Journal of Applied and Natural Science
16(2), 922 - 927 (2024)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Variation among cassava (*Manihot esculenta* Crantz) genotypes for storage root yield, yield components and response to cassava mosaic disease at the advanced breeding stage

Abdoul-Razak O. Mahamane
Plant Breeding Program, Pan African University Life and Earth Sciences Institute (Including Health and Agriculture), Ibadan, Nigeria
Bunmi Olasanmi*
Department of Crop and Horticultural Science, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria
Udemba I. Oluwadamilola
Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria
Edwige G. N. Mbanjo
International Institute of Tropical Agriculture, Ibadan, Nigeria.

*Corresponding author : Email: bunminadeco@yahoo.com

Article Info
https://doi.org/10.31018/jans.v16i2.5500
Received: February 25, 2024
Revised: June 09, 2024
Accepted: June 15, 2024

How to Cite
Mahamane, A-R. O. *et. al.* (2024). Variation among cassava (*Manihot esculenta* Crantz) genotypes for storage root yield, yield components and response to cassava mosaic disease at the advanced breeding stage. *Journal of Applied and Natural Science*, 16(2), 922 - 927. https://doi.org/10.31018/jans.v16i2.5500

Abstract
Cassava is a crucial starchy root crop cultivated worldwide in tropical and subtropical areas. Efforts have been made to improve its desirable characteristics to increase food and nutritional quality. However, the adoption of new cassava varieties can be influenced by their yield performance, which can be affected by cassava mosaic disease (CMD). The present study evaluated selected cassava genotypes' performance across two years at the advanced breeding stage. Using a randomized complete block design with two replications, 16 genotypes, a yellow root variety (TMS07/0593) and a white root (TMS30572) as checks were evaluated for yield, yield-related traits and response to CMD. There were highly significant ($P < 0.001$) variations among the cassava genotypes for yield-related traits, but no genetic variation was reported for fresh and dry root yields. The effect of season and genotypes × season interaction on all traits was significant only for harvest index and percentage of survival plants, respectively. Only genotype UIC-17-2428 and the two national check varieties (TMS07/0593 and TMS30572) did not resist CMD completely. At harvest, genotype UIC-17-2031 had the highest fresh root yield (39.0 t/ha), dry root yield (10.5 t/ha), and harvest index (0.63). Genotype UIC-17-58 had the highest dry matter content (37.2%) at harvesting, followed by UIC-17-46 (36.4%) while genotype UIC-17-583 had the lowest value (22.8%). The genotypes evaluated have promising premium agronomic traits. To assess their stability, genotypes with outstanding dry root yield must be evaluated across multiple environments.

Keywords: Cassava improvement, Dry matter content, Genotype × season interaction, Harvest index, Storage root yield.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is an important staple food and industrial crop for about 800 million people in tropical and subtropical Africa, Asia and Latin America (Adekanye *et al.,* 2013; Temegne *et al.,* 2016; Otekunrin and Sawicka, 2019). It can adapt and produce appreciable yield under poor environmental conditions where most other crops fail (El-Sharkawy and Cock, 1987; De Bruijn and Fresco, 1989). Hence, it is the primary source of income for small-holder farmers in the tropics with limited access to agricultural inputs, and contributes immensely to food security in Africa (Agre *et al.,* 2017). Cassava is grown mainly for its roots and leaves, but all the plant parts are useable (Amarullah, 2021). Sequel to its high starch content, Its storage roots provide more dietary energy per hectare than any other staple crop (Francis *et al.,* 2017). The starchy roots is consumed by humans in fresh or processed forms like gari, fufu, and chips, and it can also be fed to animals (Balagopalan, 2009; Ige *et al.,* 2021). The leaves are used as vegetables in soup, or dried for livestock feed while the stems are propagation materials (Adekanye *et al.,* 2013; Codjia *et al.,* 2022).

Globally, cassava is grown on 29.65 million hectares, with a total production of 314.81 million tons and an average yield of 10.62 t/ha . Nigeria is the world's largest producer of cassava followed by Thailand and Ghana, with a total production of 59, 29, and 21 million tons, respectively (FAOSTAT, 2021). Nevertheless, cassava yields in Nigeria are low at average of 6.9 t/ha of fresh roots (FAOSTAT, 2021). This low yield can be attributed to low soil fertility, poor agronomic practices and drought stress which results to about 80% yield losses (Omolara *et al.,* 2021; Adjebeng-danquah *et al.,* 2022). Although cassava has a broad range of adaptability to diverse environmental conditions, the adaptability of individual varieties in most cases is limited and exhibits significant genotype by environment (G × E) interaction effects (Tumuhimbise *et al.,* 2014). G × E interaction adversely impacts the effectiveness of selection in plant breeding, leading to reduced genetic gain. Consequently, plant breeders frequently evaluate crops in multiple environments to mitigate the negative impact of G × E interaction and identify genotypes that display stability and adaptability (Adjebeng-danquah *et al.,* 2022). Thus, the main objective of this study was to evaluate the performance and stability of some cassava genotypes across seasons. The specific objectives were to (i) identify high-yielding cassava genotypes for fresh and dry root yield, (ii) evaluate their response to cassava mosaic disease, and (iii) determine the interaction between seasons and genotypes for fresh and dry root yield of the cassava genotypes.

MATERIALS AND METHODS

Planting materials

A total of eighteen cassava genotypes (Table 1) were evaluated in this experiment. They included sixteen University of Ibadan Cassava (UIC) genotypes from cassava germplasm of the Department of Crop and Horticultural Sciences, University of Ibadan, Nigeria, and two (2) national check varieties. The UIC genotypes were selected with the aid of molecular markers and evaluated over the years at advanced yield trial stages.

Experimental design

The field experiment was conducted at the Teaching and Research Farm of the Department of Crop and Horticultural Sciences, University of Ibadan, Nigeria (latitude 7° 27' and longitude 3° 53') during the 2021/2022 and 2022/2023 cropping seasons.

The land at the experimental site was cleared and partitioned into plots of size 20 m^2 (four rows of 5m length with 1 m alley apart). Subsequently, ridges of about 30 cm in height were made manually on the plots. Planting was done in March in each season. Using a spacing of 1 m × 1 m, 20 healthy cuttings of 25 cm long containing 4 to 6 nodes of each genotype/variety were planted per plot to give a population of 10,000 plants/ha. The cuttings were totally buried in the soil in a slant position. The experiment was laid out using randomized complete block design with two replicates. Weeding was done as and when due.

Pre-emergence herbicide with active ingredients of atrazine 250 g/l and metolachlor 250 g/l was sprayed at the rate of 4 l/ha. Weeds were subsequently controlled using post-emergence herbicide and manual weeding as required. Manual weeding was used at early stage of growth of the plants while post-emergence contact herbicide with paraquat dichloride 276 g as an active ingredient was applied about three months after planting at the rate of 2.5 l/ha. Systematic post-emergence herbicide (360 g of glyphosate) was used to control the weeds at the rate of 2.5 l/ha from six months after planting. Rouging was done about 1 to 2 weeks after herbicidal application to remove resilient weeds.

Data collection

Number of surviving plants in each plot was recorded one month after planting. The plants were also scored for CMD severity at 1, 3, and 5 MAP on a scale of 1 to 5 where 1 represented no symptom expression and 5 represented the presence of severe symptoms. The cassava genotypes were scored for plant architecture (Arch) shortly before harvesting using a scale of 1 to 5, where 1 represented no branching and 5 represented high branching. At harvest (12 MAP), 6 plants in the net of each plot were harvested and data were collected on the number of storage roots per plant (Roots/plt), root quality (Rootqlt) and fresh root weight (kg). Fresh root yield (t/ha) was estimated using the formula:

Eq.1:

$$\text{Fresh root yield}\left(\frac{\text{t}}{\text{ha}}\right) = \frac{10{,}000}{1{,}000} \times \frac{\text{storage root weight}}{\text{number of plants}}$$

Root dry matter content determination

The storage roots were first chopped into pieces and a representative sample of about 100 g was taken and oven-dried at 70°C for 48 h. Each sample was reweighed till constant weight was attained. The dry matter content of the sample was estimated using the formula:

$$\text{Dry matter content (\%)}\frac{\text{Dry weight}}{\text{Fresh weight}} \times \frac{100}{1}$$ Eq.2:

Dry root yield (t/ha) was estimated from dry matter content and fresh root yield as:

$$\text{Dry root yeild}\left(\frac{t}{ha}\right) = \text{DMC} \times \text{FRY} \quad \text{Eq.3:}$$

Harvest Index was estimated as follows:

$$\text{Harvest index} = \frac{\text{Fresh storage root weight}}{\text{Total biomass}} \quad \text{Eq.4:}$$

Data analysis

All data collected were analysed using GenStat Discovery Edition 2011. Data were subjected to descriptive and correlation analyses and analysis of variance (ANOVA). Significantly different means were separated using the Duncan Multiple Range Test ($P \leq 0.05$).

RESULTS

There was a significant difference among the cassava genotypes for all the evaluated variables except for fresh and dry root yield, while seasonal effect was significant for only the harvest index (Table 2). Significant genotype × season interaction was observed for only the percentage of survival plants. The mean and other descriptive statistical parameters of the evaluated traits are summarized in Table 3.

The evaluated cassava had plant architecture and root quality that ranged from 2 (UIC-17-2040) to 5 (TMS07/0593, UIC-17-108 and UIC-17-2174) and from 2 (TMS07/0593 and UIC-17-2031) to 4 (UIC-17-2040, UIC-17-627, UIC-17-208, and UIC-17-58), respectively. Meanwhile, CMD's severity ranged from 1 (UIC-17-2428) to 5 (TMS30572). Varieties TMS07/0593 and TMS30572 had CMD scores of 2 and 5, respectively. Genotype UIC-17-2600 and variety TMS07/0593 produced the least number of roots (5) per plant while genotype UIC-17-2031 had the highest number (11). Variety TMS07/0593 and genotype UIC-17-58 had the lowest (58%) and highest (100%) survival rate, respectively. The fresh and dry storage root yields range between 21 t/ha (TMS30572) and 39 t/ha (UIC-17-2031) and 4.9 t/ha (UIC-17-583) and 10.5 t/ha (UIC-17-2031), respectively. The mean harvest index (HI) across seasons ranged from 0.41 (UIC-17-2174) to 0.63 (UIC-17-2031). The mean root DMC ranged from 22.8% to 37.2%, averaging 29.0%. Genotype UIC-17-58 had the highest DMC (37.2%), while UIC-17-583 had the lowest DMC (22.8%).

The results from the pairwise correlation among traits are presented in Table 4. The most strongly correlated traits were fresh (FRY) and dry root yield (DRY) ($r = 0.87$; $P < 0.001$). Root quality (Rootqlt) and DMC at harvesting had a significant positive moderate correlation ($r=0.50$; $P < 0.001$). Conversely, FRY and DRY had a negative correlation with CMD.

Table 1. Cassava genotypes evaluated for fresh and root dry yield in Ibadan in 2021 and 2022

S/N	Genotypes
1	TMS07/0593 (Check)
2	TMS30572 (Check)
3	UIC-17-108
4	UIC-17-110
5	UIC-17-2009
6	UIC-17-2031
7	UIC-17-2040
8	UIC-17-2081
9	UIC-17-2174
10	UIC-17-2428
11	UIC-17-2576
12	UIC-17-2600
13	UIC-17-375
14	UIC-17-46
15	UIC-17-58
16	UIC-17-583
17	UIC-17-627
18	UIC-17-833

DISCUSSION

The result of evaluation of the selected cassava genotypes across 2021/2022 and 2022/2023 cropping seasons revealed that all genotypes were high-yielding based on the fresh root yield of the national check variety TMS30572. The negative correlation observed between CMD severity and each of FRY and DRY in this study further corroborates reports from earlier studies that cassava mosaic disease causes a significant reduction in yield due to reduced light interception resulting from the reduction in leaf area of infected cassava plants (Thresh *et al.,* 1994; Egesi *et al.,* 2007; Alabi *et al.* 2011; Bisimwa *et al.,* 2015). Only the two check varieties (TMS30572 and TMS07/0593) and one genotype (UIC-17-2428) did not exhibit complete resistance to CMD in the course of this study. The cultivation of such susceptible CMD varieties or the selection of susceptible genotypes should be discouraged. According to Olasanmi *et al.* (2017), adopting resistant genotypes will reduce the population of cassava mosaic virus and the rate of spread of the pathogen by whiteflies. The observed non-significant effect of season on severity of CMD in this study suggests that Ibadan could be a reliable location for screening for the disease.

Plant architecture is an agronomic parameter that influences, to an extent, farmers' adoption of new cassava genotypes because it determines how such genotypes will fit into the prevailing cropping system of the farmers. For monocropping, genotypes with high levels of branching, such as TMS07/0593, UIC-17-108, UIC-17-2174, UIC-17-2600 and UIC-17-375 will be more suitable. Cultivation of such genotypes will minimize weed growth and weeding requirements from about three months after planting when the land will be almost covered. On the other hand, genotypes with a minimum

Table 2. Combined analysis of variance for survival rate, response to cassava mosaic disease, plant architecture, yield and yield components among some cassava genotypes at the advanced breeding stage

Source of variation	DF	Arch	Rootqlt	DMC(%)	CMDSS	%Surv	FRY(kg/ha)	HI	DRY(kg/ha)	Roots/plt
Genotypes (G)	17	2.85***	1.54***	71.96***	5.80***	475.30***	91.88	0.01***	9.89NS	9.27**
Season (S)	1	0.89	0.22	0	0.013	21.31	165.42	0.49***	15.27	13.84*
GxS	17	0.27	0.28	0	0.10	71.55**	100.24	0.005	8.76	3.78
Residual	35	0.34	0.40	20.49	0.09	23.43	76.06	0.004	7.103	2.92

*,**, *** significant at probability <0.05, 0.01 and 0.001 levels, respectively; Arch = Plant architecture; Rootqlt = Root quality; DMC (%) = Dry matter content; CMDSS = Cassava Mosaic Disease Severity Score; %Surv = Percent survival rate; FRY = Fresh Root Yield; HI = Harvest Index; DRY = Dry Root Yield; Roots/plt = Number of roots per plant.

Table 3. Mean performance of traits of the 18 cassava genotypes evaluated in 2021/2022 and 2022/2023 cropping seasons in Ibadan

Genotype	Arch	Rootqlt	DMC (%)	CMDSS	%Surv	FRY (t/ha)	HI	DRY (t/ha)	Roots/plt
TMS07/0593	5a	2de	26.1defg	2b	58d	24.1b	0.43de	6.3ab	5e
TMS30572	4ab	3bcde	26.5defg	5a	99ab	21.0b	0.53bcd	5.6b	7cde
UIC-17-108	5ab	3cde	23.0fg	1c	91b	27.8ab	0.48cde	6.3ab	7cde
UIC-17-110	3cd	3bcde	30.6abcdef	1c	100a	25.9ab	0.51bcd	7.9ab	8bcd
UIC-17-2009	4bc	3bcde	29.3bcdefg	1c	100a	31.4ab	0.49bcde	9.3ab	7cde
UIC-17-2031	3de	2e	27.1cdefg	1bc	99ab	39.0a	0.63a	10.5a	11a
UIC-17-2040	2e	4abc	27.7cdefg	1c	100a	25.9ab	0.49bcde	6.8ab	9abc
UIC-17-2081	3de	4ab	34.4abc	1c	99ab	23.0b	0.52bcd	7.9ab	8bcd
UIC-17-2174	5ab	3abcd	33.2abcd	1c	100a	26.4ab	0.41e	8.7ab	10ab
UIC-17-2428	4bc	3bcde	31.6abcde	5a	98ab	21.9b	0.43de	6.7ab	7cde
UIC-17-2576	4ab	3cde	26.8cdefg	1c	76c	27.6ab	0.53bcd	7.8ab	7cde
UIC-17-2600	5ab	2de	25.1efg	1c	99ab	24.0b	0.49bcde	6.1ab	5de
UIC-17-375	5ab	2e	27.3cdefg	1c	91b	34.5ab	0.58abc	9.2ab	7cde
UIC-17-46	3cd	3abcd	36.4ab	1c	99ab	21.3b	0.58ab	7.8ab	8bcd
UIC-17-58	4ab	4a	37.2a	1c	100a	27.8ab	0.56abc	10.4a	8abcd
UIC-17-583	3de	3cde	22.8g	1c	98ab	21.4b	0.50bcde	4.9b	6cde
UIC-17-627	4ab	4abc	30.9abcde	1c	99ab	25.0ab	0.44de	7.7ab	9abc
UIC-17-833	3de	3bcde	26.6defg	1c	99ab	29.5ab	0.50bcde	7.8ab	9abc
Mean	4	3	29.0	1	95	26.5	0.50	7.6	8
CV (%)	0.24	0.27	0.18	1.21	0.13	0.35	0.23	0.38	0.27

Arch = Plant architecture (1-5 scoring); Rootqlt = Root quality; DMC (%) = Dry matter content; CMDSS = Cassava Mosaic Disease Severity Score; %Surv = Percentage of survival rate; FRY = Fresh Root Yield; HI = Harvest Index; DRY = Dry Root Yield; Roots/plt = Number of roots per plant; CV (%) = Coefficient of Variation.

Table 4. Correlation coefficients among traits of eighteen cassava genotypes evaluated in 2021/2022 and 2022/2023 cropping seasons in Ibadan, Nigeria

	Arch	CMDSS	DMC	DRY	FRY	HI
CMDSS	0.14					
DM_%	-0.13	-0.03				
DRY	-0.02	-0.22	**0.36****			
FRY	0.03	-0.22	-0.12	**0.87*****		
HI	**-0.25***	-0.12	0.006	0.07	0.08	
Rootqlt	-0.17	-0.06	**0.50*****	0.01	**0.24***	-0.09

Arch = Plant architecture; Rootqlt = Root quality; DMC = Dry matter content; CMDSS = Cassava Mosaic Disease Severity Score; FRY = Fresh Root Yield; HI = Harvest Index; DRY = Dry Root Yield.

level of branching, such as UIC-17-2040 are desirable for intercropping because such will ensure minimal competition among the crops for light. The number of roots per plant recorded in this study (5 to 11) was within the range earlier reported by El-Sharkawy (2004). The author elucidated that cassava plant typically produces 6-12 storage roots at a population density of 10,000 plants/ha.

The dry matter content (DMC) of cassava roots is a critical characteristic that plays a vital role in selecting cassava varieties suitable for industrial use. Dry matter content above 30% is considered to be high (Teye *et al.,* 2011). The DMC observed in this study are lower than the values reported in previous studies (Anthony *et al.,* 2015; Navangi *et al.,* 2020). The DMC obtained for the check variety TMS07/0593 (26.1%) is slightly more than the value of 24.3% obtained by Maroya *et al.* (2012). In addition, Raji *et al.* (2007) with a value of 39.2% and Edoh *et al.* (2016), with a value 33%, reported higher values of DMC for TMS30572 (26.5%). Root dry matter content is affected by planting dates, crop ages at harvest, and periods of drought before harvesting (Bakayoko *et al.*, 2009; Enesi *et al.,* 2022). The non-significant correlation observed between DMC and FRY of the cassava genotypes in this study is in tandem with a report by Amelework *et al.* (2022). Meanwhile, positive association recorded between DRY and DMC suggests that an increase in dry matter content of this cassava population may lead to an increase in their dry root yield. Hence, both the fresh root yield and dry matter content of the cassava population can be improved to enhance their dry root yield.

Harvest index (HI) is employed to assess the efficiency of cassava genotypes in partitioning dry matter to economically valuable storage root. The significant variation in harvest index reported among the cassava genotypes evaluated and across the two seasons in this study corroborates the submission by Navangi *et al.* (2020) for cassava genotypes evaluated in their study. Nine genotypes (UIC-17-110, UIC-17-2031, UIC-17-2081, UIC-17-2576, UIC-17-375, UIC-17-46, UIC-17-58, UIC-17-583, UIC-17-833) and check variety TMS30572 with HI of 0.50 or more were outstanding based on the value of 0.50 to 0.60 recommended by Chikoti *et al.* (2016) as optimum HI for cassava.

Conclusion

The study revealed significant variation among the cassava genotypes for all traits studied except fresh (FRY) and dry root yield (DRY). The performance of the cassava genotypes did not vary across seasons except harvest index and there was no significant genotype × season interaction. The positive correlation between dry matter content and dry root yield indicated that the former influenced the latter. Only the two check varieties (TMS30572 and TMS07/0593) and one genotype (UIC-17-2428) did not resist CMD completely. Hence, selection from this cassava population for release to farmers will help to reduce the cassava mosaic virus load on farmers' fields. The high-yielding genotypes with complete resistance to CMD (UIC-17-20-31, UIC-17-375, UIC-17-2009, UIC-17-833 and UIC-17-108) should be evaluated across locations to ascertain their stability.

ACKNOWLEGEMENTS

The authors appreciate the African Union Commission through the Pan African University Life and Earth Sciences Institute (including Health and Agriculture), Ibadan, Nigeria, by providing the funding for this research.

Conflict of interest

The authors declare that they have no conflicts of interest.

REFERENCES

1. Adekanye, A., Ogunjimi, S. I. & Ajala, A. O. (2013). An Assessment of Cassava Processing Plants in Irepodun Local Government Areas, Kwara State, Nigeria. *World Journal of Agricultural Research,* 1, 14-17. doi:10.12691/wjar-1-1-4
2. Adjebeng-danquah, J., Asante, S., Agbenyega, O. & Sunday, A. D. (2022). Evaluation and Selection of Elite Cassava Varieties for Storage Root Yield in Evaluation and Selection of Elite Cassava Varieties for Storage Root Yield in the Transition and Guinea Savannah Ecologies of Ghana. *International Journal of Plant & Soil Science,* 34, 572-580. doi:10.9734/ijpss/2022/v34i2231411
3. Agre, A. P., Bhattacharjee, R., Dansi, A., Becerra, L. L. A., Dansi, M. & Sanni, A. (2017). Assessment of cassava (Manihot esculenta Crantz) diversity, loss of landraces and farmers preference criteria in southern Benin using farmers' participatory approach. *Genetic Resources and Crop Evolution,* 64, 307-320. doi:10.1007/s10722-015-0352-1
4. Alabi, O. J., Kumar, P. L. & Naidu, R. A. (2011). Cassava Mosaic Disease: A Curse to Food Security in Sub-Saharan Africa. *APSnet Features.* doi:10.1094/APSnetFeature-2011-0701
5. Amarullah (2021). Morphological, Physiological and Agronomic Characteristics of Cassava Superior Variety of Coastal Land. *IOP Conference Series: Earth and Environmental Science,* 748, 1-13. doi:10.1088/1755-1315/748/1/012030
6. Amelework, A. B., Bairu, M. W., Marx, R., Owoeye, L., Laing, M. & Venter, S. L. (2022). On-Farm Multi-Environment Evaluation of Selected Cassava (Manihot esculenta Crantz) Cultivars in South Africa. *Plants,* 11, 1-13. doi:10.3390/plants11233339
7. Anthony, P., Yona, B., Titus, A., Robert, K., Edward, K., Anton, B., Christopher, A. O., Paul, G., David, S. O., Dennis, M. & Phinehas, T. (2015). Stability of resistance to cassava brown streak disease in major agro-ecologies of

Uganda. *Journal of Plant Breeding and Crop Science,* 7, 67-78. doi:10.5897/jpbcs2013.0490

8. Bisimwa, E., Walangululu, J. & Bragard, C. (2015). Cassava Mosaic Disease Yield Loss Assessment under Various Altitude Agroecosystems in the Sud-Kivu Region, Democratic Republic of Congo. *Tropicultura,* 33, 101-110.
9. Balagopalan, C. (2009). Cassava utilization in food, feed and industry. In: *Cassava: Biology, Production and Utilization* (pp 301-318). CABI Publishing: Kerala, India..
10. Bakayoko, S., Tschannen, A., Nindjin, C., Dao, D., Girardin, O. & Assa, A. (2009). Impact of water stress on fresh tuber yield and dry matter content of cassava (Manihot esculenta Crantz) in Côte d'Ivoire. *African Journal of Agricultural Research,* 4, 21-27. doi:10.5897/AJAR.9000405
11. Chikoti, P. C., Shanahan, P. & Melis, R. (2016). Evaluation of Cassava Genotypes for Resistance to Cassava Mosaic Disease and Agronomic Traits. *American Journal of Plant Sciences,* 7, 1122-1128. doi:10.4236/ajps.2016.77107
12. Codjia, E. D., Olasanmi, B., Agre, P. A., Uwugiaren, R., Ige, A. D. & Rabbi, I. Y. (2022). Selection for resistance to cassava mosaic disease in African cassava germplasm using single nucleotide polymorphism markers. *South African Journal of Science,* 118, 1-7. doi:10.17159/sajs.2022/11607
13. De Bruijn, G. H. & Fresco, L. O. (1989). The importance of cassava in world food production. *Netherlands Journal of Agricultural Science,* 37, 21-34.
14. Edoh, N. L., Adiele, J., Ndukwe, I., Ogbokiri, H., Njoku, D. N. & Egesi, C. N. (2016). Evaluation of High Beta Carotene Cassava Genotypes at Advanced Trial in Nigeria. *The Open Conference Proceedings Journal,* 7, 144-148. doi:10.2174/2210289201607010144
15. Egesi, C. N., Ogbe, F. O., Akoroda, M., Ilona, P. & Dixon, A. (2007). Resistance profile of improved cassava germplasm to cassava mosaic disease in Nigeria. *Euphytica,* 155, 215-224. doi:10.1007/s10681-006-9323-0
16. El-Sharkawy, M.A. 2004. Cassava biology and physiology. *Plant Molecular Biology,* 56, 481-501. doi:10.1007/s11103-005-2270-7
17. El-Sharkawy, M. A. & Cock, J. H. (1987). Response of cassava to water stress. *Plant and Soil,* 100, 100-125. doi:10.1007/BF02370950
18. Enesi, R. O., Hauser, S., Pypers, P., Kreye, C., Tariku, M. & Six, J. (2022). Understanding changes in cassava root dry matter yield by different planting dates, crop ages at harvest, fertilizer application and varieties. *European Journal of Agronomy,* 133, 126448. doi:10.1016/j.ejq.2021.126448
19. FAOSTAT (2021) [accessed 2023 Aug 13] https://www.fao.org/ faostat/en/#data
20. Francis, N. A., Mbatsogo, A., Constant, F., Ijang, T. P., Atanga, N. S., Mewouo, M., Clarisse, Y., Delphine, M. & Simon, N. T. (2013). Effects of Cassava Cultivation on Soil Quality Indicators in the Humid Forest Zone of Cameroon. *Greener Journal of Agricultural Sciences,* 3, 451-457. doi:10.15580/GJAS.2013.6.030613519
21. Ige, A. D., Olasanmi, B., Mbanjo, E. G. N., Kayondo, I. S., Parkes, E. Y., Kulakow, P., Egesi, C., Bauchet, G. J., Ng, E., Lopez-Lavalle, L. A. B., Ceballos, H. & Rabbi, I. Y. (2021). Conversion and Validation of Uniplex SNP Markers for Selection of Resistance to Cassava Mosaic Disease in Cassava Breeding Programs. *Agronomy,* 11, 1-19. doi:10.3390/agronomy11030420
22. Maroya, N. G., Kulakow, P., Dixon, A. G. O. & Maziya-Dixon, B. B. (2012). Genotype × Environment Interaction of Mosaic Disease, Root Yields and Total Carotene Concentration of Yellow-Fleshed Cassava in Nigeria. *International Journal of Agronomy,* doi:10.1155/2012/434675
23. Navangi, L. N., Githiri, S. M., Ateka, E. M., Kanju, E., Munga, T. L., Tumwegamire, S., Otsyula, R. M., Kwena, P. O., Woyengo, V. W., Malinga, J. & Okitoi, L. O. (2020). Evaluation of Cassava Genotypes for Agronomic Performance, Correlation with CMD and CBSD Parameters and Stability across Alupe, Kakamega and Kibos in Western Kenya. *Journal of Experimental Agriculture International,* 42, 47-62. doi:10.9734/jeai/2020/v42i230469
24. Olasanmi, B., Eyo, R. & Iluebbey, P. (2021). Genotypic variation for starch yield in cassava (Manihot esculenta Crantz) in Ibadan, Nigeria. *Journal of Crop Improvement,* 36, 687-700. doi:10.1080/15427528.2021.2001705
25. Omolara, O., Hauser, S., Necpalova, M., Kolawole, F., Kreye, C., Tariku, M., Six, J. & Pypers, P. (2021). Field Crops Research On-farm assessment of cassava root yield response to tillage, plant density, weed control and fertilizer application in southwestern Nigeria. *Field Crops Research,* 262, 1-9. doi:10.1016/j.fcr.2020.108038
26. Otekunrin, O. A. & Sawicka, B. (2019). Cassava, a 21st Century Staple Crop: How can Nigeria Harness Its Enormous Trade Potentials? *Acta Scientific Agriculture,* 3, 194-202. doi:10.31080/asag.2019.03.0586
27. Raji, A. A., Ladeinde, T. A. O. & Dixon, A. G. O. (2007). Agronomic traits and tuber quality attributes of farmer grown cassava landraces in Nigeria. *Journal of Tropical Agriculture,* 45, 9-13.
28. Temegne, N. C., Ngome, A. F. & Fotso, K. A. (2016). Influence de la composition chimique du sol sur la teneur en éléments nutritifs et le rendement du manioc (Manihot esculenta Crantz, Euphorbiaceae) dans deux zones agro-écologiques du Cameroun. *International Journal of Biological and Chemical Sciences,* 9, 2776-2788. doi:10.4314/ijbcs.v9i6.21
29. Thresh, J. M., Fargette, D. & Otim-Nape, G. W. (1994). Effects of African Cassava Mosaic Geminivirus on the Yield of Cassava. *Tropical Science,* 34, 26-42.
30. Teye, E., Asare, A. P., Amoah, R. S. & Tetteh, J. P. (2011). Determination of the Dry Matter Content of Cassava (Manihot esculenta, Crantz) Tubers Using Specific Gravity Method. *ARPN Journal of Agricultural and Biological Science,* 6, 23-28.
31. Tumuhimbise, R., Melis, R., Shanahan, P. & Kawuki, R. (2014). Genotype × environment interaction effects on early fresh storage root yield and related traits in cassava. *The Crop Journal,* 2, 329-337. doi:10.1016/j.cj.2014.04.008