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# Phenotypic evaluation of cassava genotypes (*Manihot esculenta*) under moisture stress

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**ABSTRACT—** Food security continues to be affected by global climatic changes which include increase in drought stress that reduces food availability to feed an ever growing population. One of the sustainable solutions is the development of crop cultivars that are tolerant to such stresses. Among food crops, cassava has a very high potential to mitigate hunger. A field experiment was conducted to evaluate the performance of 79 cassavas (*Manihot esculenta*) varieties under drought stress. The parameters evaluated were storage root fresh weight (SRFW), number of storage roots (NSR), above ground weight (AGW), plant height (PH), harvest index (HI) and leaf retention (LR). Generally, water deficit suppressed cassava growth and productivity and this was observed by lower outputs obtained from most traits under water deficit treatment as compared to well-watered treatment. SRFW was used to select best performing varieties with the highest SRFW being observed in LML/2008/363 (26 kg). Results showed significant variations among the varieties for most of the traits. Under the water deficit conditions, positive correlations were observed between SRFW and NSR (r=0.37**), AGW (r=0.30**) and HI (r=0.56**). The HI and AGW expressed a significant and negative correlation (r=-0.40**). Under non-stressed conditions, SRFW had a significant and positive correlation with NSR (r=0.43**), AGW (r=0.38**) PH (r=0.10*), HI (r=0.44**) and LR (r=0.18**). There was a significant and negative correlation between HI and AGW (r=-0.48**). Genotypes; LML/2008/363, TZ-130, M96/7151, MM06/0013, I95/034095-N, MM98/1642, I92/0427 and 29B29 performed well for important drought traits (NSR, AGW, HI and LR) and these are recommended as gene sources for cassava improvement programs and farmers that target maximum productivity under stressful conditions.

**KEYWORDS:** Phenotype, Cassava (Manihot esculenta), Drought stress, traits, Kiboko.

## 1. INTRODUCTION

Global climatic changes such as increases in frequency and intensity of drought affects agriculture and food security at large. Among the effects of climate change, drought is the most frequent [2]. Drought's effects hinder crop production [19] with estimates indicating that drought independently contributes up to 17% of yield loss of major crops when compared to other abiotic stresses [2]. The rates of yield reduction for major crops such as barley, rice, sorghum, maize and wheat are likely to increase by more than 50% in 2050 and almost 90% in 2100 if sufficient adaptation measures are not implemented [2]. A necessary and sustainable solution is to develop crop cultivars that can tolerate these climatic stresses to be able to feed the growing world population [8]. Cassava (Manihot esculenta) has a high potential to reduce hunger as compared to other crops especially in the developing countries. The crop is resilient to climatic changes and could therefore give options while other major food crops face the climatic challenges [8]. Cassava is drought tolerant because it can be grown in low fertility soils [3] and can be easily propagated [12]. Additionally, the harvestable roots which are highly perishable can be left in the soil and fetched when needed for up to 3-4 years after maturity [16]. After rice and maize, cassava is the third most important source of calories in the tropics [9]. The crop's leaves can be consumed as vegetables because they have considerable content of proteins and vitamins [20].

Cassava serves as a greater part of the diet for almost a billion people in approximately 105 countries with Africa being the largest producer with 118 million tons [10]. The ability of cassava to be tolerant to drought has been associated with several morphological traits that enable it to prevent the negative effects of drought stress. Some of the traits measured in drought adaptation studies of cassava includes number of primary stems and branches, length of primary and secondary stems, leaf retention, harvest index, plant heights, above ground biomass, storage root fresh weight, number of storage roots, root dry matter among others [16], [14], [18]. In a previous field experiment, [17] reported most of the drought tolerant genotypes showed significantly higher SRFW HI, NSR and AGB compared to most susceptible genotypes This study therefore assessed the performance of selected cassava varieties under drought conditions using morphological traits and identified high-yielding drought-tolerant cassava varieties as a means of contributing to increased food security.

## 2. Materials and methods

### *2.1 Plant material and experimental design*

Seventy-nine cassava genotypes were used in this study. Cassava cuttings of uniform length (20-30cm) were planted in a Randomized Complete Block Design (RCBD) with two replications of 4 plants of each genotype. Approximately 1.5 ha of land was ploughed and split into four blocks of equal sizes. Water regimes (well-watered and droughted) served as main plots and varieties as subplots at a spacing of 1m x1m. For plant establishment, irrigation was sustained through overhead irrigation. Thirty days after planting (DAP), the treatments were introduced whereby, well-watered (after every week) and droughted (after every two weeks). There was no application of fertilizer or any agro-chemicals. The crop was manually weeded after every two months and the treatments were applied until harvesting. Harvesting was done at 12 months after planting.

### *2.2 Measurement of phenotypic data*

Data on the plant parameters were taken using standard cassava descriptors of IITA as modified by [11] to evaluate the 79 cassava genotypes. The data were collected at three, six, nine and 12 months after planting (MAP). Vertical height (cm) was measured from the ground to the top of the canopy and recorded as plant height using a measuring stick calibrated in centimeters. Leaf retention (LR) was visually estimated as percentage proportion of leafy part of the stem to the total stem height for each plant. LR was determined at six MAP because this period normally coincides with drought stress in most cassava growing regions in eastern and southern Africa. After harvesting, storage roots (NSR) were counted manually with lengths greater than 20 cm and above ground weight (AGW) consisted of the mean fresh weight of stems, branches and attached leaves per plant. Fallen leaves were omitted from determining AGW because it was difficult to assign fallen leaf to a particular genotype. The storage fresh root weight (SRFW) per plant was measured using a weighing scale. The harvest index (HI) was determined using the formula: HI = weight of the roots/weight of roots + weight of above ground biomass.

### *2.3 Statistical analysis*

The data were subjected to a two-way analysis of variance (ANOVA) using GenStat Ver. 14.1 statistical package, 12th edition. The least significance difference (LSD) at 5% probability level was used to compare treatment means. The Pearson correlation coefficient (r) was used to analyze the inter- relationship between traits.

## 3. Results

### *3.1 Performance of the genotypes*

The performance of seventy-nine genotypes was assessed under drought stress and non-water stressed conditions using different traits. Most of the traits assessed were significantly (P<0.001) affected by both treatments and genotypes. Significant (p<0.05) variations were observed for SRFW, NSR, AGW, PH, HI and LR. Under water stress treatment (Table 1), the highest SRFW was observed in LML/2008/363 (26.0kg) with 110(07/0621HS) and NASE 14 (1.9kg) giving the least. Genotype SANGOJA had the highest NSR of 14.8 while COLICANA had the least with 3.0. The highest (14.6 kg) AGW was recorded in MM06/0143 with MM96/5280 having the least (2.1kg). SANGOJA expressed the highest PH with 290.0 (cm) with 99(07/1313HS) (79cm) as the least. Genotype MM97/1744 had the highest HI of 0.8 with MM98/1669, MM06/0082, MM06/0143, EYOPE, F19, MKUMBA-1, TME 14, 197(01/1797HS), KBH2002/066-3 and 212(07/576HS) recording the lowest 0.3. Genotypes MM97/0293, MM96/6966B, MM96/0686, MM98/1642, SANGOJA, MM96/2480, MM98/2270, ORERA and MM98/1669 produced the highest LR of 100% among others while 93(07/0756HS) had the least with 53.1%. Under non-stressed treatment (table 1), LML/2008/363 expressed the highest SRFW of 24.1 kg with MM96/1871 (2.6 kg) giving the least. Genotype SANGOJA had the highest NSR of 13.8 while MM96/6966A the least with 3.4. EYOPE had the highest (26.8 kg) AGW with MM96/1871 having the least (2.3kg). F10-30R2 expressed the highest PH with 302.5 cm with TME 14 as the least with 151.2 cm. Genotype LML/2008/363 had the highest HI of 0.8 with genotypes MM06/0143, NASE 14, MM96/O686, MIGYERA, 197(01/1797HS), MM 96/6966A and 128(05/0099HS) having lowest 0.3. Genotype TZ-130 produced highest LR of 100% among others while 93(07/0756HS) and MM06/0138 as the least with 50.0%.

**TABLE 1.** MEANS OF TRAITS MEASURED FOR 79 GENOTYPES IN STRESSED AND NON-STRESSED TREATMENTS

| | SRFW | | NSR | | AGW | | PH | | HI | | LR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | stress | Non | Stress | Non | Stress | Non | Stress | Non | Stress | Non | Stress | Non |
| 110(07/0621HS) | 1.9 | 5.6 | 5.4 | 8.5 | 2.4 | 9.7 | 224.4 | 199.9 | 0.4 | 0.5 | 87.5 | 75.0 |
| 128(05/0099HS) | 3.0 | 3.4 | 5.3 | 9.6 | 7.8 | 6.8 | 206.2 | 157.8 | 0.4 | 0.3 | 75.0 | 75.0 |
| 169(98/002HS) | 5.5 | 6.0 | 5.6 | 5.1 | 5.3 | 7.9 | 237.5 | 233.8 | 0.5 | 0.5 | 87.5 | 75.0 |
| 183907/0751HS) | 6.7 | 7.3 | 4.6 | 7.1 | 5.9 | 7.4 | 205.6 | 190.0 | 0.5 | 0.5 | 75.0 | 75.0 |
| 197(01/1797HS) | 3.5 | 4.1 | 7.1 | 5.5 | 8.5 | 11.8 | 132.7 | 205.0 | 0.3 | 0.3 | 75. | 75.0 |
| 212(07/576HS) | 2.9 | 5.6 | 8.9 | 4.9 | 3.6 | 12.3 | 117.0 | 256.2 | 0.3 | 0.5 | 75.0 | 75.0 |
| 29(06/1475HS) | 3.8 | 5.9 | 13.1 | 5.5 | 6.8 | 6.5 | 250.0 | 251.2 | 0.5 | 0.4 | 78.1 | 75.0 |
| 29B29 | 8.2 | 11.4 | 9.3 | 7.8 | 5.9 | 15.4 | 244.4 | 263.8 | 0.4 | 0.7 | 96.9 | 75.0 |
| 89(06/1475HS) | 5.4 | 7.9 | 11.5 | 7.3 | 8.6 | 11.9 | 135.1 | 242.5 | 0.5 | 0.4 | 71.9 | 75.0 |
| 93(07/0756HS) | 3.1 | 3.8 | 8.3 | 9.1 | 4.8 | 2.6 | 158.6 | 186.2 | 0.6 | 0.4 | 53.1 | 50.0 |
| 94(05/0741HS) | 7.8 | 6.5 | 8.4 | 11.3 | 8.8 | 10.2 | 257.5 | 261.2 | 0.4 | 0.5 | 87.5 | 100.0 |
| 99(07/1313HS) | 3.2 | 6.0 | 4.1 | 6.4 | 4.6 | 5.2 | 79.0 | 247.0 | 0.5 | 0.4 | 75.0 | 96.9 |
| CH05-203 | 7.2 | 6.5 | 6.5 | 10.6 | 9.6 | 6.8 | 279.4 | 261.2 | 0.5 | 0.4 | 75.0 | 100.0 |
| CK9 | 4.0 | 3.5 | 6.6 | 4.5 | 3.0 | 5.3 | 203.8 | 222.5 | 0.4 | 0.6 | 75.0 | 75.0 |
| COLICANANA | 5.4 | 7.6 | 3.0 | 12.6 | 4.8 | 5.9 | 214.3 | 245.8 | 0.6 | 0.5 | 75.0 | 75.0 |
| D31 | 4.8 | 5.4 | 9.1 | 7.4 | 4.8 | 5.6 | 239.6 | 204.4 | 0.5 | 0.5 | 75.0 | 75.0 |
| Ex-Ndolo | 3.4 | 5.3 | 7.9 | 5.8 | 4.3 | 9.7 | 280.0 | 204.4 | 0.4 | 0.5 | 78.1 | 75.0 |
| EYOPE | 7.1 | 10.7 | 12.3 | 7.0 | 11.8 | 26.8 | 224.4 | 290.0 | 0.3 | 0.4 | 84.4 | 100.0 |
| F10-30R2 | 5.2 | 4.8 | 4.8 | 6.9 | 7.8 | 9.2 | 260.6 | 302.5 | 0.4 | 0.4 | 75.0 | 75.0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F19 | 5.4 | 7.4 | 10.0 | 7.6 | 6.3 | 13.6 | 220.0 | 249.4 | 0.3 | 0.5 | 75.0 | 100.0 |
| FUMBA CHAI | 3.4 | 3.2 | 4.5 | 5.1 | 2.8 | 3.4 | 226.2 | 246.5 | 0.4 | 0.5 | 75.0 | 75.0 |
| I92/0427 | 9.9 | 8.6 | 11.4 | 7.0 | 4.7 | 8.1 | 200.6 | 230.2 | 0.5 | 0.7 | 75.0 | 75.0 |
| I95/034095-N | 11.3 | 8.7 | 9.5 | 9.5 | 9.8 | 14.3 | 162.2 | 294.5 | 0.4 | 0.5 | 75.0 | 75.0 |
| KALAWE | 6.2 | 5.7 | 7.9 | 11.5 | 7.1 | 8.6 | 261.9 | 258.8 | 0.4 | 0.5 | 75.0 | 100.0 |
| KALESO | 2.2 | 6.3 | 6.6 | 5.6 | 4.0 | 10.4 | 145.5 | 270.4 | 0.4 | 0.4 | 75.0 | 75.0 |
| Karembo | 6.0 | 6.1 | 4.4 | 7.4 | 5.0 | 7.3 | 236.9 | 253.8 | 0.4 | 0.6 | 75.0 | 75.0 |
| KBH2002/066-3 | 3.9 | 4.4 | 7.3 | 5.0 | 4.8 | 11.7 | 124.1 | 272.5 | 0.3 | 0.4 | 75.0 | 75.0 |
| KBH2006-026 | 5.1 | 5.6 | 5.6 | 6.8 | 6.5 | 6.6 | 246.2 | 254.2 | 0.4 | 0.4 | 75.0 | 100.0 |
| KIBANDAMENO | 4.1 | 6.6 | 4.5 | 9.1 | 4.1 | 12.1 | 138.4 | 258.5 | 0.4 | 0.5 | 75.0 | 75.0 |
| KIZIMBANI | 3.0 | 5.2 | 5.5 | 3.9 | 4.8 | 4.0 | 173.6 | 263.5 | 0.5 | 0.4 | 78.1 | 75.0 |
| KME 1 | 3.1 | 8.4 | 8.7 | 7.0 | 4.8 | 9.7 | 217.5 | 245.9 | 0.4 | 0.4 | 96.9 | 100.0 |
| LML/2008/363 | 26.0 | 24.1 | 13.7 | 12.4 | 7.9 | 11.3 | 172.5 | 228.2 | 0.7 | 0.8 | 87.5 | 75.0 |
| M96/7151 | 13.9 | 12.5 | 10.1 | 8.9 | 5.3 | 12.2 | 225.0 | 222.9 | 0.5 | 0.7 | 75.0 | 75.0 |
| MAGANA | 4.6 | 5.4 | 7.3 | 6.6 | 3.2 | 7.5 | 230.6 | 282.0 | 0.4 | 0.6 | 78.1 | 75.0 |
| MATUJA | 7.2 | 8.3 | 8.6 | 5.9 | 6.5 | 11.1 | 200.6 | 295.0 | 0.4 | 0.5 | 96.9 | 100.0 |
| MH95/0183 | 5.6 | 5.7 | 6.4 | 7.4 | 7.3 | 8.6 | 249.4 | 297.5 | 0.5 | 0.4 | 75.0 | 75.0 |
| MIGYERA | 2.8 | 7.4 | 5.8 | 5.9 | 5.6 | 16.4 | 270.6 | 243.2 | 0.4 | 0.3 | 75.0 | 75.0 |
| MKUMBA-1 | 4.2 | 8.8 | 7.3 | 6.0 | 4.2 | 18.2 | 204.4 | 277.8 | 0.3 | 0.5 | 75.0 | 75.0 |
| MKUMBA-2 | 4.8 | 5.0 | 9.5 | 6.1 | 6.9 | 8.2 | 257.5 | 247.5 | 0.4 | 0.4 | 75.0 | 75.0 |
| MM06/0013 | 11.6 | 8.1 | 7.0 | 12.3 | 6.9 | 7.0 | 241.9 | 270.0 | 0.5 | 0.7 | 75.0 | 75.0 |
| MM06/0046 | 4.5 | 5.2 | 8.1 | 4.9 | 5.4 | 9.6 | 153.7 | 236.9 | 0.5 | 0.5 | 78.1 | 75.0 |
| MM06/0074 | 7.1 | 8.7 | 11.5 | 10.5 | 8.5 | 9.8 | 251.2 | 246.7 | 0.4 | 0.4 | 96.9 | 75.0 |
| MM06/0082 | 5.1 | 4.7 | 6.4 | 9.1 | 5.8 | 8.7 | 241.2 | 280.6 | 0.3 | 0.5 | 71.9 | 100.0 |
| MM06/0083 | 3.9 | 6.4 | 4.0 | 5.3 | 4.8 | 5.7 | 281.2 | 223.8 | 0.6 | 0.5 | 56.3 | 75.0 |
| MM06/0138 | 7.6 | 8.3 | 6.3 | 11.6 | 7.1 | 9.1 | 191.8 | 242.5 | 0.5 | 0.5 | 84.4 | 50.0 |
| MM06/0139 | 4.4 | 5.0 | 6.7 | 9.1 | 6.8 | 4.0 | 169.9 | 259.5 | 0.6 | 0.4 | 75.0 | 75.0 |
| MM06/0143 | 3.8 | 4.6 | 6.6 | 5.6 | 14.6 | 10.7 | 235.0 | 293.8 | 0.3 | 0.3 | 87.5 | 81.3 |
| MM08/2206 | 5.0 | 6.3 | 8.1 | 5.5 | 6.2 | 9.3 | 171.4 | 267.5 | 0.4 | 0.4 | 75.0 | 75.0 |
| MM96/0669 | 6.3 | 5.7 | 6.4 | 9.6 | 5.8 | 7.3 | 262.5 | 258.8 | 0.5 | 0.5 | 87.5 | 75.0 |
| MM96/0686 | 5.4 | 7.1 | 6.3 | 12.5 | 12.9 | 5.6 | 275.0 | 251.6 | 0.5 | 0.3 | 100.0 | 100.0 |
| MM96/1871 | 2.8 | 2.6 | 3.3 | 6.3 | 5.1 | 2.3 | 212.5 | 300.6 | 0.6 | 0.4 | 75.0 | 75.0 |
| MM96/1956 | 5.1 | 3.1 | 5.0 | 6.0 | 6.2 | 3.3 | 229.0 | 206.2 | 0.5 | 0.4 | 62.5 | 75.0 |
| MM96/2480 | 4.2 | 4.9 | 9.9 | 5.6 | 5.1 | 7.2 | 240.0 | 269.2 | 0.4 | 0.4 | 100.0 | 100.0 |
| MM96/3868 | 6.2 | 5.9 | 6.3 | 8.4 | 4.9 | 6.1 | 230.0 | 251.2 | 0.5 | 0.6 | 81.3 | 87.5 |
| MM96/4684 | 7.9 | 11.9 | 10.8 | 7.1 | 5.5 | 11.2 | 240.0 | 227.5 | 0.5 | 0.6 | 75.0 | 75.0 |
| MM96/5280 | 2.1 | 10.1 | 6.1 | 4.9 | 2.1 | 12.4 | 243.8 | 227.1 | 0.5 | 0.5 | 75.0 | 100.0 |
| MM96/6966A | 3.9 | 6.2 | 12.7 | 3.4 | 8.3 | 7.0 | 176.4 | 174.4 | 0.5 | 0.3 | 87.5 | 87.5 |
| MM96/6966B | 3.8 | 17.1 | 7.1 | 7.6 | 3.7 | 10.6 | 219.4 | 257.5 | 0.6 | 0.5 | 100.0 | 81.3 |
| MM96/9308 | 4.9 | 8.3 | 9.8 | 6.8 | 4.1 | 7.4 | 221.2 | 246.2 | 0.5 | 0.5 | 75.0 | 75.0 |
| MM97/0293 | 5.6 | 6.4 | 6.9 | 6.0 | 5.4 | 3.4 | 190.0 | 250.0 | 0.7 | 0.5 | 100.0 | 75.0 |
| MM97/1744 | 4.3 | 7.8 | 7.1 | 5.5 | 3.9 | 3.3 | 210.6 | 222.0 | 0.8 | 0.5 | 75.0 | 75.0 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MM98/1642 | 10.2 | 8.8 | 7.4 | 9.1 | 10.5 | 8.2 | 268.8 | 277.7 | 0.5 | 0.5 | 100.0 | 100.0 |
| MM98/1669 | 5.4 | 8.2 | 6.0 | 8.5 | 7.2 | 20.8 | 278.8 | 288.8 | 0.3 | 0.4 | 100.0 | 100.0 |
| MM98/2270 | 7.5 | 12.5 | 13.1 | 9.4 | 7.3 | 16.8 | 220.0 | 260.6 | 0.4 | 0.5 | 100.0 | 100.0 |
| MM98/3567 | 7.5 | 8.9 | 6.3 | 9.1 | 10.0 | 4.7 | 236.2 | 260.0 | 0.6 | 0.5 | 87.5 | 100.0 |
| Mucericeri | 4.0 | 4.3 | 7.8 | 7.5 | 3.6 | 7.0 | 203.8 | 224.3 | 0.4 | 0.5 | 87.5 | 75.0 |
| NASE 14 | 1.9 | 3.8 | 7.0 | 5.0 | 3.6 | 7.5 | 258.8 | 263.8 | 0.4 | 0.3 | 75.0 | 75.0 |
| NASE 18 | 6.7 | 6.8 | 6.3 | 11.4 | 6.8 | 8.8 | 251.2 | 236.2 | 0.4 | 0.5 | 75.0 | 100.0 |
| NASE 3 | 4.2 | 6.2 | 8.9 | 6.6 | 4.0 | 9.1 | 190.6 | 170.0 | 0.5 | 0.5 | 75.0 | 75.0 |
| ORERA | 4.1 | 4.9 | 8.5 | 6.6 | 4.2 | 8.9 | 205.6 | 239.8 | 0.4 | 0.6 | 100.0 | 96.9 |
| PWANI | 7.2 | 8.2 | 10.8 | 10.4 | 8.6 | 9.7 | 257.5 | 262.7 | 0.5 | 0.5 | 75.0 | 75.0 |
| SANGOJA | 7.7 | 6.9 | 14.8 | 13.8 | 11.8 | 10.9 | 290.0 | 260.0 | 0.4 | 0.4 | 100.0 | 78.1 |
| SAUTI | 6.3 | 7.8 | 8.1 | 12.4 | 7.3 | 10.1 | 260.0 | 210.0 | 0.4 | 0.5 | 87.5 | 96.9 |
| SERERE | 3.8 | 3.9 | 5.9 | 7.6 | 4.0 | 5.4 | 231.9 | 268.6 | 0.4 | 0.5 | 75.0 | 75.0 |
| TAJIRIKA | 4.5 | 8.8 | 9.0 | 7.1 | 11.9 | 14.7 | 245.6 | 285.7 | 0.4 | 0.4 | 75.0 | 78.1 |
| TME 14 | 4.7 | 4.1 | 3.5 | 10.8 | 6.6 | 11.9 | 160.6 | 151.2 | 0.3 | 0.4 | 90.6 | 100.0 |
| TZ-130 | 15.2 | 12.0 | 14.0 | 11.6 | 7.8 | 7.9 | 252.1 | 213.8 | 0.6 | 0.7 | 87.5 | 100.0 |
| UNKNOWN 4 | 4.3 | 5.5 | 4.8 | 6.6 | 4.2 | 5.4 | 228.8 | 193.3 | 0.5 | 0.5 | 78.1 | 96.9 |
| YIZASO | 6.8 | 9.1 | 11.9 | 9.6 | 4.6 | 5.8 | 250.6 | 250.0 | 0.6 | 0.5 | 75.0 | 75.0 |
| MEAN | 5.8 | 7.0 | 7.8 | 7.8 | 6.3 | 9.0 | 219.0 | 245.5 | 0.5 | 0.5 | 80.7 | 82.0 |

Stress= mean performance in stressed treatment; Non= non-stressed treatment

### *3.2 Trait correlations*

Pearson correlation coefficient (r) was used to study the relationship between traits. Significant and positive correlations were observed between SRFW and other traits under water stressed and non-water stressed treatments.

**Table 2.** Pearson correlations between traits under stressed treatment

| | **SRFW** | **NSR** | **AGW** | **PH** | **HI** | **LR** |
|---|---|---|---|---|---|---|
| **SRFW** | 1 | | | | | |
| **NSR** | 0.37** | 1 | | | | |
| **AGW** | 0.30** | 0.32** | 1 | | | |
| **PH** | 0.07 | 0.17** | 0.09* | 1 | | |
| **HI** | 0.56** | 0.09* | -0.40** | 0.02 | 1 | |
| **LR** | 0.05 | 0.11** | 0.13** | 0.19** | -0.04 | 1 |

**Correlations significant P< 0.01; *Correlations significant at P< 0.05

**Table 3.** Pearson correlations between traits under non-stressed treatment

| | **SRFW** | **NSR** | **AGW** | **PH** | **HI** | **LR** |
|---|---|---|---|---|---|---|
| **SRFW** | 1 | | | | | |
| **NSR** | 0.43** | 1 | | | | |
| **AGW** | 0.38** | 0.31** | 1 | | | |
| **PH** | 0.10* | 0.09* | 0.21** | 1 | | |
| **HI** | 0.44** | 0.09* | -0.48** | 0.12 | 1 | |
| **LR** | 0.18** | 0.17** | 0.15** | 0.08* | -0.04 | 1 |

**Correlations significant P< 0.01; *Correlations significant at P< 0.05

**4. Discussion**

Field experiment was carried out to assess the performance of selected cassava varieties under drought conditions using morphological traits. The morphological data collected included SRFW, NSR, AGW, PH, HI and LR taken at different growth stages. Water deficit suppressed cassava growth and productivity and this was observed by lower outputs obtained from most traits like SRFW, AGW, PH and LR under stressed treatment as compared to non -stressed. Breeding crops for increased yield and adaptation to drought stress often targets crop yield as the trait of interest during selection [16]. In cassava, the storage root yield has been emphasized as the key selection index for stress tolerance. Therefore, SRFW was used to select high performing varieties in the study in terms of yield. Relative to well-watered plants, water deficit plants exhibited low tuber yield in terms of root weight in the study. Low moisture content affects the root by reducing the amount of productive foliage [5] and this reduces the number and size of tubers produced which in turn reduces final yields. In an agricultural context, farmers and breeders tend to define drought tolerant cultivars as those that maintain yield under drought conditions. In the study, varieties that had higher SRFW under water deficit treatment were classified as tolerant for example LML/2008/363 weighed significantly higher under water deficit. Higher root yield in the study has been associated with increase in NSR, AGW, PH, HI and LR. Therefore, these can be used as target traits during selection of high yielding cassava under drought stress. These observations have also been made from other previous studies [15]. Water deficit was observed to lower the NSR in the study. Past research also indicated a decline in root numbers by 19.43% as a result of moisture stress. Most of the drought tolerant varieties indicated higher NSR as compared to drought tolerant varieties and these are, MM06/0013, SANGOJA, LML/2008/363, I95/034095-N, I92/0427, 29B29 and TZ-130. Higher NSR indicates the sink strength of the roots thus in our findings, high root number led to an increase in yield as concluded by previous findings [1]. In this study, significant AGW differences were observed between different varieties and treatments. Water shortage generally showed a lower AGW as compared to well-watered plants. Significant genotypic variation for AGW in cassava and its reduction due to water stress has been reported by earlier research [2]. Varieties with high above ground weight tended to produce a good top yield which is in tandem with previous work [4] which suggested that vigorous genotypes produce better under stress than less vigorous varieties. Therefore, a genotype with optimal LR is required for the attainment of a high yield under stress conditions [7].

Plant height was significantly affected by both water treatment and genotype. Drought generally lowered the height of the plants as compared their well-watered counterparts. The magnitude of height suppression was different among varieties. The fact that there was a significant interaction between treatment and varieties shows several activities to the prevailing moisture conditions. Whether there is a relationship between the plant height and its ability to tolerate drought is not yet known, but findings of the study can be further investigated. HI, the ratio of economic yield to that of the biomass yield was measured at 12 MAP. In the study, the correlation between root weight and harvest index was found significant especially under water stressed conditions. Findings reported by [6] have also shown correlation between root weight and harvest index. The study showed that the high yielding genotypes maintain higher harvest index which suggests that evaluation of HI could be a useful indicator of genotype's ability to have higher storage root when resources are limited by water stress. In this study also, HI and AGW showed significant and negative correlations and this was attributed to formulae used to compute HI as a ratio of storage root weight to the total weight [11]. An increase in AGW increases total plant weight and lowers HI and vice versa [13] Leaf retention has also been recorded to be a very important trait when it comes to the selection of good performing varieties under drought conditions [1]. A variety like MM98/1642 which was qualified to be a resistant variety in the study, had a higher LR. Increased longevity of leaves or improved leaf retention has been suggested as a possible means of increasing productivity of cassava. The positive correlations between LR and yield indicate that it should be incorporated in breeding selection program directed to increase yield under both water stressed and stressed conditions.

## 5. CONCLUSIONS AND RECOMMENDATIONS

Although cassava is a drought tolerant crop, low soil moisture content still affects its growth and productivity. SRFW which was used as the key trait for selection, expressed significant and positive correlation with other traits. Genotypes LML/2008/363, TZ-130, M96/7151, MM06/0013, I95/034095- N, MM98/1642, I92/0427 and 29B29 performed better for important drought tolerance traits NSR, AGW, HI and LR. This suggests that the selected traits mention traits should be combined and bred in future to maximize productivity in moisture stress environments. Selected genotypes in this project is should be introduced to marginal areas for food security purposes. Molecular studies of the genotypes are recommended in order to understand factors responsible for their tolerance to water deficit.

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