

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

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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 \times 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 \times 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 (Agré *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 (Tumuhimise *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 m² (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 re-weighed till constant weight was attained. The dry matter content of the sample was estimated using the formula:

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

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

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

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). Varieties

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 |

ty 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.

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 for-

mer 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.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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