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Impacts of Field Harvesting and Conservation Practices on the Physical Quality of Yam "*Kponan*" (*Dioscorea cayenensis-rotundata*) of Côte d'Ivoire

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Abstract

Yam "*Kponan*" (*Dioscorea cayenensis-rotundata*) is a popular staple food in Côte d'Ivoire. However, its rapid decay during conservation prevents regular supply of markets. The objective of this study was therefore to assess the impact of field cultivation and conservation practices on some physical quality parameters of "*Kponan*". To this end, "*Kponan*" yam from three production areas (Bondoukou, Bouna, Kouassi-Kouassikro) was cultivated in each area. At maturity, physical parameters of yams at harvest and after 3 months of storage in field were analyzed. The results showed that injury was the most significant deterioration in yam harvest. The rate of injured yams was highest for hoe-harvested in Kouassi-Kouassikro area (16.67% - 22.22%) regardless of the origin of the cuttings. The main damage observed after the 3 months of storage was rots (22.86% - 60.00%) and weight loss (8.57% - 42.86%). However, yams stored in pits in Bouna zone had less damage (40% - 48.87%) than those stored under straw huts in Bondoukou locality (100%) and at shade under a tree in Kouassi-Kouassikro area (100%). In conclusion, the physical quality of "*Kponan*" in field is most affected by abusive use of herbicides during weeding and clearing, hoe harvesting and storage in the shade under a tree.

Keywords

"*Kponan*" Yam, Post-Harvest Loss, Cultivation Practices, Conservation Practices, Physical Quality

1. Introduction

Among the tuber root plants, yams, belonging to the genus Dioscorea are cultivated worldwide and there are about 600 species, of which 90 are considered edible [1] [2]. Yam is a staple food for over 500 million people in some tropical countries in Africa, the Caribbean, Oceania, the Pacific and Latin America [3] [4]. Yam is one of the most important dietary sources of energy consisting mainly of starch, dietary fiber with some proteins, lipids, vitamins and essential minerals [5]. Its production is mainly concentrated (more than 94% of world production) in West Africa, where it plays a very important role in the food security of at least 60 million people [4] [6] [7] [8]. Farmers grow yam for self-consumption and also generate income by marketing the surplus [9]. As a result, yam has become a cash crop that feeds urban markets [10] [11]. Nigeria is by far the largest yam producer in the world, with more than 50 million tons, or more than 66.89% of world production, estimated at 74.83 million tons in 2020 [4].

In Côte d'Ivoire, yam production is steadily increasing. Between 1971 and 2020, it increased considerably, from 1.56 million tons to 7.65 million tons. This annual rate of increase peaked at 18.03% in 1973 and then declined to 2.74% in 2020 [4]. In 2020, Ivorian production was 7.65 million tons, or 10% of world production, which ranks Côte d'Ivoire as the third largest yam producer after Nigeria (67%) and Ghana (11%) [4]. Yam occupies the first place in the production of food crops [12] and places Côte d'Ivoire at the top of consumption in West Africa with 331 kcal per capita and per day behind Benin (395 kcal) [13].

The factors that affect the yield of yams are rainfall and temperature. Among the yams, the varieties of the *Dioscorea cayenensis-rotundata* complex are much more susceptible to rot [12]. Of these varieties, "*Kponan*" is most popular among consumers in the city of Abidjan [14] [15] [16], but most prone to rotting during storage [16].

Yam "*Kponan*" sold on the wholesale markets of Abidjan comes from 6 geographical origins, the main ones being Bondoukou (60%), Bouna (33.3%) and Kouassi-Kouassikro (6.7%) [15]. Despite the importance of yam in the food system in Côte d'Ivoire, annual yam production is still insufficient to meet food needs due to the conservation of tubers [17]. This conservation of fresh yam tubers results in weight losses ranging from 65% to 85% [17] and losses of up to 50% of the crop due to dehydration, crop injury, parasites, rats and the use of chemicals [12]. Therefore, these losses greatly reduce yields, and consequently the quantity of seed tubers and sometimes cause the disappearance of certain varieties. According to several authors [11], grow, harvest and storage techniques of "*Kponan*" in the field or in urban stores had an impact on its shelf life. Unfortunately, no studies have yet assessed the level of damage of "*Kponan*" yam due to cultivation and conservation practices in Côte d'Ivoire. The objective of this study was therefore to determine the impact of harvesting and field storage practices on the vulnerability of "*Kponan*" yam in the three main production areas.

2. Materials and Methods

2.1. Study Areas

The study took place in the main "*Kponan*" yam production localities that supply the wholesale markets of Abidjan. These zones are the departments of Bouna, Bondoukou and Kouassi-Kouassikro [15]. Bondoukou is the capital of the Gontougo region and is located in the northeast of Côte d'Ivoire at 420 km from Abidjan. Bouna is the capital of the Bounkani region in the northeast of Côte d'Ivoire and is located at 603 km from Abidjan near the border with Ghana. Kouassi-Kouassikro is the capital of the sub-prefecture and department of Kouassi-Kouassikro located in the N'Zi region in the center of Côte d'Ivoire and is located at 232 km from Abidjan.

2.2. Biological Material

The biological material consists of "*Kponan*" yam variety (*D. cayenensis-rotundata*) produced in the departments of Bondoukou, Bouna and Kouassi-Kouassikro.

2.3. Methods

2.3.1. Implementation of the Experimental Device

In each of the three localities, "*Kponan*" yams from Bouna, Bondoukou and Kouassi-Kouassikro were cultivated on the same plot while retaining the cultivation techniques of a producer chose par zone. The plot (1500 m^2) was arranged in complete, randomized and balanced compartments, comprising 3 blocks or replicates B1, B2 and B3 (**Figure 1**). Each block was made up of 3 elementary plots (EP) corresponding to the three types of cutting (Bouna, Bondoukou and Kouassi-Kouassikro). The planting density was 270 mounds per block with an experimental unit or 90-mounds EP (**Figure 2**). Two factors were related to the experimental plots: the origin of the "*Kponan*" cuttings and the type of practices of the producer. The practical factor for the producer included two modalities, cultivation practices and conservation practices. Of these experimental devices, yams harvested at physiological maturity (6 months) were codified as follows:

- "*BnBn*": "*Kponan*" Yam from Bouna cultivated in Bouna area;
- "*BnKk*": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bouna area;
- "*BnBd*": "*Kponan*" Yam from Bondoukou cultivated in Bouna area;
- "*BdBn*": "*Kponan*" Yam from Bouna cultivated in Bondoukou area;
- "*BdKk*": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bondoukou area;
- "*BdBd*": "*Kponan*" Yam from Bondoukou cultivated in Bondoukou area;
- "*KkBn*": "*Kponan*" Yam from Bouna cultivated in Kouassi-Kouassikro area;
- "*KkKk*": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Kouassi-Kouassikro area;
- "*KkBd*": "*Kponan*" Yam from Bondoukou cultivated in Kouassi-Kouassikro area.

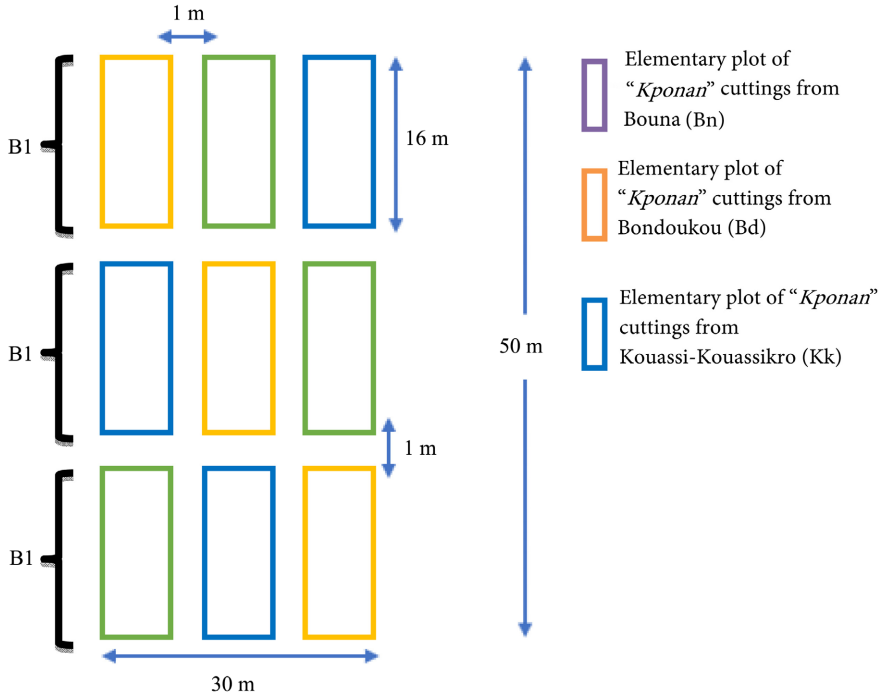

Figure 1. Experimental arrangement of the "*Kponan*" yam growing plot.

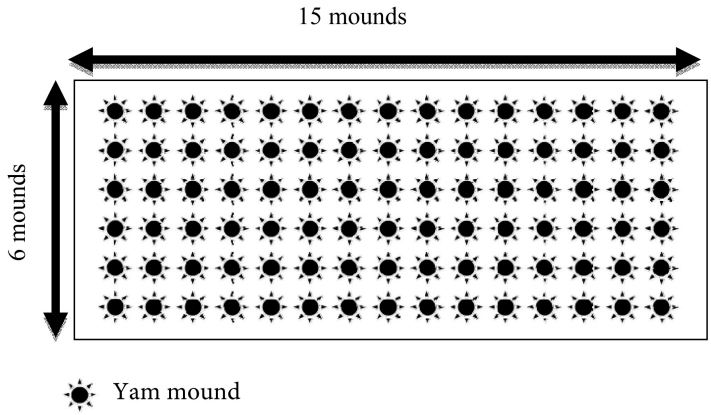

Figure 2. Density of the "*Kponan*" yam elemental parcel.

2.3.2. Yam Cultivation, Harvesting and Conservation Practices

The cultivation and storage of "*Kponan*" yam were done in each area keeping practices of a local producer. The first harvest of yam was done at 6 months of physiological maturity in August 2021. In the department of Bouna and Bondoukou, machete harvesting was carried out while hoe harvesting was used in Kouassi-Kouassikro department (Table 1). The yams in each elementary plot were harvested separately according to their origin, *i.e.* 3 groups per origin. Nine (9) groups were formed according to factorial design of 3 blocks × 3 elementary plots. Each group of yams was kept separately for 3 months in field. In Bouna area, yams were stored in pits about 1 m deep, in which the tubers are stored vertically. Large tubers are placed in the bottom, head up and tail down, and medium-sized tubers are placed on top before being covered with soil. In

Table 1. Yam cultivation, harvesting and conservation practices per area.

Area	Environmental conditions of yam growing	Cultivation practices	Harvesting practices	Conservation practices
Bondoukou	- Tree savannah vegetation - Ferruginous soil - Average rainfall: 1284.3 mm Average temperature: 26.80˚C	- Mixed cropping - Herbicide clearing - Hand weeding	Machete harvesting	Pit
Bouna	- Tree savannah vegetation - Ferruginous soil - Average rainfall: 245.4 mm (January-Jun) Average temperature: 26.80˚C	- Polyculture - Herbicide clearing - Hand weeding	Machete harvesting	Straw
Kouassi-Kouassikro	- Pre-forest area - Ferralitic soil - Average rainfall: 1193.1 mm Average temperature: 27.80˚C	- Mixed cropping - Herbicide clearing - Herbicide and manual weeding	Hoe harvesting	Shading

Bondoukou area, yams were stored on the ground in straw hut where hut (2 m^2) was built with branches of trees and corn stems and then covered with straw, under a tree and well ventilated. A makeshift door was made using tree branches to keep the entrance of the straw well closed. For Kouassi-Kouassikro, the yams were open air stored in the shade of a tree (Table 1).

2.3.3. Determination of Physical Characteristics of "*Kponan*" Yam at Harvest

1) Germination rate

The germination rate was calculated as the ratio of the number of sprouted mounds to the total number of mounds planted [18].

$$\text{Germination rate} = \frac{\sum \text{Sprouted mounds}}{\text{Total mounds planted}} \times 100 \quad (1)$$

2) Damage rate

The non-harvest damage rate was calculated as the ratio of yams pre-harvest damaged by rot, mold, rodent and insect attacks to the total number of yams harvested.

$$\%\ \text{Non-harvest damage} = \frac{\sum \text{Damaged yams before harvest}}{\text{Total yams harvested}} \times 100 \quad (2)$$

The harvest damage rate was calculated as the ratio of yams tubers injured or broken during harvest to the total number of yams harvested.

$$\%\ \text{Harvest damage} = \frac{\sum \text{Yams damaged during harvest}}{\text{Total yams harvested}} \times 100 \quad (3)$$

The healthy yam rate was calculated as the ratio of undamaged yams at harvest by the total number of yams harvested.

$$\%\ \text{Healthy yams} = \frac{\sum \text{Yams not damaged}}{\text{Total yams harvested}} \times 100 \quad (4)$$

3) Yield of yams

a) Tuber mass

Tuber mass was determined using a pre-calibrated hand scale which displays the mass directly on screen. Tubers were weighed individually and average mass (kg) was selected [19].

b) Tuber length

Tuber length (cm) was determined by measuring each tuber with one tape meter from head to tail. Tubers were measured individually and average length (cm) was selected [19].

c) Tuber circumference

Circumference (cm) was determined by measuring the contour of median portion of each tuber using a tape meter. Tubers were measured individually and average circumference (cm) was selected [19].

2.3.4. Determination of Physical Characteristics of "*Kponan*" Yam after 3 Months of Field Storage

1) Damage rates and types

The type of damage was identified by visual observations. The rate of damage per type was calculated as a ratio of each damage caused on yams to total yams in storage.

$$\%\ \text{Damage} = \frac{\sum \text{Damaged Yams}}{\text{Total yams storaged}} \times 100 \tag{5}$$

2) Weight loss

Weight loss (M) was determined by simple weighing (kg) and expressed as a percentage of initial mass loss of tubers in storage [20].

$$\%\ M = \frac{M_i - \sum M_t}{M_i} \times 100 \tag{6}$$

M_i: Initial mass of tubers at harvest;

M_t: Final mass of tubers after storage.

2.3.5. Statistical Treatment

A variance analysis (ANOVA) was performed with Stastica 7.1 software to compare averages. The differences were showed by Tukey test at significance threshold of 5%.

3. Results

3.1. Physical Characteristics of "*Kponan*" at Harvest

3.1.1. Rate of Deterioration at Harvest

The main characteristics related to the damage of "*Kponan*" yams during harvesting are summarized in **Table 2**. The planting rate of "*Kponan*" yam cuttings was 100% for all plots. However, the germination rate of cuttings ranged from 96.67% (BdBn) to 100% for most growing areas. The rate of deterioration of yam tubers at harvest ranged from 8.89% to 22.22% with a strong deterioration

Table 2. Characteristics of "*Kponan*" yam damage at harvest.

Origins of "*Kponan*"	Planting rate (%)	Germination rate (%)	Damage rate (%)	Harvest-related damage (%)	Non-harvest damage (%)
BdBd	100	100	8.89	75	25
BdBn	100	96.67	11.49	90	10
BdKk	100	100	10.00	100	0
BnBd	100	97.78	12.50	90.91	9.09
BnBn	100	100	14.44	84.62	15.38
BnKk	100	97.78	9.09	100	0
KkBd	100	100	16.67	93.33	6.67
KkBn	100	100	18.89	88.24	11.76
KkKk	100	100	22.22	80	20

"BnBn": "*Kponan*" Yam from Bouna cultivated in Bouna area, "BnKk", "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bouna area, "BnBd": "*Kponan*" Yam from Bondoukou cultivated in Bouna area, "BdBn": "*Kponan*" Yam from Bouna cultivated in Bondoukou area, "BdKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bondoukou area, "BdBd": "*Kponan*" Yam from Bondoukou cultivated in Bondoukou area, "KkBn": "*Kponan*" Yam from Bouna cultivated in Kouassi-Kouassikro area, "KkKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Kouassi-Kouassikro area, "KkBd": "*Kponan*" Yam from Bondoukou cultivated in Kouassi-Kouassikro area.

observed in all yams harvested at Kouassi-Kouassikro with 16.67% for yams from Bondoukou (KkBd), 18.89% for yams from Bouna (KkBn) and 22.22% for yams from Kouassi-Kouassikro (KkKk). The high proportion of damage observed is related to the harvest as regards 75% of Bondoukou yams cultivated in Bondoukou zone (BdBd), 100% of Kouassi-Kouassikro yams cultivated in Bondoukou zone (BdKk) and 100% of Kouassi-Kouassikro yams cultivated in Bouna zone (BnKk). In contrast, a small percentage of damage (6.67%) of Bondoukou yams cultivated in Kouassi-Kouassikro zone (KkBd) and 25% of Bondoukou yams cultivated in Bondoukou (BdBd) damage are unrelated to harvest.

3.1.2. Modes of Deterioration at Harvest

Figure 3 showed that the most significant damage to "*Kponan*" yam at harvest was injury. Tuber injury was higher for all yams cultivated in Kouassi-Kouassikro regardless of the origin of the cuttings. These injury rates were estimated at 17.78% for yams from Kouassi-Kouassikro (KkKk), 16.67% for yams from Bouna (KkBn) and 15.56% for yams from Bondoukou (KkBd). However, Bondoukou yams cultivated in Bondoukou area (BdBd), Kouassi-Kouassikro yams cultivated in Bouna area (BnKk), and Kouassi-Kouassikro yams cultivated in Bondoukou area (BdKk) had low injury rates of 8.89%, 9.09%, and 10.00%, respectively. After injury, rots and yam cracks were the lowest alterations observed with rates of 1.14% to 2.22% and 1.11% to 2.22%, respectively.

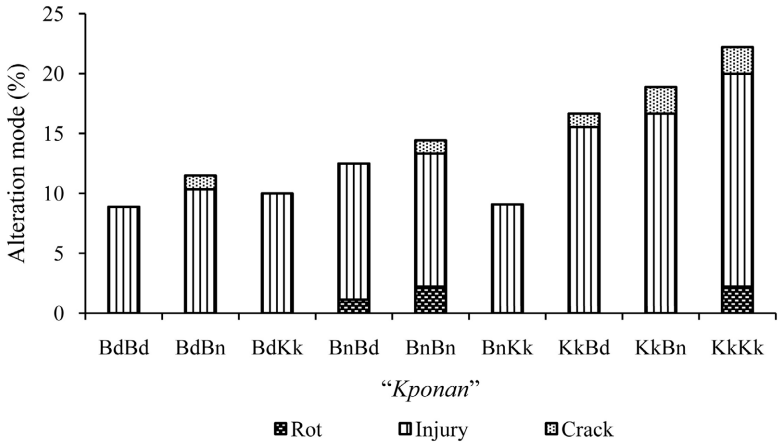

Figure 3. Alteration mode of Yam tubers "*Kponan*" at harvest. "BnBn": "*Kponan*" Yam from Bouna cultivated in Bouna area, "BnKk" "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bouna area, "BnBd": "*Kponan*" Yam from Bondoukou cultivated in Bouna area, "BdBn": "*Kponan*" Yam from Bouna cultivated in Bondoukou area, "BdKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bondoukou area, "BdBd": "*Kponan*" Yam from Bondoukou cultivated in Bondoukou area, "KkBn": "*Kponan*" Yam from Bouna cultivated in Kouassi-Kouassikro area, "KkKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Kouassi-Kouassikro area, "KkBd": "*Kponan*" Yam from Bondoukou cultivated in Kouassi-Kouassikro area.

3.1.3. Distribution of Mass at Harvest

Figure 4(a) showed that the mass (kg) of "*Kponan*" yam tubers at harvest ranged from 1.89 ± 0.72 kg to 2.57 ± 0.88 kg. The low-mass tubers (average mass < 2.30 ± 0.24 kg) are those of Bouna cultivated at Bouna (BnBn), Kouassi-Kouassikro cultivated at Bouna (BnKk) and Bondoukou cultivated at Bouna (BnBd) with respective masses of 2.11 ± 0.82 kg, 2.02 ± 0.79 kg and 1.89 ± 0.72 kg. The "*Kponan*" yams of Bouna (2.36 ± 0.95 kg) and Kouassi-Kouassikro (2.47 ± 0.84 kg) harvested in Bondoukou area (BdBn and BdKk respectively), and those of Bondoukou (2.56 ± 0.80 kg), Bouna (2.57 ± 0.88 kg) and Kouassi-Kouassikro (2.46 ± 0.93 kg) harvested in Kouassi-Kouassikro area (KkBb, KkBn and KkKk respectively) have the highest masses with an average value greater than 2.30 ± 0.24 kg.

3.1.4. Distribution of Circumference at Harvest

The diameter of the "*Kponan*" yams at harvest ranged from 29.93 ± 6.61 to 36.71 ± 5.07 cm (**Figure 4(b)**). Yams with larger diameter were those of Bouna cultivated in Bondoukou area (BdBn: 36.71 ± 5.07 cm), Bondoukou cultivated in Bondoukou area (BdBd: 33.68 ± 6.02 cm) and Bondoukou cultivated in Kouassi-Kouassikro area (KkBd: 35.72 ± 8.03 cm). With a diameter of 33.09 ± 6.38 cm, the tubers of Kouassi-Kouassikro yams cultivated in Kouassi-Kouassikro zone (KkKk) were those of medium diameter. In contrast, the diameters of Bondoukou, Bouna and Kouassi-Kouassikro yams cultivated in Bouna area (29.93 ± 6.91 cm, 31.25 ± 6.01 cm and 31.91 ± 5.94 cm, respectively) and Kouassi-Kouassikro yams cultivated in Bondoukou area (32.70 ± 6.13 cm) had the smallest circumference.

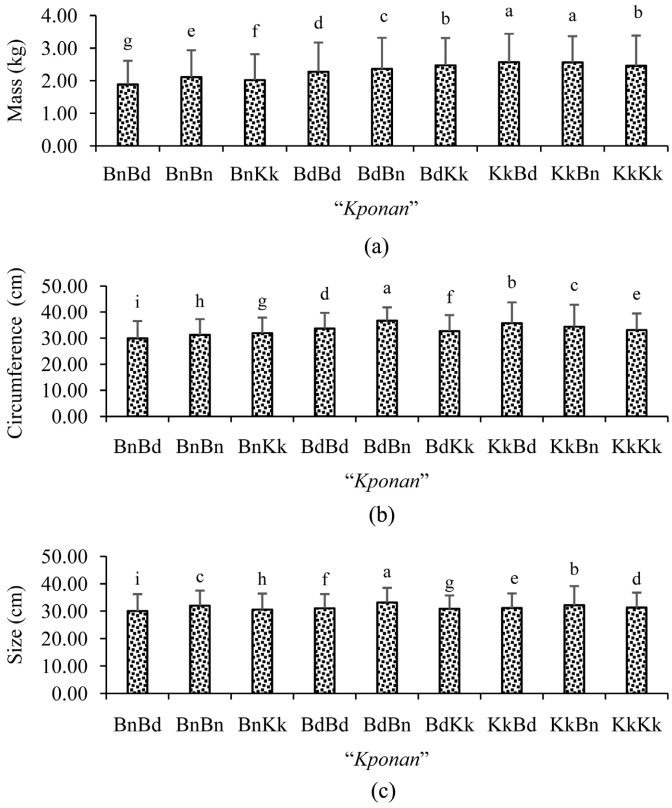

Figure 4. Distribution of mass (a), circumference (b) and length (c) of "*Kponan*" yam at harvest. "BnBn": "*Kponan*" Yam from Bouna cultivated in Bouna area, "BnKk" "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bouna area, "BnBd": "*Kponan*" Yam from Bondoukou cultivated in Bouna area, "BdBn": "*Kponan*" Yam from Bouna cultivated in Bondoukou area, "BdKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bondoukou area, "BdBd": "*Kponan*" Yam from Bondoukou cultivated in Bondoukou area, "KkBn": "*Kponan*" Yam from Bouna cultivated in Kouassi-Kouassikro area, "KkKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Kouassi-Kouassikro area, "KkBd": "*Kponan*" Yam from Bondoukou cultivated in Kouassi-Kouassikro area.

3.1.5. Distribution of Length at Harvest

Figure 4(c) showed the length of "*Kponan*" yam tubers at harvest. The longest tubers were those of Bouna cultivated in Bondoukou area (BdBn), Kouassi-Kouassikro (KkBn) and Bouna (BnBn) with lengths of 33.16 ± 5.34 cm, 32.17 ± 6.99 cm and 32.04 ± 5.49 cm, respectively. Mean sizes were observed in Kouassi-Kouassikro yams cultivated in Kouassi-Kouassikro zone (KkKk) (31.32 ± 5.50 cm) and Bondoukou yams cultivated in Kouassi-Kouassikro area (KkBd) (31.18 ± 5.35 cm). Small sizes were recorded in Bondoukou yams cultivated in Bouna (BnBd: 30.07 ± 6.14 cm) and Kouassi-Kouassikro yams cultivated in Bouna (BnKk: 30.59 ± 5.89 cm).

3.2. Physical Characteristics of "*Kponan*" after 3 Months in Field Storage

3.2.1. Modes of Alteration in Field Storage

Data of **Figure 5** showed that yam rot was the most common damage mode in

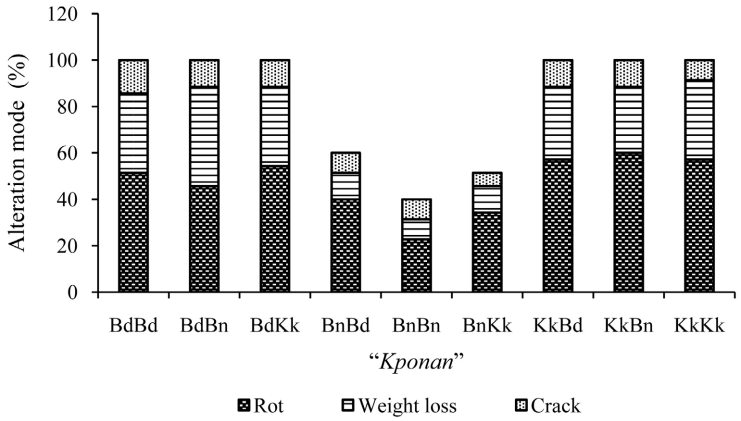

Figure 5. Variation in deterioration mode of "*Kponan*" yam in field storage. "BnBn": "*Kponan*" Yam from Bouna cultivated in Bouna area, "BnKk" "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bouna area, "BnBd": "*Kponan*" Yam from Bondoukou cultivated in Bouna area, "BdBn": "*Kponan*" Yam from Bouna cultivated in Bondoukou area, "BdKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bondoukou area, "BdBd": "*Kponan*" Yam from Bondoukou cultivated in Bondoukou area, "KkBn": "*Kponan*" Yam from Bouna cultivated in Kouassi-Kouassikro area, "KkKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Kouassi-Kouassikro area, "KkBd": "*Kponan*" Yam from Bondoukou cultivated in Kouassi-Kouassikro area.

yams. Bouna tubers cultivated in Kouassi-Kouassikro zone (KkBn) had the highest rate of rot (60%) after 3 months of field storage, followed by Bondoukou and Kouassi-Kouassikro tubers cultivated in Kouassi-Kouassikro area (KkBd and KkKk, respectively). However, Bouna tubers cultivated in Bouna area (BnBn) had the lowest rate of rot (22.86%). Weight loss was the second most important mode of deterioration after rotting. The percentage of dehydrated tubers ranged from 8.57% (BnBn) to 42.86% (BdBn). Yam crack was the lowest mode of deterioration (5.71% - 14.29%).

3.2.2. Loss Rate in Field Storage

The rate of loss of "*Kponan*" after 3 months of field storage ranged from 40% to 100% (**Figure 6**). The yams stored in pits in Bouna zone (BnBd, BnBn and BnKk) had loss rates of 42.86%, 40% and 48.57% respectively, while those stored in straw huts in Bondoukou zone (BdBn, BdBd and BdKk) and in the open air under trees in Kouassi-Kouassikro zone were all damaged (100%) after 3 months of conservation.

3.2.3. Weight Loss in Field Storage

Figure 7 showed the mass losses of "*Kponan*" tubers after three (3) months of field storage. The largest mass losses were recorded after three months of storage in the pit at Bouna (8.43% - 8.83%). The mass losses are respectively 179.43 ± 0.92 g (BnBn), 174 ± 0.76 g (BnBd) and 173.71 ± 0.76 g (BnKk).

4. Discussion

The objective of this study was to highlight the impacts of field cultivation and

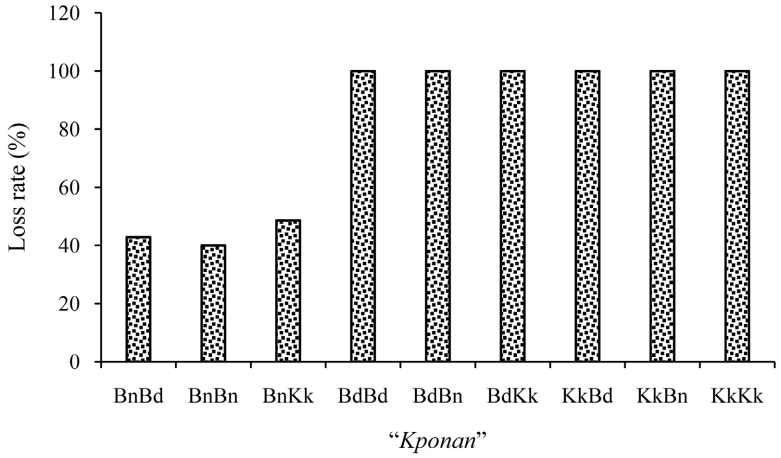

Figure 6. Variation in Yam "*Kponan*" Loss Rate after 3 months of field storage. "BnBn": "*Kponan*" Yam from Bouna cultivated in Bouna area, "BnKk" "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bouna area, "BnBd": "*Kponan*" Yam from Bondoukou cultivated in Bouna area, "BdBn": "*Kponan*" Yam from Bouna cultivated in Bondoukou area, "BdKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bondoukou area, "BdBd": "*Kponan*" Yam from Bondoukou cultivated in Bondoukou area, "KkBn": "*Kponan*" Yam from Bouna cultivated in Kouassi-Kouassikro area, "KkKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Kouassi-Kouassikro area, "KkBd": "*Kponan*" Yam from Bondoukou cultivated in Kouassi-Kouassikro area.

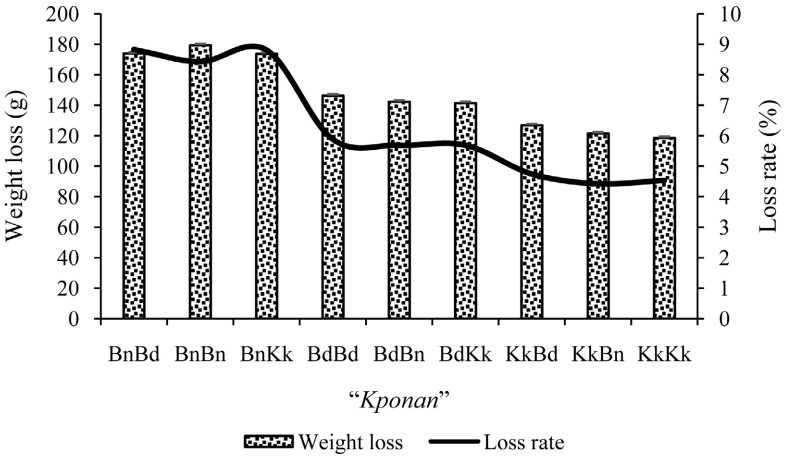

Figure 7. Variation in weight loss of "*Kponan*" yam after 3 months of field storage. "BnBn": "*Kponan*" Yam from Bouna cultivated in Bouna area, "BnKk" "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bouna area, "BnBd": "*Kponan*" Yam from Bondoukou cultivated in Bouna area, "BdBn": "*Kponan*" Yam from Bouna cultivated in Bondoukou area, "BdKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Bondoukou area, "BdBd": "*Kponan*" Yam from Bondoukou cultivated in Bondoukou area, "KkBn": "*Kponan*" Yam from Bouna cultivated in Kouassi-Kouassikro area, "KkKk": "*Kponan*" Yam from Kouassi-Kouassikro cultivated in Kouassi-Kouassikro area, "KkBd": "*Kponan*" Yam from Bondoukou cultivated in Kouassi-Kouassikro area.

conservation techniques on the physical quality of "*Kponan*" yam. The results showed that in Bouna and Bondoukou area, the harvest is generally carried out with machete with 8.89% to 14.44% damage, while in Kouassi-Kouassikro it is

carried out with hoe with 16.67% to 22.22% damage. The main damage to the harvest is the injury (75% - 100%) which is most often responsible for the rapid decay of the "*Kponan*" yam during its conservation. This hypothesis is supported by [15] who showed that for harvested tubers to have a long shelf life, they must not be injured during harvesting. When tubers are injured, they are no longer suitable for burial and must be consumed within a short period of time, at the risk of post-harvest losses [15]. According to [21], the high-water content of fresh tubers, associated with injury during or after harvest, exposes them to microorganisms.

At harvest, yams had a mass of between 1.89 and 2.57 kg. These results are corroborated by those of [22] which showed that the average weight of the tuber of "*Kponan*" is 1.83 kg. However, according to the same author, this weight varies and can reach 5 - 8 kg of fortified land [22]. The data also showed that the low-mass tubers were harvested at Bouna (1.89 ± 0.72 kg to 2.11 ± 0.82 kg) and the medium-mass tubers were harvested at Bondoukou (2.28 ± 0.90 kg). These differences in mass could be explained by rainfall. Although "*Kponan*" yam is not very rainy, its yield is negatively influenced by rain [11]. This is mainly the case in Zanzan (Bouna and Bondoukou) where [11] reported that when rain does not come in a timely manner, especially during the sowing period, yield is medium [11] as observed by the data in this study.

After the 3 months of field storage, rot (22.86% - 60.00%) was the most significant injury recorded. These results corroborate those of several authors [16] [23], who identified rot and weight loss as the main damages recorded when "*Kponan*" was kept under the influence of heat. Losses attributed to more than 30% to 50% during field storage were attributable to insects, rats and chemicals [23]. These rots are caused by fungal agents (*Penicillium sp.*, *Aspergillus sp.*, *Botryodiplodia sp.*, *Mucor sp.*, *Colletotrichum sp.*) which enter the tissues of tubers injured by insects, nematodes and by mechanical actions during and after harvest [24] [25].

Furthermore, study data showed that Bouna pit keeping deteriorated less for "*Kponan*" yam (42.86% - 48.57%) compared to Bondoukou straw keeping (100%) and Kouassi-Kouassikro shade (100%) regardless of the origin of the cultivated yams. These results corroborate with those of [15], which showed that "*Kponan*" yam has a relatively shorter shelf-life (2 - 3 months) in the open air. This conservation can even be optimized in pits for up to 6 months [11]. This variability in the shelf-life of "*Kponan*" yam is linked to cultivation practices, in particular through the use of herbicides during weeding. This hypothesis is supported by [11] who have shown a link between the use of chemical fertilizers and pesticides and the shelf life of "*Kponan*" yam.

According to these authors, 77% of producers who use chemical fertilizers and 60% of those who use pesticides, experience a considerable decrease in the shelf life of their "*Kponan*" yams. However, [26] showed that the application of higher doses of phosphorus or potassium than nitrogen results in better conservation of harvested tubers and reduced germination. However, the chemical composition

of the soil must be checked before mineral fertilizers are used, as yam has a balanced fertilization [22] [26] reported a shelf life of "*Kponan*" yam of no more than one (1) month, which was largely related to the sweeter taste and pre-ripe harvest. According to [11], poor maturity of "*Kponan*" yam can influence its shelf life, as an unmature tuber gives more easily to the effects of heat that promote its decomposition. In this study, the yams were all harvested at physiological maturity of 6 months. Therefore, maturity cannot be blamed on the variability of physical parameters of yam alteration. Similarly, the data show that yams cultivated in Kouassi-Kouassikro have the largest masses at harvest, have many crop injuries, and yams are subject to high rates of rots in open storage. On the other hand, in Zanzan, more particularly in Bouna, yams have low masses with less damage to the harvest but are better conserved in pits. Assuming that healthy yams are conserved, it can be concluded on the one hand that it is not the hoe-induced crop injury that causes the rapid deterioration of yams observed at Kouassi-Kouassikro. According to [11], clay soils have a relatively high humic concentration compared to sandy soils, which ensures that yams are mature and, by extension, have a good shelf life. This would imply that only Bouna yams would have large masses coupled with long conservation; this is not the case because, despite the low mass of Bouna yams, they have good conservation in pits. Thus, it cannot be concluded, on the other hand, that it is the conservation practices which would necessarily be blamed in the period of conservation of the yams.

Other factors such as heat, mold, animals (rodents and insects), germination, field storage conditions and chemicals use [23], coupled with soil quality and fallow time [16], may also reduce the storage time of "*Kponan*" yam. According to these authors, the combination of cultivation methods, conservation methods, soil poverty and short fallow time are the factors implicated in reducing the life span of "*Kponan*" yam in conservation. In this study, weeding of the Bouna and Bondoukou plots was done manually, whereas in Kouassi-Kouassikro area, herbicide weeding followed by manual weeding was done. In addition, the yams were kept in the open air without any protection against animals, rain and temperature variation at Kouassi-Kouassikro compared to the storage in straw hut at Bondoukou and in pit at Bouna which protected the tubers from the effects of heat. In addition, [23] showed that heat was the main cause of deterioration of "*Kponan*" tubers during field storage in Bouna, Bondoukou and Kouassi-Kouassikro departments. Thus, we can conclude that it is the action of herbicides combined with the effects of climate variation (temperature and rain) that would be the main factors in the rapid decay of the yam "*Kponan*" cultivated in Kouassi-Kouassikro zone.

5. Conclusion

The physical deterioration of "*Kponan*" yam during field storage is due to both storage and cultivation practices. Storage in pits results a longer self-life of "*Kponan*" than those under a straw hut and in the shade under a tree. The rapid

physical deterioration of "*Kponan*" during field storage in Kouassi-Kouassikro zone is correlated to the abusive use of herbicides during weeding and clearing. The innovation is the popularization of a better yam harvesting and preserving practices (machete harvesting and pits storage) for achieving yam food security. A larger sample of producers per cultivation area is needed to consolidate these data in future studies.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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