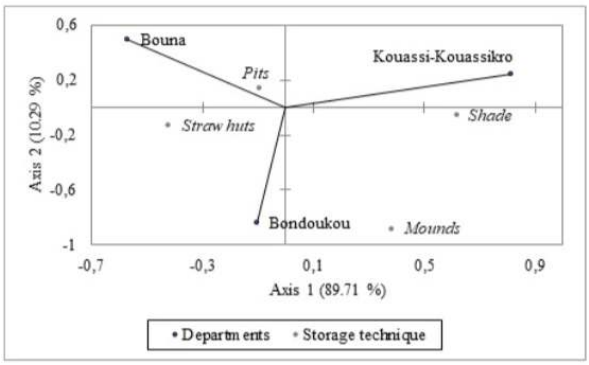


Figure 4. Yam *Kponan* storage techniques in field according to the departments

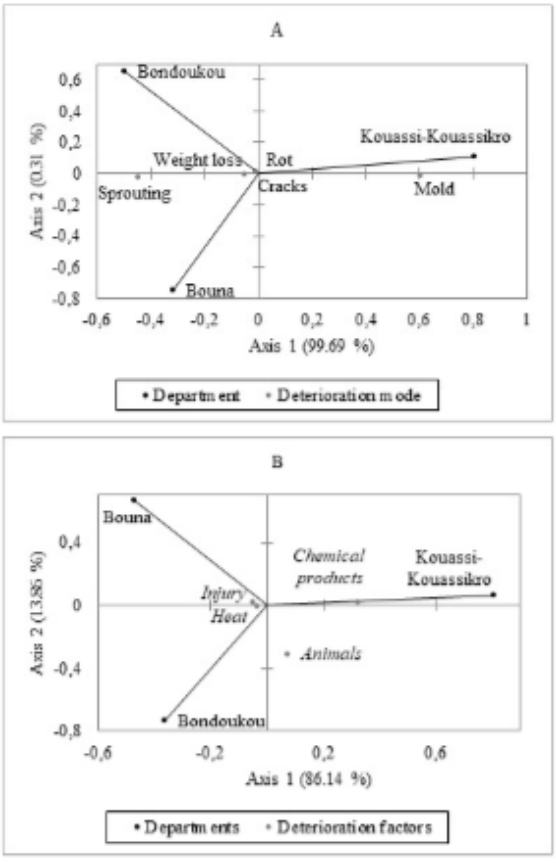


Figure 5. Deterioration modes (A) and deterioration factors of *Kponan* in field according to the departments

The producers also practice staking (93.6%, 97.00% and 100% respectively in Bondoukou, Bouna and Kouassi-Kouassikro). Fallowing is less practiced in Bouna (66.7%) and Bondoukou (74.1%) compared to Kouassi-Kouassikro (85.9%).

Land clearing: Manual clearing, chemical (herbicide) clearing, or a combination of both techniques (manual and chemical) are the means used by the producers (Figure 1). According to Correspondence Analysis (CA), the producers of the departments of Bouna and Bondoukou carry out more manual clearing than chemical clearing. Farmers from Kouassi-Kouassikro clear the land with herbicides than manual.

Ridging and fallow : The height of the mounds varies between 40 and 100 cm (Figure 2A). Bondoukou farmers make larger mounds with an average of 88.07± 16.86 cm. This average is lower in the departments of Bouna (65.7± 15.48 cm) and Kouassi-Kouassikro (61.04 ± 12.29 cm)

Table 3. Decay rate of *Kponan* yam in field

Department	Bondoukou	Bouna	Kouassi-Kouassikro	dl	χ^2	P
[1-5 %]	19.26[a]	18.52[a]	10.37[a]	2	4.875	0.087
]5-10 %]	23.70[a]	20.00[a]	21.48[a]	2	0.552	0.759
]10-15 %]	31.11[a]	27.41[a]	19.26[a]	2	5.169	0.075
]15-30 %]	17.78[a]	24.44[a]	14.81[a]	2	4.266	0.119
]30-50 %]	**8.15[b]**	**9.63[b]**	**34.07[a]**	2	40.034	**< 0.001**

Data in bold indicate significant differences at the 5% level according to the Chi-square test. χ^2: Chi-square, *P*: Probability value, dl: Degree of freedom.

The distance between mounds varies from 10 to 150 cm (Figure 2B). Bondoukou (86.15 ± 27,56 cm) recorded the highest distance between mounds and the lowest was recorded in the department of Kouassi-Kouassikro (39.18 ± 25,92 cm). After crop. After crop rotation, farmers practice fallow. The average duration of fallow is 4.49 ± 2.31 years (Bondoukou), 5.56 ± 2.37 years (Bouna) and 4.07 ± 1.53 years (Kouassi-Kouassikro) (Figure 1C).

Shelf life in field: Figure3 shows the maximum shelf life of the *Kponan* variety during post-harvest storage in the field. The shelf life for *Kponan* yams range less than one month to six months. In Bouna and Bondoukou zones, producers keep their yams up to six months compared to Kouassi-Kouassikro with a maximum of 4 months (2.96% of the producers). The majority of farmers of Bouna and Bondoukou keep their yams Between 2 months (Bondoukou (27.41%), Bouna (28.89%) and 3 months (Bondoukou (34.07%), Bouna (30.37%) in field. However, the majority (58.72%) of the producers of Kouassi-Kouassikro keep their yams less than a month.

Storage techniques: The According to Correspondence Analysis (CA) (Figure 4) showed that the most traditional conservation used by farmers are straw huts, mounds, pit and in shade. In the department of Bondoukou, straw huts are commonly used for *Kponan* storage. Bouna farmers store *Kponan* in pits or straw huts comparatively to those of Kouassi-Kouassikro whose prefer to store tubers in shade.

Deterioration modes: According to Correspondence Analysis (CA) (Figure 5A), rot, cracks and weight loss are the common damages observed in the three departments. In addition, sprouting is more observed in Bouna and Bondoukou. However, in Kouassi-Kouassikro, it is rather the attack of mold that is observed more by producers.

***Deterioration factors**:* According to Correspondence Analysis (CA) (Figure 5B), the producers of the three zones, injury and heat are the common deterioration factors during *Kponan* storage in field. The causes of *Kponan* tubers deterioration in Bondoukou and Kouassi-Kouassikro zones are also animals (rats). Nevertheless, in the department of Kouassi-Kouassikro, chemicals products (herbicide and fertilizer) are incriminated as the main factor of deterioration of *Kponan* in field.

***Decay rate**:* The rate of rotting of *Kponan* yam in field conservation varies between 1 and 50% (Table 3). The majority of producers surveyed in the departments of Bondoukou (31.11%) and Bouna (27.41%) lose between 10 and 15% of their yams during conservation in the field. However, the majority of producers in the department of Kouassi-Kouassikro (34.07%) lose between 30 and 50% of the yams during conservation in the field.

DISCUSSION

The objective of this study was to relate cultivation and storage practices to deterioration of *Kponan* in field. The results showed that cultivation and storage practices contribute to the rapid deterioration of *Kponan* tubers in the field. Indeed, cultural practices reveals that producers in the department of Kouassi-Kouassikro (88.9%) use more herbicides for defoliation and weeding compared to those of the departments of Bouna (49.6%) and Bondoukou (37%). These finding corroborate those of (Kouakou et. Anoh, 2019) where they pointed out that 7% of the producers using chemical fertilizers on the one hand and 60% using pesticides on the other hand. The high use of herbicides particularly in the department of Kouassi-Kouassikro could induce a high rate (30 to 50%) of rotting of *Kponan* yam in this locality. These results are in agreement with those of Kouakou et Anoh (2019) who state that there is a link between the use of chemical fertilizers and pesticides and the shelf life of *Kponan* yam. For these authors, chemical fertilizers or pesticides provoke a considerable decrease in the shelf life of *Kponan* yams even when buried in the ground. According to (Ngue *et al*., 2007), if higher doses of phosphorus (super simple, super triple) or potassium (chloride or sulfate of potash) are applied than nitrogen, the harvested tubers keep better and germination is reduced. Yam therefore needs a balanced fertilization. However, it is important to ascertain the chemical composition of the soil before using mineral fertilizers, which is not obvious to the average producer. Organic fertilizers are therefore strongly recommended (Ngue *et al*., 2007).

In the departments of Bondoukou and Bouna, the shelf life of *Kponan* yam in the field varies up to 6 months. However, the majority (58.72%) of the producers of Kouassi-Kouassikro keep their yams less than one month. The short storage times in the departments of Kouassi-Kouassikro are thought to be influenced by yam producer practices and storage methods used. Indeed, data showed that Bondoukou and Bouna yam producers use pit and strawbale storage methods comparatively to those of Kouassi-Kouassikro where conservation in the shade under a tree is more widely used. Kouakou et Anoh (2019) supported this hypothesis, that *Kponan* yam has a relatively shorter shelf life (2-3 months in the open air). For them, this shelf life can be optimized by pit storage. According to these same authors, with the pit storage method, *Kponan* yam can be stored for up to 6 months. Rot, cracks and weight loss are the common damages encountered by the producers. Heat and injury are the most common deterioration factors in all the departments. These results corroborate those of several authors (Gérardin, 1996; Tschannen *et al*., 2003; Mahyao, 2008) who indicated that the losses during storage are metabolic (dehydration, respiration, transpiration, germination) and parasitic (rodents, insects, pathogens). In addition, the high-water content of the tubers, associated with the injuries they suffer at harvest or after, expose them to microorganisms. According to Kouakouet Anoh (2019), to better preserve *Kponan* yam, it will also need to be harvested with great care. When tubers are injured, they are no longer suitable for burial and must be consumed within a short period at the risk of registering them as post-harvest losses. Several authors (Onwueme, 1978) have shown that the dehydration of tubers during storage is responsible for losses which can amount to 20% of the initial mass of the tuber. Water loss is the main decrease in fresh mass of the tuber during the dormant phase (Passam *et al*., 1978). The shelf life of tubers is inversely proportional to their respiratory intensity (Burton, 1974; Shippers, 1977). It is increased by tuber wounds (Kleinkopf, 1995). Respiration is accompanied by the phenomenon of transpiration, which accentuates the loss of weight and the softening of the tubers (Lisinska et Leszczynski, 1989). The shelf life of yams is influenced by several other factors, including soil type, harvesting technique and storage temperature. Indeed, clay soils have a relatively higher humic concentration than sandy soils, which ensures good maturity of the yam and, by extension, a good shelf life (Kouakou et Anoh, 2019). According to the same authors, the high nitrogen input significantly reduces the dry matter content of yam and makes it more vulnerable to the effect of heat, which accelerates its decomposition.

CONCLUSION

This study shows that the producers of Bouna and Bondoukou keep their yams longer between 2 and 3 months, and the majority of producers in Kouassi-Kouassikro keep their yam in less than a month. The storage time is influenced by clearing, weeding and conservation techniques. The farmers of Kouassi-Kouassikro use more herbicide than those of Bouna and Bondoukou. In the departments of Bouna and Bondoukou, producers use more pits and straw huts contrary to those of Kouassi-Kouassikro where the conservation in the shade is more used.

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