



ORIGINAL RESEARCH ARTICLE

EFFECT OF WATER STRESS ON YIELD AND WATER PRODUCTIVITY OF DRIP  
IRRIGATED CASSAVA (*MANIHOT ESCULENTA*) IN IBADAN, NIGERIA

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ABSTRACT

Cassava (*Manihot esculentus*) is an important staple tuber crop in many regions of Africa. It is a cash crop with wide domestic and industrial applications. Hence, there is a need to sustain its production during water scarcity. This study examined the effect of available soil moisture on phenological parameters and drought resistance of four improved varieties of cassava, TMS (30572, 980505, 920326 and 090581) using water productivity. The water management regimes (T75 maximum water regime - 75% of Evapotranspiration (ET); T50, 50% ET, T25 - 25% ET and Control, zero irrigation). The varieties and water regimes were applied and the treatment was arranged using a Latin Square design with four replications. Lynne's model was used in calculating the irrigation water requirements. The amount of water supplied to each treatment varied with the duration of irrigation. The results show that TMS 980505 at T75 had the highest tuber, stem and leaf productivities of 2.76, 1.66 and 2.05 kg m<sup>-3</sup> respectively while TMS 30572 on the control regime had the least tuber, stem and leaf productivities of 0.16, 0.21 and 0.21 kg m<sup>-3</sup> respectively. The TMS 980505 can be grown in regions where substantial crop water requirements for cassava could be met during the dry season through irrigation while TMS 090581 could be grown in water-scarce regions with a guaranteed 370 mm of water with an average yield of 4.5 t ha<sup>-1</sup>. The TMS 090581 at T75 had the highest plant height of 128 cm while TMS 30572 on control had the least height of 56 cm. TMS 920326 at T75 had the highest stem girth of 21.4 mm while TMS 30572 at T50 had the least stem girth of 10.7 mm. Therefore, full irrigation is recommended for the cultivation of TMS 980505 during the dry season. The TMS 090581 has the highest drought resistance. Therefore, it is recommended for cultivation in water-scarce regions.

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1.0 Introduction

Cassava (*Manihot esculentus*) is one of the most important staple foods in the tropics (Onwueme, 2002). It ranked the sixth most important source of calories worldwide (FAO 2013; Alfredo et al., 2000; Henry & Hershey, 2002; Hillock, 2002). In Nigeria, 50 % of the population eats cassava at least once a day (Philip, 2005). In the rest of sub-Saharan Africa (SSA), the same scenario applies to as many as 30 to 70 % of the region's inhabitants (FAOSTAT, 2005). In many parts of Africa, cassava leaves and tender shoots are consumed because they contain about 7% protein (fresh weight) and a high level of lysine (Ly et al., 2012). Cassava is a starchy root tuber crop (Luiz et

al., 2017) and is, therefore, a competitive crop, especially for the production of starch, animal feed, and alcohol (Fuglie, 2004; Oguntunde, 2005).

Cassava is cultivated mainly under a rainfed farming system because it can grow in areas with an annual rainfall of 400 mm and responds well to irrigation (Pushpalatha et al., 2020). Study has shown that drip irrigation can produce about the same yield as surface irrigation using less than 50 % of the water requirement (FAO, 2013). In Nigeria, root yields increased six-fold when the quantity of water supplied by supplementary drip irrigation was equal to that of the seasonal rainfall. Supplemental irrigation that increased the total water supply by 20 % almost doubled root yields (FAO, 2013). To improve cassava production, its cultivation should not be limited to rainfed agriculture. Sustainable and economical irrigation practices should be employed during the dry season of the tropics. As competition for increasingly scarce water resources intensifies, irrigation is under growing pressure to produce “more crops from fewer drops” and to reduce its negative environmental impacts such as soil salinization and nitrate contamination of drinking water. Greater use of water-saving precision technologies, such as drip and micro-irrigation, will make an important contribution to sustainable intensification (Aderemi et al., 2018).

Drip irrigation has proven to be successful in terms of increased yield and water productivity of a wide range of crops. Edoga and Edoga (2006) reported that under drip irrigation, the soil is maintained continuously in favourable condition for crop growth. Water management of cassava under irrigated agriculture has received little attention in SSA, it is mostly rainfed (Odubanjo et al., 2011). Cassava is known for its resistance to extreme climatic conditions. It can tolerate drought and grow in low-nutrient soil (Odubanjo et al., 2011). Even though cassava can withstand drought conditions, there have been concerns about the effect such condition has on its field. Cassava can grow in areas with average annual rainfall of 400 mm (FAO, 2013). Water availability, therefore, affects the yield of cassava. In the first three months after planting, cassava is very sensitive to soil water deficit and water stress at any time during this period will reduce the growth of roots and shoots significantly (Green Water, 2014; FAO, 2013). The hypothesis being tested is that water stress will affect cassava's yield and growth parameters. Therefore, this research aimed to study the impact of water stress on yields and water productivity of four improved varieties of cassava under a drip irrigation system in Ibadan, Southwest Nigeria.

## **2. Materials and Methods**

### **2.1 Study area**

The experiment was conducted at the Agricultural and Environmental Engineering experimental field of the University of Ibadan, Nigeria. It is located at latitude 7.4417° N and longitude 3.9000° E with an altitude of 227 m, above mean sea level. The study area is in the tropical rainforest zone of Southwest Nigeria and is characterized by distinct wet and dry seasons. The mean annual rainfall in the area is 1205 mm, falling in approximately 109 days with two rainfall peaks in June and September (Egbinola and Amobichukwu, 2013). Approximately, 50 % of the average annual rainfall occurs between April and July while 40 % occurs between August and October,

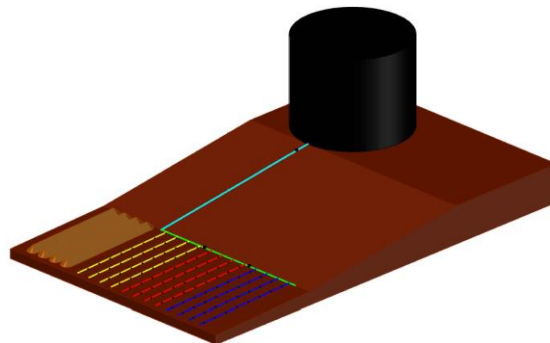
November to March is usually the driest months and temperatures tend to be higher (Ewemoje and Ewemoje, 2011). The experimental field soil was classified as sandy loam.

## 2.2 Treatments and Experimental Design

The four improved cassava varieties served as the block while four water regimes, ( $T_{75}$  maximum water regime – 75 % of Evapotranspiration (ET),  $T_{50}$  Medium water regime – 50 % of ET,  $T_{25}$  Low water regime – 25 % of ET and Control - Zero irrigation) were the treatments. The experimental design was a Latin square with four replications.

## 2.3 Layout of Drip Irrigation System

Water was sourced from the University of Ibadan water supply system. The water was stored in two 2,000 l storage tanks. The two tanks were connected in series at the base with a polyvinyl chloride pipe of diameter 38.1 mm fitted with a control valve in the middle. One of the tanks was connected to a constant head reservoir of 500 l capacity (Figure 1), the constant head was maintained in the tank by a ball valve fitted to the inlet end of the 500 l tank and this invariably maintained constant water pressure in the main line, sub-main and laterals. The constant head reservoir had an elevation of 2.7 m to the laterals, which guaranteed uninterrupted flow by gravity. The 11.35 m long main pipe of diameter 25.4 mm was connected to the outlet base of the constant head reservoir which conveyed water to the sub-main pipe. A valve is fitted on the main pipe and when the valve is opened, it supplies water directly to the  $T_{75}$  regime. The sub-main pipe of length 11.5 m and diameter 19.5 mm was connected to the main pipe by an elbow joint. Two valves were fitted on the sub-main pipe and they regulate the flow of water to the  $T_{25}$  and  $T_{50}$  regimes. These valves were operated based on the time of water application to the water regime. Twelve laterals each having a length of 8.1 m and a diameter 12.7 mm were connected to the sub-main with the use of T-joint connectors. Ninety-six (96) emitters each having a discharge of  $4 \text{ l h}^{-1}$  were connected to the laterals. The pressure compensating emitters were spaced at 1 m intervals and each lateral pipe has eight (8) emitters. Each irrigated regime of the field had four laterals fitted to supply water to the four varieties of cassava planted on each regime.



**Figure 1:** 3-D view of the drip irrigation set-up and the constant head reservoir

## 2.4 Measurements

Soil samples collected from the experimental field were weighed and oven-dried at 105°C to eliminate moisture and make it pulverized. Sieve analysis and textural triangle were used to determine soil texture. Rainfall, humidity, wind speed, sunshine hour, radiation, and daily maximum and minimum temperature were logged at intervals of 5 minutes at a weather station located 134 m from the experimental field. These variables were used in computing daily reference evapotranspiration ( $ET_o$ ) using CROPWAT 8.0. Four improved varieties of cassava, TMS 30572, TMS 980505, TMS 920326, TMS 090581 obtained from the International Institute for Tropical Agriculture Ibadan, Nigeria were planted on the 28th of November, 2016. The planting was done during the dry season in order to establish the cassava plant. The plant spacing was 1 m by 1 m. Each plot measured 4 m by 8 m and the total area of the field was 16 by 8 m<sup>2</sup>. Four rows of eight mounds per row made up each regime, hence, each plot contained 32 plant stands and it was set out such that each variety occupied an entire row of a water regime. The 25 cm long cassava stems were planted at an inclined angle of 30 degrees to the horizontal to ensure shallow roots and access to water. The regimes under drip irrigation were daily supplied with 2 mm of water while each plant on the control received 1.5 mm of water daily. After establishing the crop, the irrigation was scheduled at intervals of three days. Reference evapotranspiration under standard conditions in three days was computed using an  $ET_o$  calculator (Allen et al., 1998). Supplementary irrigation was practiced during the intersecting rainy season. Tuber, stem and leaf productivities were calculated for each variety across the regimes by dividing the weight of tuber, stem and leaf recorded at the harvest by water supplied to each regime from the day of planting till the day harvesting was carried out.

### 2.4.1 Irrigation water requirement

The irrigation water requirement was computed using Eqn. 1 (Ali, 2010):

$$IR = \frac{ET_o \times K_c \times PD \times EF \times PA}{IE} \quad (1)$$

where:

IR = irrigation water requirement measured in l day<sup>-1</sup>

$ET_o$  = reference evapotranspiration measured in mm day<sup>-1</sup>;

$K_c$  = crop coefficient, which depends on the age of the crop, 0.35 (0-60 DAP), 0.81 (61- 150 DAP), 0.35 (151-180 DAP);

PD = plant density, which is dimensionless, it increases as the vegetative cover of the crop increases and it ranges from 0.5 (Low-sparse coverage) - 1.0 (Moderate coverage);

EF = exposure factor, which is dimensionless and was assumed to be 0.65 as three of the four sides of the plot has vegetation;

PA = planted area, measured in m<sup>2</sup>;

IE = irrigation efficiency; the irrigation efficiency was calculated to be 90%.

The irrigation was done at 6 am of every three days. Plant height, stem girth, and number of nodes which are growth indicator parameters used in this study were measured and recorded weekly on each variety of the four regimes from 70 Days After Planting (DAP) till maturity. Water applied to each regime was computed every week. A correlation analysis was carried out on the plant height and water supplied to each variety on the four regimes to determine the effect of available soil moisture on plant height. The crop was harvested at 180 DAP because all the varieties studied have a maturity period of 6 months.

#### 2.4.2 Irrigation application variation

After calculating the full irrigation water required using Eqn. 1, the amount of water required to be supplied by the emitters on each irrigated regime is calculated using Eqns. 2 to 4.

$$T_{25} \text{ Emitters} = 0.25 X \frac{IR}{96} \quad (2)$$

$$T_{50} \text{ Emitters} = 0.5 X \frac{IR}{96} \quad (3)$$

$$T_{75} \text{ Emitters} = 0.75 X \frac{IR}{96} \quad (4)$$

where:

IR is as defined previously.

#### 2.4.3 Water productivity

Water productivity ( $\text{kg m}^{-3}$ ) was determined using Eqn. (5) (Zhang and Owie, 1999):

$$WP = \frac{Y}{V} \quad (5)$$

where:

Y = marketable yield (kg);

V = volume of water applied ( $\text{m}^3$ ).

### 2.5 Statistical analysis

Microsoft Excel was used for data analysis. Two-way analysis of variance (ANOVA) was carried out on tuber, stem and leaf productivities, with water regimes serving as treatment and cassava varieties as blocks. A two-way analysis of variance was carried out for tuber, stem and leaf productivity with the varieties serving as blocks and water management regimes as treatments. The analysis was carried out at a significant level  $\alpha = 0.05$  and means were compared.

### 3.0 Results and Discussion

The soil textural analysis revealed that the field is predominantly sandy loam. The amount of water received by each regime on a weekly basis is shown in Table 1. A sample of  $ET_o$  result as produced from CROPWAT 8.0 is shown in Figure 2. The leaves of TMS 920326 were observed to be shrinking at the developmental stage, the shrinkage was attributed to a mealybug attack

(*Phenacoccus manihoti*) which reached its peak during the dry season (James et al., 2000). Isopropyl alcohol solution was used to mitigate the attack

**Table I:** Weekly water supplied to each regime and control

Date	DAP	WS - N (mm)	WS - T25 (mm)	WS - T50 (mm)	WS - T75 (mm)
05/12/2015	7	10.5	14	14	14
12/12/2015	14	10.5	14	14	14
19/12/2015	21	10.5	14	14	14
26/12/2015	28	10.5	14	14	14
02/01/2016	35	10.5	14	14	14
09/01/2016	42	10.5	14	14	14
16/01/2016	49	10.5	14	14	14
23/01/2016	56	10.5	14	14	14
30/01/2016	63	8.7	9.3	10.6	11.8
06/02/2016	70	4.5	2.6	5.2	7.8
13/02/2016	77	3	2.8	5.6	8.4
20/02/2016	84	3	4.6	9.3	13.9
27/02/2016	91	4.5	3.2	6.5	9.7
05/03/2016	98	3	3.3	6.6	9.9
12/03/2016	105	14.6	14.6	18.9	23.6
19/03/2016	112	37.2	37.2	37.2	37.2
26/03/2016	119	13.2	13.2	13.2	17.5
02/04/2016	126	0	0	3	7.4
09/04/2016	133	32.6	32.6	32.6	32.6
16/04/2016	140	17.3	17.2	17.3	17.3

	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	m/s	hours	MJ/m <sup>2</sup> /day	mm/day
	22.3	36.1	67	0.7	12.0	26.4	5.53
	23.5	35.6	58	0.4	12.0	26.5	5.27
	22.8	36.4	46	0.5	12.0	26.6	5.22
	21.1	37.3	40	0.5	12.0	26.6	5.14
11	18.3	36.3	40	0.9	12.0	26.7	5.50
12	21.8	35.5	64	0.5	12.0	26.7	5.36
13	22.6	35.7	65	0.8	12.0	26.8	5.63
14	24.2	35.3	73	0.8	12.0	26.8	5.72
15	25.3	36.0	71	1.2	12.0	26.9	6.01
16	25.4	36.1	74	1.1	12.0	26.9	5.98
17	25.5	37.7	71	0.3	12.0	27.0	6.09
18	25.8	36.1	74	1.6	12.0	27.0	6.20
19	26.3	37.3	71	1.4	12.0	27.1	6.34
20	25.5	36.6	74	1.1	12.0	27.1	6.09
21	25.5	37.2	69	0.9	12.0	27.2	6.09
22	26.1	37.4	70	1.0	12.0	27.2	6.20
23	26.3	37.7	71	1.1	12.0	27.3	6.30
24	26.3	37.8	65	1.2	12.0	27.3	6.23
25	26.3	34.2	71	1.0	12.0	27.4	6.18
26	26.6	36.5	73	1.1	12.0	27.4	6.23
27	21.7	36.9	75	1.1	12.0	27.4	6.33

Figure 2. The first page of the Cropwat 8.0 software

### 3.1 Effect of soil moisture on growth indicator and parameter

Three growth indicators considered in the study are plant height, stem girth, and the number of nodes and the correlation analysis conducted between them and weekly available moisture is presented in Tables 2, 3 and 4. These parameters were subjected to ANOVA at a 95% confidence level, There are significant differences ( $p < 0.05$ ) among the means of the plant height and number of nodes for TMS 30572, TMS 980505 and TMS 920326; these significance differences ( $p < 0.05$ ) are due to different available moisture for the treatment. The TMS 090581 showed no significant difference ( $p > 0.05$ ) in means of plant height and number of nodes across the four water regimes and this could be attributed to the ability of this variety to naturally grow tall as reported by Ewemoje et al. (2015). There were significant differences ( $p < 0.05$ ) in stem diameter across the four water regimes in all four varieties.

#### 3.1.1 Plant height

TMS 980505 and 920326 had the highest coefficients of correlation ( $r^2 > 0.50$ ) for 25 % regime while they had the least  $r^2$  ( $\leq 0.30$ ) for the 50 % regime (Table 2). TMS 30572 and 090851 had the highest  $r^2$  at 25% regime while they have the least at 75% regime. This means that 25% regime for all the varieties made optimal use of water applied for phenological development than all other water regimes.

**Table 2.** Coefficient of correlation ( $r^2$ ) for plant height

Variety	Water regimes (%)			
	Control	25%	50%	75%
TMS 30572	0.45	0.50	0.36	-0.20
TMS 980505	0.31	0.50	0.25	0.38
TMS 920326	0.49	0.57	0.30	0.37
TMS 090851	0.28	0.33	0.32	0.05

### 3.1.2 Stem diameter

For TMS 30572, the  $r^2$  increased from 0.20 for the control to 0.30 for the 25% water regime but decreased from 0.32 for the 25% regime to 0.09 for the 50% regime and nosedived to produce a weak negative  $r^2$  of -0.20 from 50% regime to 75% water regime (Table). TMS 980505 had the highest  $r^2$  of 0.71 for the 50% water regime and was followed by the control while the 75% regime produced the third highest and the 25% regime produced the least. TMS 920326 had the highest  $r^2$  of 0.41 for the 50% regime followed by 75% water regime while the 25% regime produced the third highest and the control regime produced the least. TMS 090581 had an  $r^2$  which decreased gradually from 0.46 for the control to 0.29 for the 25% water regime, 0.28 and 0.23 for 50% and 75% water regimes respectively.

**Table 3.** Coefficient of correlation ( $r^2$ ) for stem diameter

Variety	Water regimes (%)			
	Control	25%	50%	75%
TMS 30572	0.20	0.32	0.09	-0.20
TMS 980505	0.68	0.27	0.71	0.38
TMS 920326	0.12	0.16	0.41	0.36
TMS 090851	0.46	0.29	0.28	0.23

### 3.1.3 Number of nodes

TMS 30572 and TMS 920326 had  $r^2$  which decreased gradually from control to 25 % regime to 50 % regime and to 75 % water regime (Table 4). TMS 980505 produced a positive correlation which increased from 0.20 for the control to 0.33 for the 25 % water regime, At the 50 % regime; the  $r^2$  gave a negative value which further decreased to -0.22 at the 75 % regime. TMS 090581 produced a positive correlation in all four regimes, with 25% and 75% regimes producing the highest and the second highest value respectively while the control produced the third highest while the 50% regime produced the least  $r^2$ .



**Table 4.** Coefficient of correlation ( $r^2$ ) for the number of nodes

Variety	Water regimes (%)			
	Control	25%	50%	75%
TMS 30572	0.44	0.15	0.14	-0.02
TMS 980505	0.20	0.33	-0.17	-0.22
TMS 920326	0.70	0.50	0.28	0.26
TMS 090851	0.21	0.35	0.20	0.29

### 3.2 Crop productivities

There is no significant difference ( $p > 0.05$ ) in the tuber, stem and leaf productivities of the varieties (Table 5). This implies that the varieties can be assumed to produce equal yields of tuber, stem and leaf. There is a significant difference ( $p < 0.05$ ) in the tuber and stem yields within the regimes. This implies that the difference in tuber and stem yields in Tables 5 to 8 were significantly different due to water regimes. There was no significant difference ( $p > 0.05$ ) in leaf productivity within the regimes. The significant difference within the regimes for tuber and stem productivity can be attributed to cassava's characteristic of storing a larger part of its dry matter and water in its root and stem (Carvalho et al., 2017).

**Table 5.** Water Productivities for TMS 30572

Parameters	Water regime			
	Control	T <sub>25</sub>	T <sub>50</sub>	T <sub>75</sub>
Water Applied ( $m^3 ha^{-1}$ )	3433	3704	3955	4268
Tuber Yield ( $Kg ha^{-1}$ )	549	2667	3797	5292
Tuber Productivity ( $Kg m^{-3}$ )	0.16	0.72	0.96	1.24
Stem Yield ( $Kg ha^{-1}$ )	721	1408	1384	1408
Stem Productivity ( $Kg m^{-3}$ )	0.21	0.38	0.35	0.33
Leaf Yield ( $Kg ha^{-1}$ )	721	2371	2690	2219
Leaf Productivity ( $Kg m^{-3}$ )	0.21	0.64	0.68	0.52

### 3.2.1 Effect of water stress on tuber yield

the control and T25 produced the lowest tuber yield and subsequently least tuber productivity while T50 and T75 regimes produced much better tuber yield and tuber productivity (Tables 5 to 8). Tuber yield of TMS 30572 at T25, T50 and T75 increased significantly by 385.8%, 591.6% and 863.9% respectively (Table 5). Tuber yields of TMS 980505 at T25 decreased significantly by 18.3% and increased significantly at T50 and T75 by 91.5% and 363.7% respectively (Table 6). Tuber yields of TMS 920326 at T25, T50 and T75 increased significantly by 16.9%, 461.7% and 412.7% respectively (Table 7). Tuber yields of TMS 090581 at T25, T50 and T75 increased significantly by 452.9%, 864.8% and 552.6% respectively.

**Table 6.** Water Productivities for TMS 980505

	Water regime			
	Control	T <sub>25</sub>	T <sub>50</sub>	T <sub>75</sub>
Water Applied (m <sup>3</sup> ha <sup>-1</sup> )	3433	3704	3955	4268
Tuber Yield (Kg ha <sup>-1</sup> )	2540	2074	4865	11779
Tuber Productivity (Kg m <sup>-3</sup> )	0.74	0.56	1.23	2.76
Stem Yield (Kg ha <sup>-1</sup> )	1064	1593	2690	7085
Stem Productivity (Kg m <sup>-3</sup> )	0.31	0.43	0.68	1.66
Leaf Yield (Kg ha <sup>-1</sup> )	1545	2852	4786	8792
Leaf Productivity (Kg m <sup>-3</sup> )	0.45	0.77	1.21	2.06

**Table 7.** Productivities for TMS 920326

	Water regime			
	Control	T <sub>25</sub>	T <sub>50</sub>	T <sub>75</sub>
Water Applied (m <sup>3</sup> ha <sup>-1</sup> )	3433	3704	3955	4268
Tuber Yield (Kg ha <sup>-1</sup> )	824	963	4628	4225
Tuber Productivity (Kg m <sup>-3</sup> )	0.24	0.26	1.17	0.99
Stem Yield (Kg ha <sup>-1</sup> )	1339	1519	1147	2177
Stem Productivity (Kg m <sup>-3</sup> )	0.39	0.41	0.29	0.51
Leaf Yield (Kg ha <sup>-1</sup> )	1991	2260	1899	3073
Leaf Productivity (Kg m <sup>-3</sup> )	0.58	0.61	0.48	0.72

**Table 8.** Productivities for TMS 090581

Parameters	Water regime			
	Control	T <sub>25</sub>	T <sub>50</sub>	T <sub>75</sub>
Water Applied (m <sup>3</sup> ha <sup>-1</sup> )	3433	3704	3955	4268
Tuber Yield (Kg ha <sup>-1</sup> )	824	4556	7950	5378
Tuber Productivity (Kg m <sup>-3</sup> )	0.24	1.23	2.01	1.26
Stem Yield (Kg ha <sup>-1</sup> )	1613	2556	1463	3030
Stem Productivity (Kg m <sup>-3</sup> )	0.47	0.69	0.37	0.71
Leaf Yield (Kg ha <sup>-1</sup> )	2780	3222	1938	3628
Leaf Productivity (Kg m <sup>-3</sup> )	0.81	0.87	0.49	0.85

#### 4 Conclusion

The study showed that irrigation is necessary for cassava cultivation during the dry season. This is because there were significant differences ( $p < 0.05$ ) in the tuber and stem productivities within the water regimes. Based on the water productivity of the cassava tuber, stem and leaf productivities, TMS 980505 performed more than the other varieties and is therefore recommended for farmers during the dry season using a drip irrigation system. TMS 30572 was the most stressed variety as seen in its phenological growth parameters in the control. It is, therefore, not suitable to be grown in water-scarce regions. TMS 090851 didn't exhibit variations in stem and leaf yield across the water regimes. Therefore, it is recommended for smallholder cassava farmers in water-scarce regions because of its high resistance to drought.

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