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RESEARCH ARTICLE

YIELD AND NUT QUALITY OF 29 CASHEW MOTHER TREES (ANACARDIUM OCCIDENTALE L) ESTABLISHED AT THE GERmplasm OF OUOGHI IN CENTRAL REGION OF BENIN

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Abstract

Description of subject: One of the main constraints to cashew crop development in Benin and Africa is the unavailability of efficient planting material for the plantations establishment. This constraint is largely responsible for the low level of nut yields obtained in cashew plantations.

Objective: This study aimed to assess the agronomic performances of 29 different cashew mother trees established in the germplasm of the Central Agricultural Research Center (CRA-Centre) of the National Agricultural Research Institute of Benin located in Savè, Central region, in sight of selecting high-performance clones to be distributed in rural areas.

Materials and Methods: Nuts production, unit nuts weight and the kernel rate data were collected on 29 cashew mother trees during the harvest seasons from 2017 to 2020. These data were submitted to the analysis of variance and comparison of the means tests with software R.

Results: The average nut yields of the 29 cashew mother trees varied from 0.85 to 11.98 kg / tree with a general average of 3.57 kg / tree at the age of 7 years old. Average unit nut weights ranged from 4.61 to 8.28 g with an overall average of 6.40 g. The average kernel ratio of nuts ranged from 24.08% to 32.46% with an overall average of 27.18%. The average weight of a kernel varied from 1.43 to 2.15g with an average of 1.71g. At the end of the four years assessment, five of the 29 cashew mother trees with a minimum nut yield of 5 kg / tree were preselected as the first efficient cashew clones from Benin.

Conclusion: These preliminary results are very important for the cashew breeding program in Benin. Further studies will plan to assess the cashew mother trees performance at 10, 15, 20 and 25 years old.

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Introduction:-

The cashew tree is nowadays an important export crop for the African continent which accounts for more than 55% of the world cashew nut production. Cashew nuts are an increasingly demanded export product on world markets and offer considerable potential for the industrial development of producing countries through local processing. Likewise, the economic potential of cashews offers opportunities throughout value chains. The cashew sector also allows to answer the current issues of climate change and migration (RONGEAD, 2015). West Africa had become the largest cashew production area in the world since 2015 with a production exceeding 1,350,000 tonnes (RONGEAD, 2015). In Benin, cashew nut production was 110,117 tonnes in 2017 (DSA / MAEP, 2017). The cultivated areas keep increasing year by year. They were estimated in 2015 at 285,568 ha (Adégbola and Crinot, 2016). Cashew nut contributes to 3% of the Gross National Product (GNP) and to 7.4% of the Gross Domestic Agricultural Product (GDAP); which raises it in 2nd position after the cotton sector which contributes to 25% of the GDAP (Tandjiékpou, 2010). Benin has large favorable areas for the cashew trees cultivation. Currently, cashew is produced in 5 of the 8 agro-ecological zones of Benin. These zones include 8 of the 12 departments of the country, namely: Alibori, Atacora, Borgou, Collines, Couffo, Donga, Plateau and Zou (Adégbola and Crinot, 2016). Despite these assets, the average nut yield of cashew trees remains very low (3 to 6 kg/tree) compared to that obtained in main producer countries in the world (10 to 15 kg/tree) such as India, Vietnam, Brazil and Tanzania (Masawe, 2010; Tandjiékpou, 2010). This low productivity of cashew trees considerably weakens the nut production and the incomes of growers, processors, traders and the State. This low productivity of cashew trees is due to several factors, including the insufficiency or lack of improved planting material (MAEP, 2011). It is to overcome this lack of improved planting material that a cashew breeding program was started in Benin in 2011. This study addresses the intermediate results of this program. It presents the cashew nuts yields and the quality of nuts produced by 29 cashew mother trees established in the Ouoghi's germplasm in the Central region of Benin. The objective is to assess these 29 cashew mother trees performance at 7 years old and to pre-select the first cashew clones from Benin.

Material and methods:-

Study area:

This study was conducted at Ouoghi in Savè Commune in the central region of Benin (figure 1). Savè Commune is in the agro-ecological zone V of Benin which is characterized by a Sudano-Guinean type climate with two rainy seasons in the South and a rainy season in the North with an average annual rainfall varying between 1,000 and 1,200 mm per year (Boko, 1992). But in recent years, this zone's climate has given way to a tropical Sudanese-type climate marked by a rainy season and a dry season (AFRIQUE CONSEIL, 2006). The average monthly water level varies from 7.1 mm in January to 223 mm in August. The average monthly temperature fluctuates between 24°C in July and 29°C in March (Akoègninou et al., 2006). The soils found there are tropical ferruginous soils. Hydromorphic soils are also observed in lowlands and river valleys. Overall, these different types of soils are relatively fertile (AFRIQUE CONSEIL, 2006).

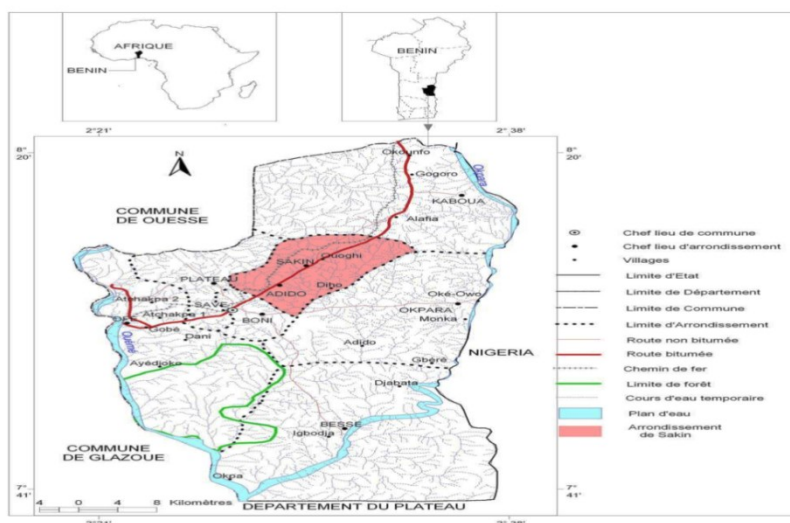


Figure 1:- Geographic situation of the study area.

Source: Ahouandjinou et al. (2017)

Materials:-

The plant material used consists of 29 of the 30 cashew mother trees established in the Ouoghi'sgermplasm in August 2012. These cashew trees represent the best cashew mother trees identified in farmer's plantations in 2011 (N'Djolossè, 2015). The plants used to establish this germplasm were produced by grafting. In germplasm, each cashew mother tree occupies a plot of 15 trees spread over 3 rows. The technical equipment used is composed of a 25 kg balance, 5 kg electronic balance, caliper and hornbill pliers. As agricultural equipment, jute bags, various sizes bags, gloves, alcohol and cotton were used.

Methodology:-

Being the second cash crop after cotton, the cashew tree has experienced a certain revival of interest in recent years in Benin through its nuts. Planting material is one of the key components for better yields. The study on the selection process of high-performance variety focuses on the nut yield per tree, the average weight of a nut, the average weight of kernel and the average kernel rate according to studies done in other countries like Tanzania (Masawe, 2010). The used methods for each activity are as follows:

Evaluation of nut yield from cashew mother trees:

For the nut yields assessment from the different cashew mother trees, the produced nuts which fell under the trees were collected, tree per tree, dried and weighed. The nuts were harvested once a week from mid-January to the end of April of the years 2017, 2018, 2019 and 2020. Each year, the nut yield of each tree was obtained by summing the weights recorded during the various weighings during harvests.

Assessment of the quality of nuts produced by the cashew mother trees:

The quality of the produced nuts was assessed in 2019 and 2020. To achieve this, three samples of 2 kg of nuts were taken per plot (cashew mother tree) at the peak of the harvest period (the beginning of March in 2019 and 2020). Each nuts sample was processed to determine the average weight of a nut, of a kernel, and kernel rate. The number of nuts in 1 kilogram was counted. To calculate the average weight of a nut, the weight of one kilogram of nuts was divided by the number of nuts. Then, each of the nuts in 1 kilogram was cut lengthwise using the hornbill pliers. Then, the kernel were collected with the skins and weighed. Finally, the kernel rate is determined by dividing the weight of the kernel by the total weight of the nuts.

Statistical analysis:

Analysis of variance were performed for each of the variables using R software, 3.5.0 version. The means comparisons and structuration were carried out using the Student-Newman-Keuls (SNK) test.

Results and Discussion:-**Nut yield from the different cashew mother trees:**

The average nut yields obtained for the 29 cashew mother trees assessed in Ouoghi'sgermplasm at the ages of 4, 5, 6 and 7 years old are presented in Table 1.

Analysis of variance carried out showed highly significant differences between these 29 cashew mother trees ($P < 0.0001$) for the variable "nut yield" during the 4 years assessment. The analysis of Table 1 reveals the following observations:

1. The average nut yields obtained at 4 and 5 years old ages of the 29 cashew mother trees were generally very low and were less than 1 kg/tree. However, the SNK test carried out to compare the means made it possible to separate the cashew mother trees into three groups;
2. The average nut yields obtained at 7 years old age from the 29 cashew mother trees were at least two to ten times higher than the nut yields obtained at 4, 5 and 6 years old;
3. At 7 years old age, more than half of cashew mother trees have produced at least 4 kg of nuts per tree and at least 45% of cashew mother trees have at least 5 kg of nuts per tree;
4. At 7 years of age, the segregation of the cashew mother trees in relation to the variable "nut yield" was more pronounced. The SNK test carried out to compare the means allowed to go from 3 to 5 groups of cashew mother trees.

The nut yields obtained for these cashew mother trees are very low compared to those obtained for the cashew clones selected in Tanzania (Masawe, 2016) and which varied from 4 to 15 kg/tree and from 8.48 to 24.84 kg/tree respectively for the ages of 4-5 and 7 years old.

These low nut yields obtained for the majority of the cashew mother trees under assessment are not necessarily linked to poor performance. They would also be due to the low rainfall recorded in the area since the establishment of the germplasm in 2012. They varied from 815 mm to 1,001 mm against an annual rainfall average of 1,100 mm with the lowest values at the start of fruiting of cashew trees at 3 and 4 years old. These observations confirm those of Bello et al. (2017) who concluded that current climate change is negatively affecting cashew production in Benin. According to Amoussou et al. (2016), precipitation experienced a significant decrease of 7% in the study area over the period from 1981 to 2010 compared to the period from 1951 to 1980.

Quality of nuts produced by cashew mother trees:

The quality of the nuts produced by the cashew mother tree was assessed at 6 and 7 years old using three parameters: the nut weight, the kernel weight and the kernel rate. The results of the nut quality assessment are shown in Tables 2, 3 and 4.

The average nut weight of cashew mother trees was varying from 4.61 to 8.28 g with a general average of 6.40 g. This proves that one could have on average 156 nuts per kg. In fact, the graining reflects the nuts average size. The greater the number obtained, the more nuts are in a kg and the smaller they are. In the current study, the graining remains slightly higher than the selection criterion for genetic materials and improved mother trees compared to the graining which could vary between 100 to 150 nuts per kg (Masawe, 2016). This gives a good appreciation of the graining of these genotypes.

Analysis of variance carried out revealed highly significant differences between the 29 cashew mother trees ($P < 0.0001$) for the two assessed parameters. The analysis of Table 2 shows:

1. A large inter-cashew mother trees variability for the two parameters used to assess nut quality. The SNK test carried out to compare the means made allowed to separate the 29 cashew mother trees into more than 09 groups;
2. Most of the cashew mother trees studied produced good nut quality, at least two-thirds, as following:
 1. only seven (7) cashew mother trees of the 29 had an average unit nut weight less than 6 g; and
 2. two of the 29 cashew mother trees had a kernel rate less than 25%.

Table 1:-Average nut yields (kg/tree) of cashew mother trees in the Ouoghi's germplasm from 4 to 7 years old.

Sources of scions/mother trees			Mean of nut yield (kg/tree) at:			
N°	Commune	REFERENCE	4 years (2017)	5 years (2018)	6 years (2019)	7 years (2020)
1	Savè	SAKA06	1,307 a	1,097 a	7,880 a	7,671 bc
2	Djougou	DGFO08	0,588 bc	0,816 a	6,370 b	11,98 a
3	Kétou	KEIL02	0,343 bc	0,152 c	5,289 bc	8,672 b
4	Tchaourou	TCTC07	0,504 bc	0,705 a	4,069 c	5,654 bcde
5	Péhunco	PHBO04	0,410 bc	0,763 a	3,849 c	5,152 bcde
6	Kouandé	KOBE04	0,530 bc	0,563 a	3,707 c	5,021 bcde
7	Dassa	DAOD07	0,734 bc	1,413 a	3,294 c	5,853 bcde
8	Ouessè	OSGB26	0,348 bc	0,377 bc	3,215 c	5,115 bcde
9	Ouessè	OSAG07	0,526 bc	0,259 bc	3,185 cd	5,400 bcde
10	Ouessè	OSID06	0,834 bc	0,157 c	3,009 cd	6,792 bcd
11	Kétou	KEEW01	0,937 ab	0,163 c	2,807 cd	4,051 bcde
12	Pèrèrè	PEKP04	0,185 c	0,418 ab	2,800 cd	4,251 bcde
13	Dassa	DADO08	0,552 bc	0,206 bc	2,624 cd	4,731 bcde
14	Djidja	DJZA02	0,511 bc	0,328 bc	2,535 cd	5,058 bcde
15	Savalou	SLLO06	0,819 bc	0,515 ab	2,325 cd	3,932 bcde
16	Kouandé	KOSE03	0,296 c	0,777 a	2,166 cd	4,778 bcde

17	Bantè	BABO04	0,315 b	0,175 c	2,133 cd	4,010 bcde
18	Kouandé	KOSE01	0,388 b	0,501 ab	1,886 d	4,334 bcde
19	Glazoué	GLGB01	0,196 c	0,224 bc	1,589 d	2,698 cde
20	Djougou	DGWA07	0,242 c	0,722 a	1,588 d	2,703 cde
21	Dassa	DAAK04	0,450 bc	0,793 a	1,530 de	5,228 bcde
22	Djougou	DGFO07	0,153 c	0,770 a	1,508 de	1,625 de
23	Kétou	KEEW03	0,140 c	0,209 bc	1,268 de	0,885 e
24	Savalou	SLDO03	0,089 c	0,257 bc	1,147 de	2,005 de
25	Savè	SAOK01	0,060 c	0,200 bc	0,987 de	1,294 e
26	Savè	SABE05	0,261 c	0,496 ab	0,964 de	1,073 e
27	Dassa	DADO07	0,465 b	0,214 bc	0,863 e	5,853 bcde
28	Bantè	BAAG03	0,055 c	0,470 ab	0,749 e	0,850 e
29	Savalou	SLAZ01	0,081 c	0,720 a	0,692 e	1,382 e
P			< 0,0001	< 0,0001	< 0,0001	< 0,0001
In the same column, the numbers accompanied by the same letters are not significantly different at the 1% level.						

The average of unit nut weights obtained in this study, which varied from 4.6 to 8.20 g, are lower than those obtained for the cashew clones selected in Tanzania which varied from 7.13 to 11.9 g (Masawe, 2017). On the other hand, the kernel rates results varying from 24.08% to 32.46% with an overall average of 27.18%, are close to those obtained in Tanzania. The kernel rates of produced nuts by selected cashew clones in Tanzania ranged from 25.49 to 44.02% (Masawe, 2017)

Table 2:- Average weights of nuts produced by cashew mother trees in Ouoghi's germoplasm at 6 and 7 years old.

Sources of scions/mother trees			Mean of nut weight (g)	Mean of nut weight (g)
N°	Commune	REFERENCE	in 2019	in 2020
1	Savè	SAKA06	6,104 m	6,680 g
2	Djougou	DGFO08	5,917 p	5,391 n
3	Kétou	KEIL02	6,536 j	7,235 d
4	Tchaourou	TCTC07	4,613 t	4,618 q
5	Péhunco	PHBO4	7,049 e	7,512 c
6	Kouandé	KOBE04	5,882 p	5,92 k
7	Dassa	DAOD07	6,030 o	5,669 l
8	Ouessè	OSGB26	7,201 d	6,553 h
9	Ouessè	OSAG07	6,542 k	7,085 e
10	Ouessè	OSID06	5,580 q	5,394 n
11	Kétou	KEEW01	5,405 r	5,030 o
12	Pèrèrè	PEKP04	5,324 s	4,706 p
13	Dassa	DADO08	7,353 c	7,753 b
14	Djidja	DJZA02	6,623 i	5,685 l
15	Savalou	SLLO06	5,296 s	5,703 l
16	Kouandé	KOSE03	7,201 d	6,423 i
17	Bantè	BABO04	7,201 d	5,475 m
18	Kouandé	KOSE01	6,030 n	6,136 j
19	Glazoué	GLGB01	6,711 h	6,390 i
20	Djougou	DGWA07	6,536 j	6,416 i
21	Dassa	DAAK04	8,016 a	7,468 c
22	Djougou	DGFO07	7,353 c	7,128 e
23	Kétou	KEEW03	6,803 g	7,000 f
24	Savalou	SLDO03	7,307 cd	6,943 f
25	Savè	SAOK01	7,246 cd	6,952 f
26	Savè	SABE05	7,576 b	7,111 e
27	Dassa	DADO07	6,944 f	6,959 f
28	Bantè	BAAG03	7,314 cd	8,280 a

29	Savalou	SLAZ01	6,289 l	6,100 j
P			< 0,0001	< 0,0001
In the same column, the numbers accompanied by the same letters are not significantly different at the 1% level.				

Table 3:-Average weight of kernels produced by cashew mother trees in Ouoghi's germoplasm at 6 and 7 years Old.

Sources of scions/mother trees			Mean weight of an kernel(g) in 2019	Mean weight of an kernel(g) in 2020
N°	Commune	REFERENCE		
1	Savè	SAKA06	1,646 g	1,833 gh
2	Djougou	DGFO08	1,964 c	1,753 i
3	Kétou	KEIL02	1,797 f	1,940 d
4	Tchaourou	TTC07	1,198 k	1,266 o
5	Péhunco	PHBO04	1,789 f	2,013 c
6	Kouandé	KOBE04	1,547 h	1,631 k
7	Dassa	DAOD07	1,434 i	1,574 l
8	Ouessè	OSGB26	1,993 c	1,932 d
9	Ouessè	OSAG07	1,647 g	1,865 fg
10	Ouessè	OSID06	1,405 ij	1,513 m
11	Kétou	KEEW01	1,346 j	1,625 k
12	Pèrèrè	PEKP04	1,335 j	1,301 o
13	Dassa	DADO08	1,985 c	2,100 b
14	Djidja	DJZA02	1,675 g	1,423 n
15	Savalou	SLLO06	1,333 j	1,532 lm
16	Kouandé	KOSE03	1,755 f	1,807 h
17	Bantè	BABO04	1,784 f	1,430 n
18	Kouandé	KOSE01	1,560 h	1,673 j
19	Glazoué	GLGB01	1,638 g	1,705 j
20	Djougou	DGWA07	1,458 i	1,580 l
21	Dassa	DAAK04	1,936 d	1,920 de
22	Djougou	DGFO07	1,765 f	1,926 d
23	Kétou	KEEW03	1,578 h	1,822 gh
24	Savalou	SLDO03	1,788 f	1,780 hi
25	Savè	SAOK01	2,036 b	1,902 def
26	Savè	SABE05	2,341 a	1,990 c
27	Dassa	DADO07	1,917 de	1,871 efg
28	Bantè	BAAG03	1,876 ef	2,150 a
29	Savalou	SLAZ01	1,629 g	1,465 n
P			< 0,0001	< 0,0001

In the same column, the numbers accompanied by the same letters are not significantly different at the 1% level.

Table 4: Average kernel rate of nuts produced by cashew mother trees in Ouoghi's germoplasme at 6 and 7 years old

Sources of scions/mother trees			Kernel rate(%) in 2019	Kernel rate(%) in 2020
N°	Commune	REFERENCE		
1	Savè	SAKA06	26,97 e	27,37 cdef
2	Djougou	DGFO08	33,20 a	32,46 a
3	Kétou	KEIL02	27,50 d	26,86 efgh
4	Tchaourou	TCTC07	25,97 fg	27,40 cde
5	Péhunco	PHBO04	25,38 ghij	26,80 efgh
6	Kouandé	KOBE04	26,30 f	27,49 cde
7	Dassa	DAOD07	23,78 n	26,89 efgh
8	Ouessè	OSGB26	27,67 cd	29,43 b
9	Ouessè	OSAG07	25,21 hij	26,34 fgghi
10	Ouessè	OSID06	25,36 ghij	28,06 cd
11	Kétou	KEEW01	24,90 jkl	32,39 a
12	Pèrèrè	PEKP04	25,08 ijk	27,55 cde
13	Dassa	DADO08	27,00 e	27,11 defg
14	Djidja	DJZA02	25,30 ghij	25,06 jk
15	Savalou	SLLO06	25,18 ij	26,9 efgh
16	Kouandé	KOSE03	24,38 lm	28,19 c
17	Bantè	BABO04	24,78 jkl	26,21 gh
18	Kouandé	KOSE01	25,87f gh	27,26 cdef
19	Glazoué	GLGB01	24,40 lm	26,70 efgh
20	Djougou	DGWA07	22,30 p	24,67 k
21	Dassa	DAAK04	24,70 jkl	25,75 ij
22	Djougou	DGFO07	24,00 mn	27,08 defg
23	Kétou	KEEW03	23,20 o	25,99 hi
24	Savalou	SLDO03	24,48 klm	25,62 ij
25	Savè	SAOK01	28,10 c	27,29 cdef
26	Savè	SABE05	30,90 b	27,95 cd
27	Dassa	DADO07	27,60 cd	27,73 cde
28	Bantè	BAAG03	25,65 ghi	25,95 hi
29	Savalou	SLAZ01	25,90 fg	24,04 l
P			< 0,0001	< 0,0001

In the same column, the numbers accompanied by the same letters are not significantly different at the 1% level.

The results of this study reveal that the average kernel rate in the nuts varied from 24.08% to 32.5% with an overall average of 27.18% in the 7th year. This average rate of 27.18 is similar to the results obtained by some authors. In Nigeria, Ogunwolu et al. (2016) recorded the following qualities: average out-turn of 47.53 lbs / 80 kg bag, average kernel rate of 25.33% with an average nut size of 181 nuts.kg⁻¹. The results obtained are in line with the observations of Masawe&Kapinga (2013a and 2013b) with regard to the kernel rate and graining. According to these authors, in cashew tree's breeding, it is strongly recommended to select mother trees with a kernel rate greater than 25%. According to these authors, genotypes (varieties, clones or hybrids) that have kernel rate greater than 25% are considered to be good genotypes. Cashew nut processing industries accept nuts with a graining less than or equal to 200 nuts.kg⁻¹ or less (Masawe et al., 2015a). These authors pointed out that nuts with a graining greater than 200 nuts.kg⁻¹ are difficult to process due to their small size.

Performance of the first preselected cashew clones in Benin:

At the end of the first four years assessments, from 2017 to 2020, the first 5 efficient cashew clones in Benin were preselected by combining the 3 main parameters of yield and nuts quality. These first preselected clones produced at least 5 kg/tree at 7 years old. They had the best nut yields, but not necessarily the best nut qualities (Table 5). These yields are two to three times the national average yields recorded in farmers' plantations in Benin, which were 2.28 and 4.06 kg/tree respectively for the age groups of 3 to 9 years old and 10 and 20 years old (DSA/MAEP, 2017).

In addition to these first 5 pre-selected clones, four other clones present slight deficiencies in their nut quality (values highlighted in yellow). Future observations will allow to better appreciate and to confirm or not them as efficient clones of cashew trees in Benin. They will be also used in the breeding program by hybridization.

Sources of scions/mother trees			Nut yield (kg/tree) at 6 years (2019)	Nut yield (kg/tree) at 7 years (2020)	Nut weight (g) at 6 years (2019)	Nut weight (g) at 7 years (2020)	Kernel rate(%) at 6 years (2019)	Kernel rate(%) at 7 years (2020)
N°	Commune	REFERENCE						
1.	Savè	SAKA06	7.880 a	7.671 bc	6.10 m	6.680 g	26.97 e	27.37 cdef
2.	Djougou	DGFO08	6.370 b	11.980 a	5.92 p	5.391 n	33.20 a	32.460 a
3.	Kétou	KEIL02	5.289 bc	8.672 b	6.54 j	7.235 d	27.50 d	26.86 efgh
4.	Péhunco	PHBO04	3.849 c	5.152 bcde	7.05 e	7.512 c	25.38 ghi j	26.80 efgh
5.	Kouandé	KOBE04	3.707 c	5.021 bcde	5.88 p	5.92 k	26.30 f	27.49 cde
6.	Dassa	DAOD07	3.294 c	5.853 bcde	6.03 o	5.669 l	23.78 n	27.73 cde
7.	Ouessè	OSGB26	3.215 c	5.115 bcde	7.20 d	6.553 h	27.67 cd	29.43 b
8.	Ouessè	OSAG07	3.185 cd	5.400 bcde	6.47 k	7.085 e	25.21 hij	26.34 fghi
9.	Djidja	DJZA02	2.535 cd	5.058 bcde	6.62 i	5.685 l	25.30 ghij	25.06 jk

Table 5:- Performances of the first preselected cashew clones in Benin at 7 years old.

In the same column, the numbers accompanied by the same letters are not significantly different at the 1% level.

Conclusion:-

The results of this study are the preliminary results of the assessment of the 29 cashew mother trees established in the Ouoghi'sgermplasm in the Central region of Benin. They made it possible to assess the productive performance of each cashew mother trees as well as the quality of the nuts that each of them produced. At the end of these first assessments, the first 5 efficient cashew clones of Benin which produced at least 5 kg of nuts per tree were preselected. The assessments of these cashew mother trees will continue in order to select the best cashew clones in Benin. At the same time, the important results of this study will be used to progress in the cashew breeding program in Benin by starting hybridization between clones and by implementing orchards for polyclonal cashew seeds production.

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Conflict of Interest:

The authors have declared no conflicts of interest.

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