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Determining the Tolerance of Selected Cassava (*Manihot esculenta Crantz*) Genotypes to Drought and Salinity using Chlorophyll, Phenol and Yield as Screening Tools

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Authors' contributions

This work was carried out in collaboration between both authors. Author BAM wrote the first draft under the professional supervision of author OJO. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To ascertain and compare the tolerance of the selected cassava (*Manihot esculenta*) genotypes to drought and salinity using chlorophyll, total phenolic acid content and yield attributes as the screening parameters.
Study design: The design was factorial consisting of ten cassava genotypes, three treatments (and control) with six replications laid out in a randomized complete block design (RCBD).
Place and duration of study: Department of Botany, University of Ibadan, between January and July, 2019.
Methodology: There were a total of 240 experimental units, 60 units in each group. It was semi-field as the plants were potted, treatments controlled while still exposed to natural environmental factors such as direct sunlight, air etc. All plants were watered for 6 weeks before exposing them to the physiological stresses of drought (D), salinity (S) and their interaction (D×S). The designated plants were subjected to S by applying 100mM of NaCl solution, D by with-holding water for 2wks interval, (D×S) by combining the two stresses and the first block (the first 60 units) serve as control.

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Results: With respect to total chlorophyll content (TCC) at the final stage, the highest TCC was synthesized by TMEB419 (42.84 mg/g) under drought (D), IBA120008 (48.23 mg/g) and (39.80 mg/g) under salinity (S) and under drought and salinity (D×S) respectively while the least TCC was recorded in genotypes I070593 (4.37 mg/g) under D, I920326 (21.86 mg/g) under S and I098510 (15.65 mg/g) under D×S. With respect to total phenolic acid content (TPC), the most tolerant genotype was the salt-stressed I070593 (4.201 mg/g) among all the stressed genotypes and their controls while the least tolerant was combined stressed I980581 (1.89 mg/g). With respect to tuber yield (fresh weight), cassava genotype I980581 is the most tolerant in all the stresses (174g under D, 350g under S and 224g under D×S) while the least tolerant were TMEB693 (23.97g) under D, IBA120008 (39.53g) under S and I010040 (16.80g) under D×S.

Conclusion: In conclusion, genotype I980581 is the most tolerant under all the stresses while the least tolerant were TMEB693 under D, IBA120008 under S and I010040 (D×S).

Keywords: Cassava genotypes; chlorophyll; phenol; drought; salinity and environment.

1. INTRODUCTION

Since time immemorial, environment has always been altered by man's incessant activities or natural disasters which may also occur as a result of man's accumulated alterations in the environment. Some of the results of such alterations are drought and salinity which both have devastating effects on agricultural productivity.

Cassava (*Manihot esculenta* Crantz) is a woody shrub from the family Euphorbiaceae. It has an edible starchy tuberous root, a major source of carbohydrates. It can serve as both food and cash crops [1]. Cassava has many genotypes which respond differently to soil, climatic and biotic factors [2]. Cassava is mainly cultivated in the low land tropics where there is warm climate [3,4]; with day-length between 10-12 hours [5].

Cassava is currently world's fourth most important staple and carbohydrate-enriched food (about 85% starch content on dry weight basis of peeled storage roots) after rice, wheat and maize; and is an important component in the diet of over 800 million people across continents [6].

Cassava roots and leaves are deficient in sulfur-containing amino acids such as cysteine and methionine [7,8]. As a result, cassava is often considered an inferior food. However, in many cassava-growing areas, its importance in terms of food security cannot be overemphasized. Cassava is also grown for industrial purposes such as fermentation into ethanol and production of starch [9,10].

Water is a fundamentally important component of metabolism in living organisms that facilitates many vital biological reactions by being a solvent, a transport medium and an evaporative coolant [11]. Water is a major limiting factor in world agriculture [12]. Cassava is one of the most drought-tolerant crops. However, its growth and productivity in marginal areas are constrained by severe drought stress, especially during the earlier stages of growth [13,14].

Plant growth in saline medium is affected first by an osmotic stress and then by toxic and nutritive stresses [15]. Salt may arise naturally in the subsoil or be introduced by brackish irrigation waters [16]. Osmotic adjustment is one of the essential methods deployed by plants to combat soil salinity. Here, all cells accumulate sufficient solutes to balance extra osmotic pressure in the soil solution to maintain turgor [17]. At the early stage of salinity stress within a plant, all the major processes such as photosynthesis, protein synthesis and; energy and lipid metabolism are affected [18].

Chlorophylls are abundant biological pigments in nature [19] that are necessary for photosynthesis. In most crops, photosynthetic rates decrease greatly with leaf age [20]. The quantity of solar radiation absorbed by a leaf is a function of the chlorophyll concentration [21], a plant's photosynthetic potential is directly proportional to the quantity of chlorophyll present in the leaf tissue [22] and so, photosynthetic potential can be reduced when concentration of chlorophyll is low [23]. Report from early findings showed that both moderate and severe water deficit can greatly affect chlorophyll formation [24].

In cassava, root yield and total biomass increase linearly as leaf chlorophyll increases [25,26,27]. The effect of drought can be direct (primary); or secondary such as oxidative stress which mostly occur under multiple stress conditions [28,29]. Drought and salinity greatly affect photosynthesis [30,31] by restricting CO_2 diffusion into the chloroplast, disrupting leaf photochemistry and carbon metabolism; although the effects vary with intensity, duration of the stress, plant species and leaf age [32,33,34,35,36,37].

Phenolics are aromatic compounds bearing one or more hydroxyl substituents. Plant phenolics include phenolic acids, flavonoids, tannins, stillbenes and lignins. However, flavonoids and phenolic acids are the most common polyphenols in our diet and are distributed widely in fruits, vegetables, cereals and beverages [38,39]. Phenolics can function as a filter by absorbing radiation and limiting the excitation of chlorophyll during unfavourable conditions such as drought [40]. A study on extra virgin olive oils using four different methods also showed that where there is a high concentration of total polyphenol content, antioxidant activity significantly increases [41]. This is also in line with a work on cassava stems [42].

In addition to being exposed to notable genotypes and environmental interactions, farmers' preferences enables geographically decentralized cassava breeding [43], which affects yield and productivity of both new clones and old cultivars of cassava. Fresh cassava root tubers (Plate 1) are highly perishable due to short postharvest life than any of the major root crops [5,44]. The reduction in tuber yield is dependent on the duration of water shortage and different sensitivity of the growth stages also [5].

From agronomic perspective, salt-tolerance is based on yield of the harvestable organ and as such, it becomes pertinent to understand how salinity affects vegetative and reproductive developments of plants in order to curb its detrimental effects on such plants [45].

The aim of the study was to ascertain and compare the tolerance of the selected cassava (*Manihot esculenta*) genotypes to drought and salinity using chlorophyll, total phenolic acid content and yield attributes as the screening parameters.

The basis of this research is to provide information on these new genotypes so as to help farmers and others concerned to select genotypes that is naturally best adapted to their soil types and environment (desert and/or coastal areas); hence, maximise yield.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out on the field at the Department of Botany, University of Ibadan, Ibadan, Oyo state.

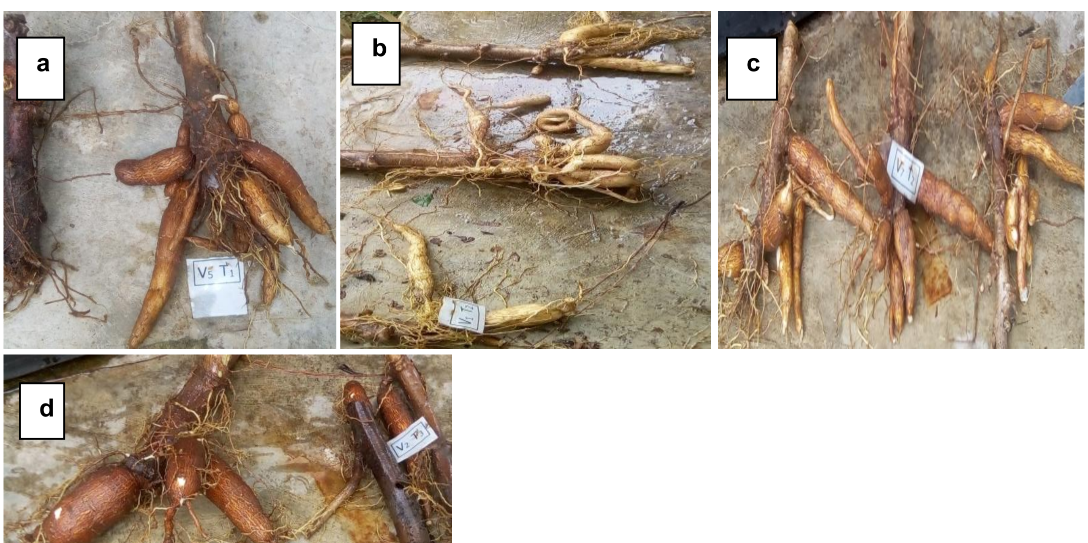

Plate 1. Pictures showing the tuber yields of some of the cassava genotypes under control, drought and salinity (1a-d)

a- TMEB419 (C), b- IBA120008 (D), c- I011368 (D) and d- I098510 (S)

2.2 Soil Sampling and Analysis

Soil samples were collected from the Nursery of Department of Botany, identified from Agronomy department; University of Ibadan, and routine analysis was carried out. Two hundred and forty Bagco bags (20kg each) were filled with 15kg of soil. The bags were perforated for aeration and to release excess water if there is any. This made it a semi-field experiment because the plants were potted, treatments controlled while still exposed to natural environmental factors such as rain, direct sunlight, air etc.

2.3 Sources of Planting Materials

The stakes of the ten cassava genotypes were collected from the International Institute of Tropical Agriculture (IITA) and were screened for tolerance to drought and salinity using chlorophyll and total phenolic acid contents with yield, as the screening parameters. The ten cassava genotypes used in the present study were:

1. IBA120008
2. I098510
3. I010040
4. I070539
5. TMEB419
6. TMEB693
7. I011368
8. I980581
9. I070593
10. I920326

2.4 Experimental Design

The experiment was carried out in a factorial arrangement consisting of ten cassava genotypes, four treatments with six replications laid out in a randomized complete block design (RCBD); making a total of 240 experimental units.

The treatments were : Cassava + Water stress (Plate 2), Cassava+ salinity (NaCl) and Cassava + Water stress + salt stress (D×S). Cassava + watering (control).

2.5 Planting and Cultural Practices e.g. Weeding and Watering

Each bagged soil was watered to field capacity and the cassava stakes were planted in the soil in a slanting position with the buds facing upward.

All plants were watered for 6 weeks before exposing them to the physiological stresses of drought, salinity and their interaction (D×S). During the first 6 weeks, all plants were watered with (1 l) of water every other day. Afterwards, plants for control and salinity were watered (1 l) once a week while those of drought and D×S were watered (1 l) once in two weeks. The bags with the plants for D and D×S were sealed from the mouth with pins and masking tape in order to control water entry. Subsequently, clearing of weeds was done as and when due.

2.6 Salt Application

The designated plants were subjected to salt stress by applying 100mM of NaCl salt solution once a week for (S) and once in two weeks for (D×S). The 100mM was derived by dissolving 5.86g of NaCl per 1litre of water.

2.7 Harvesting

The plants were harvested at six months (24 weeks) after planting (January-July, 2019). The plants were divided into two; shoot and tuberous roots and their fresh and dry weights were taken to determine yield.

2.8 Data Collected

2.8.1 Determination of chlorophyll content

Chlorophyll content was analyzed twice at 16^{th} and 23^{rd} weeks (both stressed and control samples) after planting. Using extracts from fully expanded fresh leaves of each replicate (from each treatment and control) to determine their absorbance with the aid of a visible spectrophotometer at 663nm and 645nm wavelengths, total chlorophyll; chlorophyll a and chlorophyll b were estimated as described by the method of Arnon [46].

2.8.2 Determination of total phenolic acid content

Total phenolic acid content was the biochemical character analyzed at 23^{rd} week after planting. This was done following the description of Marinova et al. [47]. Absorbance was determined using visible spectrophotometer at 750nm, gallic Acid serving as blank solution.

2.8.3 Yield determination

All plants were harvested at the 24^{th} week when the fresh weights of shoot and tuberous roots were obtained by weighing on the weighing balance. Then, they were oven-dried at 80^{o}C for 8 days until constant weights were obtained.

Plate 2. Picture showing a section (treatment) of the cassava farm for drought

2.9 Statistical Analysis

Data obtained in this study were recorded as means of replicates and analysed using GLM Procedures based on statistical Analysis of Variance (ANOVA) by using Statistical Analysis Software (IBMSAS 9.1). Means of the treatments and controls were also compared and separated using Duncan Multiple Range Test (DMRT) at significance level set at α .05. Graphs were plotted using Graph pad (Prism 6) statistical tool.

3. RESULTS

3.1 Chlorophyll

It was generally observed that drought and salt stresses with their combination had varying effects on the chlorophyll contents in all the cassava genotypes studied (Figs. 1-3). With respect to drought, genotype TMEB419 had the highest total chlorophyll content (TCC) of 42.84 mg/g (with its control having 47.81 mg/g) while I070593 had the least TCC of 4.37 mg/g (with the control value of 18.16 mg/g) (Fig. 1).

It was observed that salinity significantly affected all the cassava genotypes when compared with their corresponding controls with the exception of I010040, I980581 and I070593 (Fig.2). Genotype IBA120008 was the most tolerant to salinity as it had the highest TCC of 48.23 mg/g among the salt stressed cassava genotypes (while its control had 46.49 mg/g) but I920326 had the least TCC of 21.86 mg/g (while its control had 34.34 mg/g).

The responses of the cassava genotypes to the combined effect of drought and salinity with respect to chlorophyll contents are reported in Fig 3. With regard to TCC, genotype IBA120008 was the most tolerant by synthesizing 39.80 mg/g of TCC (with the control having 46.49 mg/g) while I098510 was the least tolerant with TCC of 15.65 mg/g (with the control having 42.85 mg/g).

The chlorophyll a contents of genotypes TMEB419 and I098510 were the least and most significantly affected by the combined stress respectively while the chlorophyll b contents of genotypes I920326 and I098510 were the least and most significantly affected respectively.

3.1.1 Total phenolic acid contents (TPC)

The effects of drought, salinity and their combination on TPC in all the selected cassava genotypes are presented in Fig. 4. It was observed that the stressed cassava genotypes in most cases synthesized more TPC than their corresponding controls. The cassava genotypes that produced the highest and lowest TPC were the most and least tolerant respectively; in comparison with their corresponding controls.

Among all the stressed and unstressed genotypes (controls), it was observed that salt stressed I070593 had the highest TPC of 4.201 mg/g as compared to its control (2.47 mg/g). However, the least TPC were recorded in combined stressed I980581 (1.89 mg/g) while its control had 2.95 mg/g.

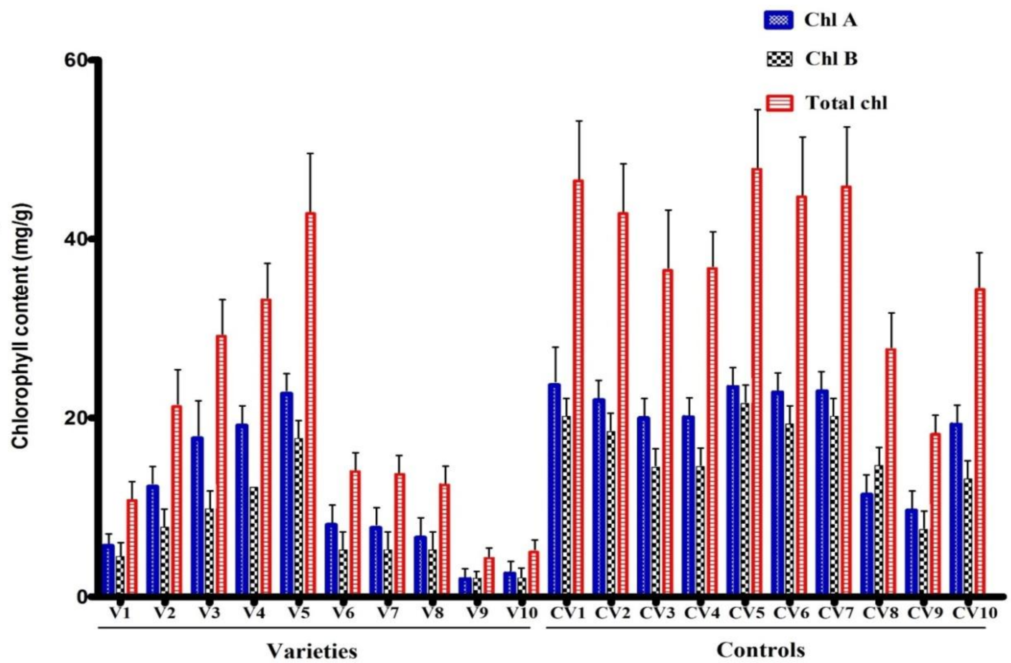

Fig. 1. Bar chart showing the effect of drought on the chlorophyll contents of the selected genotypes of cassava at the 23rd week; Error bar equivalent to standard error of the means (SEM)

Keys: V1-IBA120008, V2-I098510, V3-I010040, V4-I070539, V5-TMEB419, V6-TMEB693, V7-I011368, V8-I980581, V9-I070593, V10-I920326 and C- Control

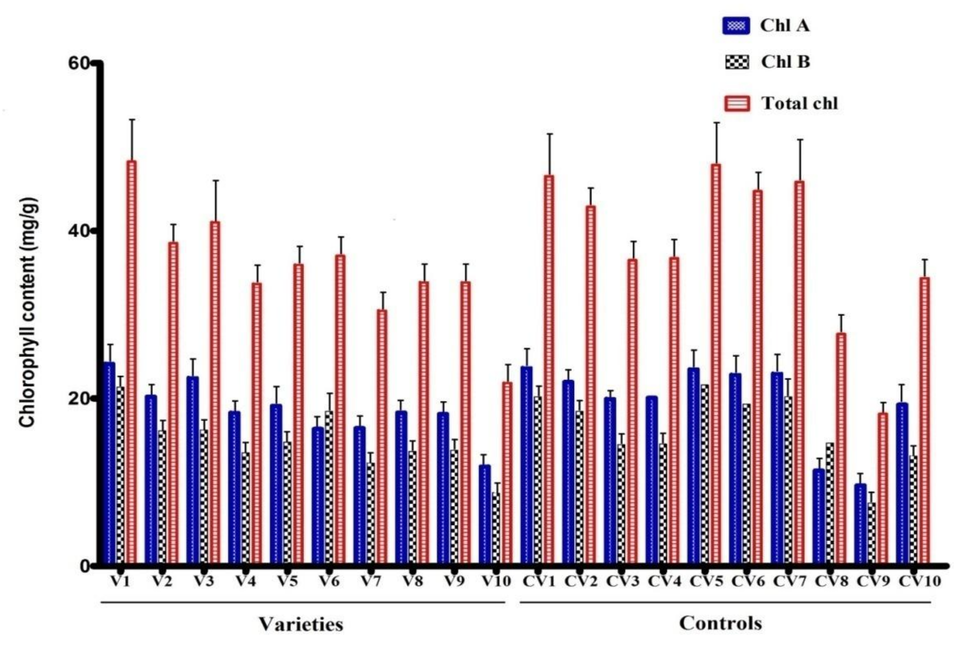

Fig. 2. Bar chart showing the effect of salinity on the chlorophyll contents of the selected cassava genotypes at the 23rd week; Error bar equivalent to standard error of the means (SEM)

Keys: V1-IBA120008, V2-I098510, V3-I010040, V4-I070539, V5-TMEB419, V6-TMEB693, V7-I011368, V8-I980581, V9-I070593, V10-I920326 and C- Control

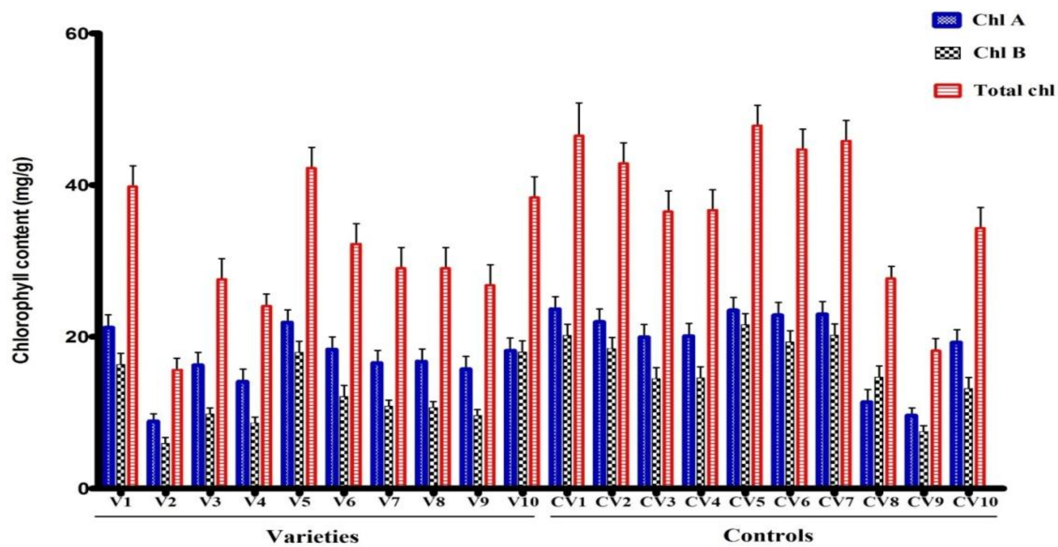

Fig. 3. Bar chart showing the combined effect of drought and salinity on the chlorophyll contents of the selected cassava genotypes at the 23rd week; Error bar equivalent to standard error of the means (SEM)

Keys: V1-IBA120008, V2-I098510, V3-I010040, V4-I070539, V5-TMEB419, V6-TMEB693, V7-I011368, V8-I980581, V9-I070593, V10-I920326 and C- Control

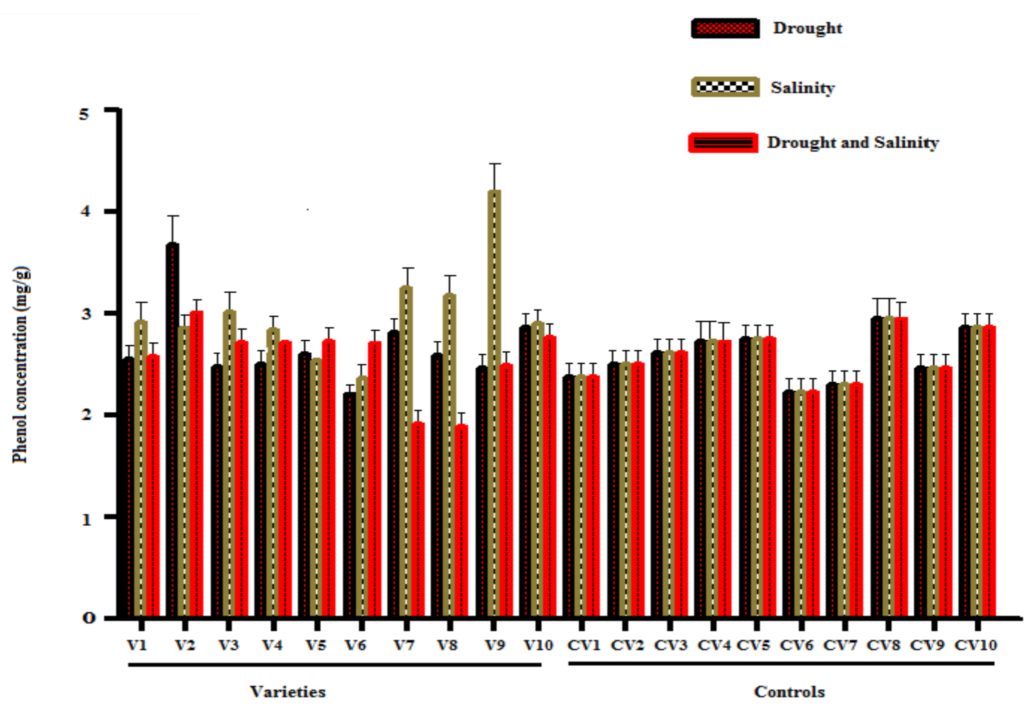

Fig. 4. Bar chart showing the total phenolic acid contents of the selected cassava genotypes under drought, salinity and their combination; bars equivalent to standard error of the means (SEM)

Keys: V1-IBA120008, V2-I098510, V3-I010040, V4-I070539, V5-TMEB419, V6-TMEB693, V7-I011368, V8-I980581, V9-I070593, V10-I920326 and C- Control

3.1.2 Yield parameters

The responses of all the cassava genotypes and their controls to the selected stresses with regard to yield parameters are presented in Tables 1-3.

It was observed that the shoot fresh weight (SFW) of genotypes I070539 and I010040 were the least and most significantly affected by drought respectively. In terms of the tuber dry weight (TDW), the highest and lowest among the drought stressed genotypes were I011368 (34.62 g) and TMEB693 (04.35 g) (Table 1).

For all the salt-stressed genotypes (Table 2), I980581 and IBA120008 were the least and most significantly reduced in terms on number of tubers (NOT). For tuber fresh weight (TFW), the most and least tolerant to salinity were genotypes I980581 (350.87 g) and IBA120008 (39.530 g) respectively.

Under the combined effect of drought and salinity, genotypes TMEB693 and TMEB419 had the highest and lowest SFW of 162.73 and 28.44 g respectively. For TFW, the most and least tolerant to the combined stress were genotypes I980581 (224.17 g) and I010040 (16.80 g) respectively.

4. DISCUSSION

Cassava is a rustic crop that strives under unfavourable environmental and soil conditions. However, the results from this study showed that at varying rates; drought, salinity and their combination have significant effects on several aspects of cassava studied which are chlorophyll contents, total phenolic acid contents and yield parameters.

Chlorophyll is the primary pigment for photosynthesis and as such, it is directly proportional to photosynthetic activities of plants [48]. At 23rd week after planting (17 weeks after treatment application), chlorophyll a, b and

Table 1. The yield parameters of selected cassava genotypes under drought

Genotypes	SHOOT FW (g)	SHOOT DW (g)	NO OF TUBER	TUBER FW (g)	TUBER DW (g)
IBA120008	185.57^{ab}	78.42^{b}	4.33^{bc}	74.53^{c}	15.81^{bc}
I098510	98.94^{c}	35.50^{c}	4.33^{bc}	76.07^{c}	18.30^{bc}
I010040	59.14^{c}	25.18^{c}	2.00^{e}	42.12^{d}	10.43^{e}
I070539	221.95^{abc}	86.95^{a}	3.33^{d}	65.98^{cd}	16.62^{c}
TMEB419	158.83^{ab}	67.02^{bc}	6.00^{b}	125.88^{b}	27.87^{b}
TMEB693	66.39^{c}	29.64^{d}	3.33^{d}	23.97^{e}	4.35^{f}
I011368	105.40^{ab}	51.31^{bc}	7.33^{c}	143.37^{ab}	34.62^{b}
I980581	97.96^{c}	42.23^{c}	6.67^{c}	174.54^{a}	29.48^{b}
I070593	138.62^{ab}	65.96^{bc}	3.67^{d}	80.56^{c}	17.42^{c}
I920326	97.24^{c}	37.03^{c}	3.33^{d}	82.98^{bc}	15.15^{bc}
Control IBA120008	166.73^{ab}	69.43^{bc}	5.33^{b}	56.17^{d}	13.02^{d}
Control I098510	172.82^{ab}	73.23^{b}	2.50^{e}	147.09^{ab}	26.39^{b}
Control I010040	256.49^{abc}	89.18^{a}	3.67^{d}	75.43^{c}	9.97^{d}
Control I070539	140.67^{ab}	58.55^{bc}	4.33^{bc}	109.18^{b}	23.48^{b}
Control TMEB419	125.17^{ab}	49.30^{c}	8.00^{a}	178.94^{a}	42.51^{ab}
Control TMEB693	233.49^{abc}	96.04^{a}	2.00^{e}	95.58^{b}	23.82^{b}
Control I011368	268.57^{abc}	86.77^{a}	4.67^{bc}	99.99^{b}	20.76^{b}
Control I980581	158.45^{ab}	50.52^{bc}	5.33^{b}	253.61^{a}	68.75^{a}
Control I070593	76.59^{c}	33.05^{c}	2.00^{e}	49.36^{d}	11.12^{d}
Control I920326	132.20^{ab}	39.84^{c}	5.33^{b}	185.62^{a}	32.22^{b}
N	54.00	54.00	56.00	56.00	56.00
Alpha	.05	.05	.05	.05	.05
Df	53	53	55	55	55
Standard Error of the mean	12.48	4.79	0.28	9.49	2.34
Sum of Square	445746.30	65516.89	248.21	277110.30	16819.86
Harmonic Mean of Cell Sizes	148.04	57.94	4.32	103.97	22.34
F Value	1.44	1.10	2.31	3.46	3.46
Sig	0.173	0.397	0.015	0.001	0.001

Mean values across each column having the same superscript letters are not significant according to Duncan Multiple range test (DMRT).

Table 2. The yield parameters of selected cassava genotypes under salinity

Genotypes	SHOOT FW (g)	SHOOT DW (g)	NO OF TUBER	TUBER FW (g)	TUBER DW (g)
IBA120008	109.43[cd]	43.92[cd]	1.00[e]	39.53[e]	08.76[d]
I098510	253.14[a]	69.92[ab]	4.33[ab]	163.49[ab]	36.97[bc]
I010040	161.34[c]	84.38[a]	2.67[cd]	106.09[c]	20.11[c]
I070539	173.91[c]	67.80[ab]	4.33[ab]	103.93[c]	23.72[c]
TMEB419	72.10[de]	29.81[d]	7.00[a]	110.81[c]	29.01[c]
TMEB693	92.02[de]	41.87[c]	3.00[c]	109.14[c]	31.70[bc]
I011368	88.88[de]	41.45[c]	5.33[b]	109.29[c]	26.17[c]
I980581	192.59[bc]	79.04[a]	8.00[a]	350.78[a]	77.18[a]
I070593	84.58[de]	38.68[d]	4.00[ab]	70.67[d]	13.40[d]
I920326	227.01[b]	67.62[ab]	5.33[b]	197.72[b]	37.14[bc]
Control IBA120008	111.15[d]	69.43[ab]	5.33[b]	56.17[cd]	13.02[d]
Control I098510	115.21[d]	73.23[ab]	2.50[cd]	147.09[b]	26.39[c]
Control I010040	256.49[a]	89.18[a]	3.67[c]	75.43[d]	09.97[d]
Control I070539	140.67[c]	58.55[c]	4.33[ab]	109.18[c]	23.48[c]
Control TMEB419	41.72[e]	30.31[d]	8.00[a]	178.94[b]	42.51[b]
Control TMEB693	155.66[c]	96.04[a]	2.00[d]	95.58[c]	23.82[c]
Control I011368	268.57[a]	86.77[a]	4.67[ab]	99.99[c]	20.76[c]
Control I980581	158.45[c]	50.52[c]	5.33[b]	253.61[a]	68.75[a]
Control I070593	76.59[de]	33.05[d]	2.00[c]	49.36[e]	11.12[d]
Control I920326	132.20[c]	39.84[d]	5.33[b]	185.62[b]	32.22[bc]
N	60.00	50.00	51.00	51.00	51.00
Alpha	.05	.05	.05	.05	.05
Df	59.00	49.00	50.00	50.00	50.00
Standard Error of the mean	14.82	4.74	0.32	15.58	3.74
Sum of Square	777423.00	54923.60	264.71	619212.60	35633.40
Harmonic Mean of Cell Sizes	142.44	61.66	4.53	135.43	29.75
F Value	22.41	0.77	2.03	12.007	81.24
Sig	<0.00011	0.71700	0.03800	<0.00011	<0.00011

Mean values across each column having the same superscript letters are not significant according to Duncan Multiple range test (DMRT).

total chlorophyll were greatly reduced by drought. A similar report to the present study was made by [49] on cassava. The chlorophyll content decreased to a significant level at higher water deficits in sunflower plants [50], drought stressed cotton [51] and *Catharanthus roseus* [52]. In barley (*Hordeum vulgare* L.) however, it was reported that leaf chlorophyll content remained relatively unaffected by water stress [24] and also in corn leaves [22].

The effect of salinity on chlorophyll content was significant as the control chlorophyll values were higher than the salt-stressed values among all the cassava genotypes studied with the exception of I010040, I980581 and I070593. Similar observation was made under the combined drought and salinity with the exception of I070593 and I920326. Total chlorophyll concentration of cassava decreased with increasing salt concentration [53].Salinity reduced chlorophyll a and b in cotton [54]. NaCl salinity does not affect chlorophyll a content in wheat [55] which contradicted the report of this study. A decline in photosynthetic rate was reported in rice under salinity. This reduction may be caused by water deficit in the leaf cells due to accumulation of salt in the apoplast, in addition to CO_2 shortage [56]; which is usually and partly caused by stomatal closure.

Under drought, salinity and their combination, phenol contents greatly increased when compared with their corresponding controls. Similar reports were observed under salinity by Colla et al. [57]; Hura et al. [40] and; Nacif de Abreu and Mazzafera [58]. Increased production of phenolics under drought may be caused by accumulation of soluble carbohydrates in plant cells due to reduced transportation of soluble sugars [59]. Zhu et al. [49] reported an increase in total phenols of cassava as as a defense

Table 3. The yield parameters of selected cassava genotypes under the combined stresses of drought and salinity

Genotypes	SHOOT FW (g)	SHOOT DW (g)	NO OF TUBER	TUBER FW (g)	TUBER DW (g)
IBA120008	160.87^{ab}	52.46^{c}	4.00^{b}	84.30^{b}	17.26bc
I098510	124.93^{ab}	51.93^{c}	5.00^{a}	180.84^{a}	44.47^{b}
I010040	79.77^{c}	34.58^{d}	2.00^{c}	16.80^{e}	3.45^{d}
I070539	103.09^{b}	43.23^{c}	4.67^{b}	154.69^{ab}	37.79^{b}
TMEB419	28.44^{d}	20.62^{d}	6.00^{a}	161.71^{ab}	44.10^{b}
TMEB693	162.73^{ab}	81.13^{a}	2.33^{c}	48.64^{c}	13.06^{c}
I011368	096.80^{ab}	45.57^{c}	8.67^{a}	142.28^{ab}	26.88^{bc}
I980581	073.98^{c}	37.54^{cd}	5.00^{b}	224.17^{a}	56.97^{a}
I070593	109.83^{ab}	59.45^{c}	3.67^{b}	28.64^{d}	5.45^{d}
I920326	086.07^{c}	42.84^{c}	4.33^{b}	134.44^{ab}	18.01b^{c}
Control IBA120008	111.15^{b}	69.43^{b}	5.33^{a}	56.17^{c}	13.02^{c}
Control I098510	115.21^{b}	73.23^{b}	2.50^{c}	147.09^{a}	26.39^{bc}
Control I010040	256.49^{a}	89.18^{a}	3.67^{b}	75.43^{bc}	9.97^{d}
Control I070539	140.67^{ab}	58.55^{c}	4.33^{b}	109.18^{ab}	23.48^{bc}
Control TMEB419	41.72^{d}	49.30^{c}	8.00^{a}	178.94^{a}	42.51^{b}
Control TMEB693	155.66^{ab}	96.04^{a}	2.00^{c}	95.58^{ab}	23.82^{bc}
Control I011368	268.57^{a}	86.77^{a}	4.67^{b}	99.99^{ab}	20.76^{bc}
Control I980581	158.45^{ab}	50.52^{c}	5.33^{a}	253.61^{a}	68.75^{a}
Control I070593	076.59^{c}	33.05^{d}	2.00^{c}	49.36^{c}	11.12^{d}
Control I920326	132.20^{ab}	39.84^{c}	5.33^{a}	185.62^{a}	32.22^{b}
N	60	54	55	55	55
Alpha	.05	.05	.05	.05	.05
Df	59	53	54	54	54
Standard Error of the mean	11.42	4.32	0.33	10.80	3.003
Sum of Square	6323.62	953.51	4.97	3412.25	296.89
Harmonic Mean of Cell Sizes	124.16	55.33	4.44	121.18	26.90
F Value	3.39	1.16	8.99	3.51	2.91
Sig	<0.0001	0.3420	<0.0001	0.0010	0.0030

Mean values across each column having the same superscript letters are not significant according to Duncan Multiple range test (DMRT).

mechanism to drought. A contrasting report to the present study was given by Krol et al. [60], that drought stress caused reduction in total phenolic compounds in grapevine leaves and roots.

Generally, it was observed in this study that drought significantly affected other yield parameters but not the shoot fresh and dry weights of the studied cassava genotypes. However, the studied genotypes also showed varying levels of tolerance here as the values of some genotypes under stress exceeded their controls. Orek et al. [61] reported strong genetic variability for drought tolerance during a field trial on cassava. Drought reduced yield in soybean [62], rice [63] and cassava [5,64,65]. Reduction in yield parameters of plants by drought could be attributed to a resultant decrease in photosynthesis [30]. Drought or salinity had significant effect on shoot fresh and dry weights [66]. Many other earlier studies reported decline in yield of cassava under drought [67,68,69]

Generally, it was observed that salinity; and the combined stress of drought and salinity significantly affected all the yield parameters except the shoot dry weights. This was in line with the reports of Qasim et al. [70], where salinity significantly affected shoot mass and seed yield of canola (*Brassica napus* L.) and Ali et al. [55], on wheat where salinity significantly reduced grain yield and shoot weights. Reduction in the biomass of cassava by salinity was reported but that younger, pre-tuberous plants are more susceptible than older plants that had already developed tubers [53,71]. Soil salinity reduces the water potential of the soil thereby, causing movement of water out of the plant cells with higher water potential than that of the soil leading to plant dehydration. In contrast, salinity does not affect fresh and dry matter in wheat [72].

5. CONCLUSIONS AND RECOMMENDATIONS

The observed changes in the morphology, physiology and biochemistry of the stressed cassava genotypes compared to their corresponding controls showed that the cassava genotypes had varying levels of tolerance to the stresses studied.

Since the end result (tuber) justifies the means (other parameters like chlorophyll and phenol contents), it can be concluded that genotype I980581 is the most tolerant under all the stresses while the least tolerant were TMEB693 under drought, IBA120008 under salinity and I010040 under combined stress (D×S).

There is need to cultivate the most tolerant genotypes for each stress in the affected natural regions (like arid regions and coastal areas) to further validate the results of the present study while further research should be conducted on the less tolerant genotypes in order to improve their tolerance and hence, increase productivity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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