International Journal of Food Science and Nutrition
ISSN: 2455-4898; Impact Factor: RJIF 5.14
Received: 07-11-2018; Accepted: 09-12-2018
www.foodsciencejournal.com
Volume 4; Issue 1; January 2019; Page No. 22-26

Effect of harvesting period on some agronomic parameters of the cassava roots (*Manihot esculenta* Crantz) of the yacé variety, consumed in Côte d'Ivoire

Allou Christian Armel Gnamien[1], Adingra Kouassi Martial-Didier[2], Brou Koffi Siméon[3], Tra-Bi Fezan Honora[4], Tano Kablan[5*]

[1, 2, 3, 5] Department of Food Sciences and Technology, University of Nangui Abrogoua, Abidjan, Côte d'Ivoire

[4] Department Sciences of Nature, University of Nangui Abrogoua, Abidjan, Côte d'Ivoire

Abstract
This study investigated the impact of the harvest period on some agronomic parameters of the tuberous roots of yacé cassava variety. Fresh weight, number, length, girth, state, and yield per roots block based on harvest period (11th, 12th, 13th and 14th months after planting) were determined. The roots state (good or rotten) and roots number are not influenced by the harvest period. The roots number ranged from 6.4 to 6.8 from the eleventh to the fourteenth month of harvest. However, the highest yield was obtained at the fourteenth month of harvest after the cuttings were planted (20.46 tons / ha). Also, cassava cuttings harvested in the fourteenth month showed maximum fresh weight (1.02 Kg), length (39.38 cm), and circumference (24.15 cm).

Keywords: cassava roots, harvest period, agronomic parameters, yield

1. Introduction
Cassava (*Manihot esculenta* Crantz) is mainly grown for their roots and leaves and contributes to food safety (Vincenza *et al*., 2016) [1]. It is an important crop that is commonly grown in tropical and subtropical areas. It grows very well in a less fertile soil in contrast to many other crops. It's able to express a good yield of roots, under favorable production conditions or not. Millions of people around the world depend on it to subsist (Vásquez *et al*., 2012) [2]. This culture is an important staple food in world, particularly in Africa (Faostat, 2013) [3]. It is a crop that is high in carbohydrates in the roots. It occupies the 5th products consumed after maize, rice, wheat and potatoes (Proder, 2010) [4]. It's to African population as rice is for the Asian one, or wheat and potatoes are for the European people. Cassava roots yield more carbohydrates per hectare than cereal crops and can be grown at a considerably lower cost (Ukwuru *et al.*, 2013) [5].
In Côte d'Ivoire, cassava is the second most important food crop after yam (Faostat, 2010) [6]. It's also the world's fourth-largest plant product after maize (1068.9), wheat (727.9 million tons) and rice (531 million tons) according to FAO (2018) [7]. Its production was estimated in 2018 at 277.07 million tons against 160.73 million tons for Africa in the same year. Nigeria is the leading producer country with 56 million tons, while Côte d'Ivoire produces an average 5.37 million tons in 2018 (FAO, 2018) [7]. This culture mainly grown in the south of the country (Kouadio *et al*., 2010) [8] and transformed, traditionally, into fermented products (e.g., *attieke, placali, gari, lafun*) and then to the rapid preparation of meals (Pierre, 2012, Kouamé *et al*., 2012) [9, 10]. Freshly harvested cassava roots deteriorate rapidly and the process begins 1-3 days after harvest (Kakou *et al*., 2007) [11]. The composition of fruits and vegetables, particularly roots depending on their harvest periods can be influenced. Yacé variety of cassava roots are considered ripe as from the age of twelve months after planting, but are often left in the ground until sixteen months in Thailand (Sriroth *et al.*, 1999) [12], up to 24 months in Nigeria (Ngendahayo & Dixon, 1998) [13] and occasionally up to 48 months in the past before the development of improved varieties (Odigboh, 1976) [14].
Due to high demand, some producers prefer early harvest, neglecting the impact of the harvest period on agronomic and biochemical properties. However, an inadequate harvest can influence these parameters.
Only a few publications were found on the influence of tuber age on the properties of cassava roots (Kazeem & Abdulganiy, 2013) [15].
The aim of this study was to evaluate and compare the agronomic parameters of cassava roots harvested at different periods after planting in order to suggest their suitable users.

2. Materials and Methods
2.1 Raw material
Fresh tuberous cassava roots from yacé variety were used in this study. These roots were harvested 11th, 12th, 13th and 14th months after cultivation in Abobo-Ndotre (Côte d'Ivoire).

2.2 Methods
2.2.1 Experimental apparatus
The cultivation was carried out on experimental plot in Abobo-Ndotre (latitude: 5.463611 N; longitude: -4.115969 W and altitude: 99.00), to the north of Abidjan. The field was made with 20 cm cuttings with 5 to 7 nodes, from healthy 12-month-old stems. They were planted at a spacing of 0.8 m x 0.8 m, a density of 15625 plants/hectare. The experimental plot, delimited by a 3 m firewall, was divided into 4 blocks (A, B, C and D) of 125 m^2 each and 3 m apart. Each block consisted of ten (10) ridges of ten (10) plants. The lines were 0.8 m apart inside the blocks, giving a total area of 1870 m^2. Two months after planting, the soil was enriched with NPK (15-15-15) at the rate of 20 g/plant. The tuberous roots were harvested at 11th, 12th, 13th and 14th months after planting.

2.2.2 Sampling
Thirty (30) cassava plants were randomly selected from each of the 4 blocks depending on the stage of harvest. At harvest,

the stems were cut 30 cm from the ground and the roots detached, being careful not to cut them. At each stage of harvest, the roots were harvested and used on the same day to determine the agronomic parameters retained.

2.2.3 Agronomic parameters of cassava roots

The agronomic parameters studied during this study, namely fresh weight, number, length, circumference and state of roots, were evaluated according to Kouadio *et al*. (2014) [16]. The yield per block of the roots, at different stages of harvest was determined according to Koné (1997) [17] by the formula:

$$PT = PU \times D \quad (1)$$

With:
PT: Total production
D: Density or culture area
$Pu = \Sigma\ pi\ 1 / N$
$D = \Sigma\ ni \times 1/10000\ m^2$
ni: Total number of roots per block
pi: amount of roots harvested per plant
N: total number of plants where cassava tubers harvested

2.2.4 Statistical analysis

Data obtained were subjected to statistical analyses using STATISTICA 7.1 software package. Analysis of variance (ANOVA) was done. If necessary, Duncan test was done to determine significant differences at 5 % probability between means.

3. Results & Discussion

The present study evaluated the effect of the harvest period on five agronomic parameters of the tuberous roots of yacé cassava variety (*Manihot esculenta* CRANTZ), consumed in Côte d'Ivoire.

The results of roots state determined for yacé cassava variety at 11th, 12th, 13th and 14th months after cultivation are as presented in figure 1. Data show that cassava tubers harvested from the eleventh to the fourteenth month are in good condition whatever the harvest time. Otherwise, tubers in poor condition occupy a small proportion (2.92 ± 0.07 % à 6.67 ± 0.09 %). Statistical analysis reveals no significant difference ($P > 0.05$) between root rates in good condition for different harvest periods. It is the same for the root rates in bad condition for different harvest periods.

The high rate of roots in wealthy state could be explained by the fact that the soil was well drained. Indeed, according to Raffaillac and Second (1997) [18], soils engulfed with water cause root rots and slower growth. Regarding the low rate of roots in bad, it could be explained by manual harvesting. According to Pouzet (1983) [19], the mechanization of the harvest of a plot of cassava presents big losses.

Figure 2 presents the number means of roots per plant from the cassava harvested at different months. It was observed that the number of roots per plant was higher in the fourteenth month (6.8 ± 2.97) and varied from 6.4 ± 2.63 to 6.8 ± 2.97 at the eleventh to fourteenth month. The statistical analysis reveals no significant difference ($P > 0.05$) between the values of the number means of roots per plant. This is an indication that between the eleventh and the fourteenth month, there are not new ramifications of the principal root. According to Raffaillac (1992) [20], 4 to 6 weeks after planting the cuttings, the total number of tuberous roots is already fixed by the number of primary roots initially released. Which roots originate at the base and at the nodes of the cutting (N'zué, 2004) [21]. This number of roots depends on the rate of root uptake, which is conditioned by the good quality of the cuttings and climatic conditions (Egle, 1992) [22]. Also, the number of roots changes with the planting mode (horizontal or oblique or vertical), the length and the number of nodal and basal roots of the cutting (Raffaillac, 1992) [20]. The number means of roots per plant observed during our work was 6.65. This value corroborates with data (6.8) obtained by Raffaillac (1992) [20].

The roots average weight varied from 0.56 ± 0.30 kg to 1.29 ± 0.69 kg at the eleventh and fourteenth month of harvest after planting. Statistical analysis revealed a significant difference ($P < 0.05$) between the roots average weight values of the first two months (eleventh and twelfth) and those of the last two months (thirteenth and fourteenth). It reached its maximum value (1.29 kg) at fourteenth month. The average roots weight was higher at the fourteenth month. According to Silvestre and Arraudeau (1983) [23], growth of the weight of the roots by tuber would result from the increase in weight in the individual roots. During their maturity, cassava roots stored the products of photosynthesis, especially carbohydrates, causing an increase in the roots weights (Kouadio *et al*., 2014) [16]. Indeed, from the first weeks after planting the cuttings, and throughout the crop cycle, the roots will accumulate the carbohydrates produced by the aerial parts, in the form of starchy tubers (Miege 1957; Indira & Sinha, 1970) [24, 25]. Our results are similar to those of Tewodros and Biruk (2012) [26], Bakayoko *et al*. (2012) [27] and Michael *et al*. (2015) [28], they got high roots weight between the twelfth and the fifteenth month after cultivation.

The study of the mean tuber length and the average circumference of roots showed that these two parameters are higher at the fourteenth month of harvest. They values ranged from 27.45 ± 6.69 cm to 39.38 ± 9.14 cm for the means tuber length and from 20.72 ± 2.37 cm to 24.15 ± 2.60 cm for the average circumference of the eleventh to fourteenth month of harvest (Figure 4).The statistical analysis reveals a significant difference ($P < 0.05$) between the circumference values but also a difference between those of lengths of the first two months (eleventh and twelfth) and the last two months (thirteenth and fourteenth).

The study of mean tuber length and average circumference of roots showed that these parameters are higher at the fourteenth month of harvest after cultivation. This increase in circumference and the length of cassava roots could be explained by their continuous growth before full maturity. According to Mukendi *et al*. (2018) [29], cassava roots grow until they reach full maturity. Also, when the number of roots per tuber is not high, the distribution of carbohydrates to the tuberous roots, elaborated by the aerial parts of the plant is high (Raffaillac, 1992) [20]. The roots length (25.88 ± 9.71 cm), the number per plant (4.60 ± 2.98) and the individual fresh weight (409.10 g) obtained by Kouadio *et al*. (2014) [16] are lower than those observed during our work because of the climatic conditions, the rational use of inputs and the good maintenance of the plots. Indeed, Silvestre and Arraudeau (1983) [23] attribute this difference to variety and ecological conditions. Also, mean tuber length and average circumference of roots values were higher than those reported by N'zoré (1983) [30]. It showed that the length and the circumference respectively located between 20 to 50 cm and 5 to 15 cm. Several authors showed that the length of the tubers and the circumference increase with cassava maturity

stage (Grace, 1977; Onwuene, 1978; Knoth, 1993 and Kazeem & Abdulganiy, 2013) [31, 32, 33, 15].

Roots yield evaluation, by block, showed that it increased with the harvest period. It ranged from 17.27 t/ha to 20.5 t/ha from the eleventh to the fourteenth month (Figure 5). This result indicated that yield is higher in the fourteenth month. The statistical analysis revealed a significant difference ($P < 0.05$) between the yield values s of the different months.

The study of roots yield showed that it was lower and higher, at the eleventh and fourteenth months of harvest after cultivation respectively. The low yield observed at the eleventh month of harvest was due to early harvest according to Tawurunga *et al*. (1998) [34] and IITA-DRC (2012) [35]. Indeed, the roots haven't yet reached their physiological maturity stage (Mukendi *et al*., 2018) [29]. Thus, they continue to store carbohydrates (in form of starch) produced by the leaves during photosynthesis (Cock *et al*., 1979, Tan & Cock, 1979) [36, 37]. Also, high yield observed at the fourteenth month of harvest was due to the fact that the roots haven't been attacked by mites, viruses or diseases. Particularly, mites involve yield losses which can reach 80 % (N'zué *et al*., 2008) [38]. Diseases can cause yield losses ranging from 20 to 95 % (Hillocks *et al*., 2001) [39]. As for the African cassava mosaic virus, it reduces the development of roots of young plants (Raffaillac *et al.*, 1988) [40]. Also, yield which increases with the advanced of the month of harvest could be explained by the fact that we used the cuttings coming from the lower parts of the main stems. Indeed, Leihner (1986) [41] recommended to use the lower parts of the main stems to ensure a 100 % cuttings recovery. According to Egle (1992) [22], yield can also be conditioned by the rate of recovery of the roots. This rate of root uptake depends on the good quality of cuttings associated with climatic conditions. The yield obtained regardless of the month of harvest with yacé variety of cassava is lower than improved varieties (TMS4 (2) 1425 and Yavo (30 t/ha), Bocou 1, 2 and 3 (32-34 t/ha), obtained by N'zue (2008) [38]. Several authors found that improved varieties had significantly higher yields than local varieties (Wydra & Verdier, 2002, Bakayoko *et al*. (2012), Kouadio *et al.* (2014)) [42, 27, 16]. In fact, the low level of yield of local varieties compared to improved varieties could be explained by their difficult adaptation to climate change and the effects of pests and diseases.

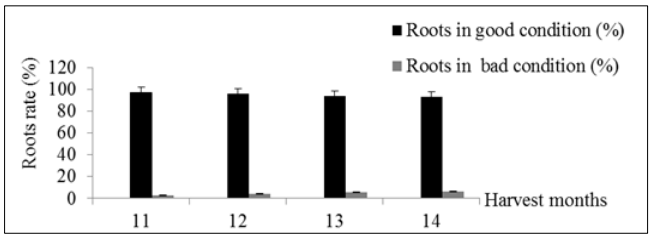

Fig 1: percentage (%) of roots in good and bad condition

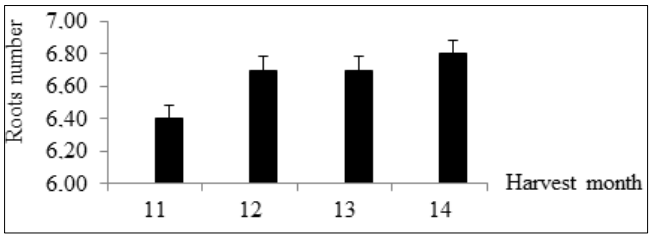

Fig 2: roots number based on harvest months

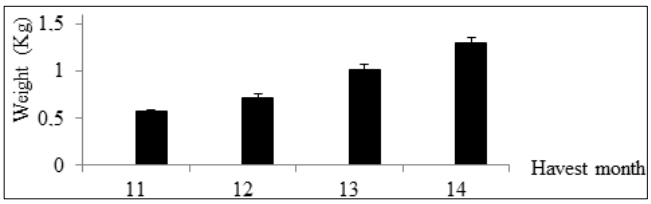

Fig 3: Roots average weight depending on the harvest month

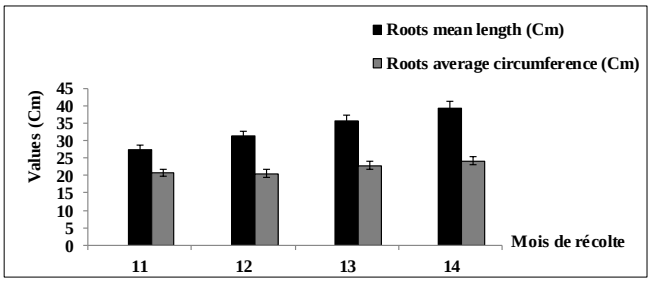

Fig 4: average length and circumference of roots depending on harvest month

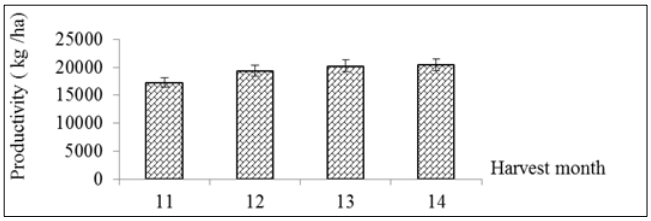

Fig 5: yield of each (kg/ha) depending on the harvest month

4. Conclusion

This study consisted in determining the effect of the harvest period on the agronomic parameters. The fourteenth month of harvest has the highest agronomic parameters. The number and state of the roots are not influenced between the 11th and 14th months after planting. However, weight, length, circumference, and yield are influenced by the stage of roots harvest. Thus the fourteenth month may be advised to producers who want a high agronomic yield to increase their income. But, it would be interesting to check that the fourteenth month of harvest could meet the requirements of roots transformers and consumers of the products obtained during this period.

5. References

1. Vincenza F, Clara P, Keith T, Manuela EP. Cassava (*Manihot esculenta* Crantz) and Yam (Dioscorea spp.) Crops and Their Derived Foodstuffs: Safety, Security and Nutritional Value. Crit Rev Food Sci Nutr. 2016; 56(16):2714-2727.
2. Vásquez A, López C. Identificación de polimorfismos en genes candidatos de resistencia en yuca (*Manihot esculenta* Crantz). *Acta Agron.* 2012; 61(2):133-142.
3. Faostat. FAO statistical database. Rome: Food and Agriculture Organization of United Nations, 2013, http:/www.fao.org.
4. Proder. Quarterly newsletter of rural development projects: production and multiplication of healthy cassava cuttings, 2010, 28.
5. Ukwuru MU, Egbonu ES. Recent development in cassava-based products research. Acad J Food Res. 2013; 1(1):1-13.

6. Faostat. Undernourishment around the world in. Rome: FAO, 2010, 3 http:/ www.fao.org.
7. FAO. Food Outlook - Biannual Report on Global Food Markets, 2018, 104, Rome. Licence: CC BY-NC-SA 3.0 IGO.
8. Kouadio KKH, Dao D, Tschannen A, Girardin O. Comparative profitability of cassava-based cropping systems in eastern Ivory Coast. J Anim Plant Sci. 2010; 9 (1):1094-1103.
9. Pierre MTA. Influence of the controlled fermentation, pressing and mechanized granulation of manioc (*Manihot esculenta* Crantz) on the physicochemical and sensory characteristics of *Attiéké*. PhD. Thesis, Nangui Abrogoua University, Côte d'Ivoire, 2012.
10. Kouamé AK, Djéni TN, N'guessan FK, Dje MK. Microflora post-treatment of commercial *attiéké* (fermented cassava product) produced in southern Ivory Coast. Lett App Microbiol. 2012; 56:44-50.
11. Kakou AC, Koussemon M, Koffi RN, Toka M, Guede-guina F, Dosso M, *et al*. Physicochemical and microbiological studies of cassava paste during storage. In Act of the 1st International Workshop on Potentiality for Manioc Processing (*Manihot esculenta*, CRANTZ), West Africa Abidjan-Cote d 'Ivoire, 2007, 256-260.
12. Sriroth K, Santisopasri V, Petchalanuwat C, Piyachomkwan K, Kurotjanawon K, Oates C. Cassava Starch Granule Structure- Functional Properties: Influence of Time and Condition at Harvest on Four Varieties of Cassava Starch. Carbohydr Polym. 1999; 38(2):161-170.
13. Ngendahayo M, Dixon AGO. Effects of Varying Stages of Harvest on Tuber Yield, Dry Matter, Starch and Harvest Index of Cassava in Two Ecological Zones in Nigeria In: Root Crops In the 21 Century, 1998.
14. Odigboh EUA. Cassava Peeling Machine: Development, Design and Construction, Journal of Agric. Engr. Research. 1976; 21:361-369.
15. Kazeem O, Abdulganiy R. Effects of Tuber Age and Variety on Physical Properties of Cassava [*Manihot esculenta* (Crantz)] Roots. Innovat Syst Des Eng. 2013; 4(9):15-25.
16. Kouadio KKH, Ettien DJB, Bakayoko S, Soro D, Girardin O. Physico-morphological variability of tuberous cassava roots grown on ferralsol in the West African forest zone. J Appl Bio Sci. 2014; 82:7316-7325.
17. Koné S. Comparative study of two methods of volume estimation in savannah formations. Case of the village soil of Déh. Graduation thesis. Engineering Cycle of Waters and Forests. IPR / IFRA. University of Mali, 1997, 36.
18. Raffaillac JP, Second G. Le manioc. In : L'amélioration des plantes tropicales, A. Charrier *et al*. édl, Montpellier, France, Cirad-Orstom, collection Repères, 1997.
19. Pouzet D. Cassava accompaniment research. Agronomy program. Report No. 9, Bouaké, IDESSA, Côte d'Ivoire, 1983, 79.
20. Raffaillac JP. Rooting cassava cuttings (*Manihot esculenta* Grantz) during the first few weeks of growth. Trop agro. 1992; 46(4):273-281.
21. N'zué B, Zohouri PG, Sangaré A. Performances agronomiques de quelques variétés de manioc (*Manihot esculenta* Crantz) dans trois zones agroclimatiques de la Côte d'Ivoire. Agronomie africaine, 2004, 1-7.
22. Egle K. Study of the variability of the components of cassava yield (*Manihot esculenta* Crantz, number, as a function of soil fertility. University of Lomé, Bénin, 1992; 111:312-524.
23. Silvestre P, Arraudeau M. Cassava: Agricultural Techniques and Tropical Productions. Paris (France): Edition G. P. Maisonneuve and Larousse and ACCT (Agency for Cultural and Technical Cooperation), 1983, 263.
24. Miege J. Cultural trials on cassava. J Agric Trop Bot. 1957; 4(9-10):402-441.
25. Indira P, Sinha SK. Studies on the initiation and development of tubers in *Manihot esculenta* Crantz. Indian Plant Physiol. 1970; 13:24-39.
26. Tewodros M, Biruk A. Cassava (*Manihot esculenta* Crantz) Varieties and Harvesting courses Influenced by Yield and Yield related Components. J Nat Sci Res. 2012; 2224-3186, 2(10):122-128.
27. Bakayoko S, Kouadio KHH, Soro D, Tschannen A, Nindjin C, Dao D, *et al*. Fresh tuber yield and dry matter content of seventy new cassava varieties (*Manihot esculenta* Crantz) grown in central Ivory Coast. J Anim Plant Sci. 2012; 14(2):1961-1977.
28. Michael Edet A, Tijani-Eniola H, Lagoke SO, Gbassay T. Yield related components and Harvest Time in Ibadan, Southwestern Nigeria. J Nat Sci Res. 2015; 5(9):87-92.
29. Mukendi TD, Tshimbombo JC, Muyayabantu MG, Tshiamala NT, Kamukenji NMA, Beya MS, *et al*. Assessment of the optimum age of maturation of the various locally grown and improved varieties of cassava (*Manihot esculenta* Crantz) grown at Ngandajika in DR Congo. J Appl Biosci. 2018; 121:12121-12128.
30. N'zoré K. *Attiéké* transformation, economic analysis, Postgraduate thesis agronomic, 1985, 30.
31. Grace M. Cassava treatment. Agricultural Services Bulletin No. 8. Fao Rome, 1977, 130.
32. Onwueme IC. The Tropical Tuber Crops: Yams, Cassava, Sweet Potato, Cocoyams. John Wiley and Sons Ltd, 1978, 234.
33. Knoth J. Traditional storage of yams and cassava and its improvement. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, 1993, 20.
34. Tawurunga Ojulong P, Dixon AGO. Genetic variability among cassava genotypes and its growth performance in Root crops and Poverty alleviation. Processes of the 6th Symposium of ISTRC-African Branch IITA. Ibadan, Nigeria, 1998, 242-248.
35. IITA-DRC. Research and Development Support Project for the Cassava Industry in DRC, program of activities, 2012-2013.
36. Cock JH, Franklin D, Sandoval J, Juri P. The ideal cassava plant for maximum yield. Crop Sci. 1979; 19:272-279.
37. Tan SL, Cock JH. Branching clothes as yield determination in cassava. Field Crop Res. 1979; 2:281-289.
38. N'zué B, Zohouri GP, Yapi GV, Djedji C. Technical note: Cultivating cassava in Ivory Coast. Directorate of Research Programs and Development Support - Innovations and Information Systems Branch. National Center for Agronomic Research (CNRA) of Côte d'Ivoire, 2008, 4.

39. Hillocks JM, Thresh AC. Bellotti. Cassava, Biology, Production and Utilization. CAB International, Wallingford, UK, 2001, 67-89.
40. Raffaillac JP, Nedelec G. Cassava behavior at the beginning of the cycle as a function of the duration of storage of the cutting. In: VIP symposium of the International Society for Tropical Tuberous Plants, Gosier, Guadeloupe. Paris, INRA, 1988, 675-685.
41. Leihner DH. Current practices in the production of cassava planting material. In: Global workshop on root and spinning crops: proceedings of a regional workshop held in Cali, Colombia. Cali, CIAT, 1986, 41-46.
42. Wydra K, Verdier V. Occurrence of cassava diseases in relation to environmental, agronomic and plant characteristics. Agric Ecosyst Environ. 2002; 93:211-226.