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Enhancement of *Manihot Esculenta* Crantz (Cassava) Tolerance to Salt and Drought Stress Using Arbuscular Mycorrhizal Fungi (*Glomus Mosseae* (T. H. Nicolson & Gerd) Gerd. &Trappe)

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A B S T R A C T

Drought and salinity are environmental factors capable of adversely affecting plant growth and productivity. Arbuscular Mycorrhizal Fungi (AMF) has been utilised in ameliorating several environmental conditions capable of limiting plants productivity. This study assessed the enhancement of cassava tolerance to both salinity and drought using AMF. A factorial experiment was conducted at the screen house of the Department of Botany University of Ibadan where three levels of salinity (0 mM, 80 mM and 100 mM, and four levels of water regime (1 daily, 2/wk, 1/wk, and 1 (2wks) and 50 grams of crude inoculum of AMF and 0g as control were applied to the cassava plant to monitor its morphological and agronomic responses for the period of three months. The results from the morphological and agronomic data showed that at higher levels of salinity, the interactive effect of salinity and drought was significant (at $p<0.001$) on growth parameters such as plant height, the total number of leaves and number of leaves produced per week. The shoot and root dry and fresh weights of cassava, as well as tuber initiation, was also affected at high drought and salinity. The effect of AMF (at $p<0.05$) significantly improved plant height, total number of leaves and shoot dry weight while parameters such as leaf area, the total number of leaves, number of leaves produced, number of leaves dropped, and tuber initiated were insignificantly improved.

Keywords:ArbuscularMycorrhizal Fungi (AMF), Cassava (*Manihotesculenta*crantz), Drought, Salinity, environmental tress, tuber initiation.

1. Introduction

Plants growth and development to a greater extent is dependent on the environmental conditions. The effect of environmental stress on crops has been seriously dreaded by farmers globally. The Intergovernmental Panel on Climate Change (IPCC, 2007) reported that deviations in the regular environmental climate will aggravate environmental stress. The major environmental stress constraining plant growth and development is water deficit, on account of drought and salinity (Almansouri*et al*. 2001). Both salinity and drought are caused by irregular precipitation and aggregation of salt in the soil (Sarr*et al.* 2011).

The term stress as defined by Levitt (1972) and cited by Verma and Verma (2014) is the effect of abiotic factors which can lead to an impairment or reduction in metabolism and development. The combined effect of drought and salt stress are common threats for plant growth, development, and survival in several species (Munns& Tester, 2008; Ouda*et al.* 2008; Carpici*et al.* 2010).

Arbuscular Mycorrhizal Fungi (AMF) are soil microbes which mutually associates with roots of plants (Daipé&Monreal, 2004). Plants associating with AMF have been observed to have better nutrient absorption, root formation, plant establishment, adaptability to stress and healthy vegetation (Priyadharsini&Muthukumar, 2015). AMF ascertain plant survival (Sanders, 2004), by improving plant growth (Meir, *et al.* 2010) productivity (Oyetunji*et al.* 2007; Lekberg & Koide, 2005) soil quality (Piotrowski *et al.* 2004; Li *et al.* 2007) and resistance to disease- causing organisms (Sikes, *et al.* 2009).

Cassava is an important crop with a wide cultivation range, especially in the tropical climes. Wide cultivation of cassava is attributed to its adaptive ability in diverse environmental conditions. The majorly consumed parts of the plant by both humans and animals are the root tuber and leaves due to the presence of starch, protein, vitamins, and minerals (Ospina & Ceballos, 2012). According to FAO (1999), cassava cultivation provides food and generates income to millions of people globally. It has also become a potential hunger eradicating crop in poorer countries because of its level of productivity even in poor environmental condition (Burns *et al.* 2010). Another important part of cassava plant is the stem which is regarded to be the better propagative part in comparison to the seed (Alves, 2002).

Although cassava can survive, grow and produce tuber in areas with insufficient rainfall, prolong dry season and poor soil condition (El-sharkawy, 1993; Jorgensen *et al.* 2005 and Burns *et al.* 2010) and mild salinity (Cruz *et al.*, 2017), prolong exposure to severe degree of both conditions can affect root storage and yield. Salinity has been reported to affect both the morphological growth and physiological activities of cassava (Gleadow*et al*., 2016).

Over the years, plant breeders; have employed the use of fertilizers and biocide to boost crop productivity under adverse abiotic conditions. The resultant effect of the use of these chemicals has led to environmental degradation and pollution (Chapin *et al.* 2000; Barabasz*et al*. 2002; Parmessan&Yohe, 2003; Zhong & Cai, 2007). This problem, therefore, necessitates taking advantage of the beneficial association of AMF and plants to enhance cassava tolerance to both drought and salt stress.

2. Materials and Methods

This study was conducted at the screen house of the Department of Botany, Faculty of Science, University of Ibadan. The study site lies between latitude 7 30˚N and longitude 3 54˚E in Ibadan, Oyo state of Nigeria. The screen house is used so as to control the watering of the experimental units. The experiment was carried out in a factorial arrangement consisting of one (1) level of Cassava variety x two (2) categories of AMF inoculation x three (3) levels of salt treatment x four (4) levels of irrigation x three (3) replicates laid out in a Completely Randomized Design (CRD). Hence, a total of 72 experimental units were used for this research. Mycorrhizal inoculated treatments received 50g mycorrhizal inoculants, which was mixed with the soil in the pots and 0g for the control. Cassava stakes (20cm long) were horizontally buried in each experimental pot. All the pots were watered daily with the same amount of water (500ml) before salinity is imposed. Subsequently, for each salinity level (0g, 4.68g and 5.86g) x AMF levels, water was applied daily, twice a week, once a week and once in two weeks. Salinity was imposed 61 days after planting. Three levels of salt concentration 0g (control), 4.68g and 5.86g of NaCl was dissolved in water to produce 0mM, 80 mM and 100mM NaCl. The saline solution was applied once a week throughout the period of the experiment.

2.1 Growth and Morphological Parameters

Data collection started 30 days after planting. Data for Plant height (cm), leaf area (cm2), number of leaves, number of leaves produced and dropped per week were collected at an interval of 7 days.

2.2 Plant Biomass Determination

Shoot and root dry and fresh weights were obtained at week 9 after treatment application according to the method of Oyetunji and Imade (2015). Plants were carefully washed using tap water to get rid of soil particles from the root and shoot before taking their fresh weight. The same plant samples were subjected to 800C in an oven for 4 days to obtain the root and shoot dry weight with a weighing balance.

23 Statistical Analysis

Data obtained were subjected to multivariate Analysis of variance (ANOVA) using IBM SPSS Statistics version 20, and means were separated using least significant difference (LSD).

3. Results

The result of this experiment in Table 1 shows the interactive effects of water, AMF inoculation, sodium chloride on morphological characters of the cassava plant (TME 419). The water regimes had a highly significant ($p<0.001$) effect on the plant height and the total number of leaves. AMF inoculation had a significant effect ($p<0.05$) on plant height and number of leaves. Effect of Sodium chloride was highly significant on leaf area, plant height and number of leaves. The interactive effect of Water regime x AMF was also highly significant on leaf area, plant height and the total number of leaves while the effect of the interaction of Water regimes x NaCl was only highly significant on plant height and the number of leaves. The interactions of Water x Week, AMF x NaCl, AMF x Week, Water x AMF x NaCl x Week, AMF x NaCl x Week, and Water x AMF x Week had no significant effect on leaf area, plant height and the number of leaves in cassava. The interaction of Water x AMF x NaCl was highly significant in the number of leaves but moderately significant in plant height. Table 3 shows water regimes, NaCl and water regimes x AMF significantly affected the number of leaves produced at $p<0.001$ while AMF x NaCl was significant at $p<0.05$ but other treatments did not significantly affect the number of leaves produced.

The interactive effect of water regimes, NaCl, AMF, and weeks (Table 2**)** showed that water regime, number of weeks, water regime x NaCl, water regime x number weeks, AMF x week, NaCl x number of week and water regime x NaCl x week significantly affected the number of leaves dropped per week ($p<0.001$). The interaction between AMF x NaCl and NaCl x week significantly affected number of leaves dropped per week ($p<0.01$) while water regime x AMF x week and water regime x AMF x NaCl x week significantly affected the number of leaves dropped but AMF, NaCl, water regimes x AMF X NaCl and AMF x NaCl x week did not significantly affect the number of leaves dropped.

Table 3 shows the effects of different water regimes, Sodium chloride and AMF on the morphological characters of the cassava plant (TME 419). The height of cassava plants watered daily was the highest (103.02 cm) and significantly differs from others while the least plant height (80.54 cm) was obtained in cassava plants watered once in two weeks. There was no significant difference in the leaf area of cassava plant treated with different water regimes. The highest (114.56 cm2) and least (99.86 cm2) leaf area were recorded in plants watered once a week and once in two weeks respectively. The highest (27.09) and least (21.56) number of leaves were recorded in cassava plants watered daily and once in two weeks, respectively. The number of leaves in plants watered daily and once in two weeks significantly differed from those watered twice a week and once a week. The number of leaves produced per week in cassava plants watered daily and once in two weeks significantly differed from each other while those treated with twice watering/week and once watering/week did not differ significantly from each other. The highest (2.51) and lowest (1.63) number of leaves produced per week were recorded in plants watered daily and once in two weeks, respectively. The number of leaves dropped from cassava plant watered daily differed significantly from other water regimes. The highest (2.47) and lowest (0.67) number of leaves dropped from cassava plant was recorded in those watered once in two weeks and those watered daily respectively.

Plants treated with 0mM NaCl had the highest plant height (109.31cm), leaf area (124.38 cm2), number of leaves (28.54) and number of leaves produced per week (2.62). Least plant height (76.37) was obtained in plants treated with 80 mM NaCl, least leaf area (94.04 cm2) was recorded in plants at 100 mM salinity level so also the total number of leaves. The highest number of leaves dropped (2.08) was recorded in plants treated with 100 mM NaCl and the least in plants treated with 0mM NaCl but no significant difference was observed among treatments.

The effect of AMF on cassava morphological characters (Table 3) showed that plants treated with AMF had higher plant height, leaf area, number of leaves, number of leaves produced and also the number of leaves dropped. Plant height and the total number of leaves in AMF treated plant significant differed non-treated plants but there was no significant difference at p<0.05 in the leaf area, the total number of leaves, number of leaves produced and number of leaves dropped per week.

3.1 Plant Biomass

The interactive effect of AMF, water, and salinity on the shoot and root dry and fresh weights (Table 4) showed that the effect of water regimes on shoot fresh, dry weights and root fresh weight was highly significant at p<0.001 and also significant on root dry weight at p<0.01. AMF was only significant in shoot dry weight at p<0.05. NaCl significantly affected both shoot fresh and dry weight and root fresh weights at p<0.001 and dry root weight at p<0.01. Interaction between water regimes x AMF significantly affected shoot dry weight at p<0.001 but was not significant on shoot fresh weight and root fresh weight at p<0.001 and shoot dry weight at p<0.01. Water regimes x NaCl significantly affected the shoot fresh and dry weight and also the root fresh weight but was not significant on the root dry weight. The interactive effect of AMF x NaCl and water regimes x AMF x NaCl was not significant.

The effect of water regime (Table 5) showed that plant watered daily, had the heaviest shoot fresh and dry weights and also root fresh and dry weights compared to other treatments and significantly different from other treatments. The lowest shoot fresh and dry weights and root fresh and dry weights were obtained from plants watered once in two weeks. Shoot dry weight of AMF treated plants (Table 5) significantly differ from those of the non-treated plants. However, there was no significant difference at p<0.05 between the shoot fresh weight, root fresh and dry weights of both treatments. The highest shoot fresh and dry weight at 0mM (81.73g and 21.31g) significantly differed from the other treatments, while the lowest was obtained from plants treated with 100mM NaCl concentration. Highest fresh root was obtained from plants treated with 80mM NaCl concentration which significantly differed from other treatments and plant treated with 100Mm NaCl had the lowest. Root dry weight was higher at 00mM NaCl level and significantly different from the plants treated with 100mM NaCl.

Table 1 Interactive Effectsof Water, AMF Inoculation, Sodium Chloride and Number of Weeks on some Morphological Characters of the Cassava Plant (TME 419)

Sources of variation	Df	Leaf area	Plant height	Total Number of leaves
Water	3	6154.98	14579.51***	828.30***
AMF	1	10506.43	6082.43*	316.68*
NaCl	2	46505.06***	62089.12***	3125.43***
Week	8	31612.24***	46863.51***	1196.35***
Water regime × AMF	3	7121.65^{ns}	11606.80***	892.02***
Water regime × NaCl	6	9916.55^{ns}	10350.176***	465.83***
Water × Week	24	4963.50^{ns}	860.56^{ns}	96.006^{ns}
AMF × NaCl	2	5488.91^{ns}	2677.46^{ns}	67.18^{ns}
AMF × Week	8	6481.67^{ns}	182.07^{ns}	27.24^{ns}
NaCl × Week	16	6301.19^{ns}	932.53ns	60.54^{ns}
Water regime × AMF × NaCl	6	6464.65^{ns}	2836.98*	269.52***
Water regime × AMF × Week	24	5335.89ns	386.20ns	21.76ns
Water regime × NaCl × Week	48	5671.03ns	318.03ns	34.80ns

AMF × NaCl × Week	16	5518.18ns	178.98ns	20.82ns
Water regime × AMF × NaCl × Week	48	5650.21^{ns}	207.98^{ns}	16.42^{ns}
Error	432			
Total	648			
Corrected total	647			

Note: * = significant at p<0.05, ** = significant at p<0.01, *** = significant at p<0.001, ns = not significant, Df= degree of freedom

Table 2 Interactive Effects of Water Regimes, AMF Inoculation, Sodium Chloride and Number of Weeks on the Number of Leaves Dropped Per Week by Cassava Plant (TME 419)

Sources of variation	Df	Number of leaves producedper week	Number of leaves dropped per week
Water	3	18.45***	61.81***
AMF	1	4.34^{ns}	0.336^{ns}
NaCl	2	47.76***	6.06^{ns}
Week	4	219.32***	193.27***
Water regime × AMF	3	3.12^{ns}	7.83^{ns}
Water regime × NaCl	6	3.55^{ns}	19.71***
Water regime × Week	12	5.04*	24.58***
AMF × NaCl	2	0.76^{ns}	29.17**
AMF × Week	4	3.58^{ns}	32.44***
NaCl × Week	8	3.35^{ns}	11.92**
Water regime × AMF × NaCl	6	1.58^{ns}	4.44^{ns}
Water regime × AMF × Week	12	2.53^{ns}	9.83*
Water regime × NaCl × Week	24	2.92^{ns}	22.74***
AMF × NaCl × Week	8	2.85^{ns}	4.66^{ns}
Water regime × AMF × NaCl × Week	24	2.47^{ns}	7.12*
Error	240		
Total	360		
Corrected total	359		

Note: * = significant at p<0.05, ** = significant at p<0.01, *** = significant at p<0.001, ns = not significant, Df=degree of freedom

Table 3: Effect of Water Regimes, Sodium Chloride and AMF on Morphological Characters of Cassava Plant (TME 419)

Water Regimes	Plant height	Leaf area (cm^2)	Total number of leaves	Number of leaves produced per week	Number of leaves produced per week
Daily watering	103.02^{c}	110.13^{a}	27.09c	2.51^{b}	0.67^{a}
Watering twice/week	91.61^{b}	107.49^{a}	24.38^{b}	2.02^{ab}	1.79^{b}
Watering once/week	86.92^{ab}	114.56^{a}	24.58^{b}	2.06^{ab}	2.38^{bc}

Watering once /two weeks	80.54[a]	99.86[a]	21.56[a]	1.63[a]	2.47[c]

NaCl Concentration	Plant Height (cm)	Leaf area (cm^2)	Total Number of Leaves	Number of leaves produced per week	Number of leaves dropped
00 mM	109.31[c]	124.38[b]	28.54[c]	2.62[b]	1.67[a]
80 mM	76.37[a]	103.60[a]	23.62[b]	1.66[a]	1.72[a]
100 Mm	85.88[b]	94.04[a]	21.05[a]	1.90[a]	2.08[a]

AMF	Plant Height	Leaf Area	Number of leaves	Number of leaves produced per week	Number of leaves Dropped
Without	87.46[a]	103.98[a]	23.70[a]	1.97[a]	1.7[9a]
With	93.58[b]	112.04[a]	25.10[b]	2.14[a]	1.86[a]

Means with the same letter in a column for each treatment did not differ significantly at $p<0.05$.

Table 4: Interactive Effects of Water Regimes, AMF and Sodium Chloride (NaCl) on the Shoot and Root Biomass

Source of variation	Df	Shoot		Root	
		Fresh weight	Dry weight	Fresh weight	Dry weight
Water	3	8922.36***	603.13***	3563.30***	34.19**
AMF	1	350.82[ns]	134.21*	13.26[ns]	7.80[ns]
NaCl	2	13493.01***	1112.33***	1017.50***	31.92**
Water regime ×AMF	3	737.18[ns]	186.51**	67.00[ns]	6.29[ns]
Water regime ×NaCl	6	1457.22***	112.58**	382.50***	12.25[ns]
AMF × NaCl	2	421.39[ns]	4.44[ns]	3.91[ns]	0.99[ns]
Water regime ×AMF × NaCl	6	304.03[ns]	23.11[ns]	19.51[ns]	2.20[ns]
Error	48				
Total	72				
Corrected total	71				

Note: * = significant at $p<0.05$, ** = significant at $p<0.01$, *** = significant at $p<0.001$, ns = not significant

Table 5: Effects of different Water Regimes, Sodium Chloride and AMF on the Shoot and Root Biomass of Cassava (TME 419)

Water regimes	Fresh weight (g)	Shoot Dry weight (g)	Fresh weight (g)	Root Dry weight (g)
Daily watering	86.31[a]	21.67[a]	31.15[a]	4.45[a]
Wateripng twice/week	49.76[b]	13.94[ab]	18.06[b]	3.14[ab]
Watering once/week	47.98[b]	11.23[b]	18.02[b]	1.96[c]
Watering once/two weeks	34.24[c]	8.15[c]	11.87[c]	1.32[c]

AMF	ShootShoot Fresh weight (g)	Dry weight (g)	RootRoot Fresh weight (g)	Dry weight (g)
Without	52.36[a]	12.38[a]	1.32[a]	0.41[a]
With	56.78[a]	15.11[b]	1.32[a]	0.41[a]

Concentration of NaCl	ShootFresh weight (g)	ShootDry weight (g)	RootFreh weight (g)	RootDry weight (g)
00 Mm	81.73[a]	21.31[a]	20.07[b]	3.48[a]
80 Mm	44.02[b]	11.82[b]	26.13[a]	3.28[a]
100 Mm	37.97[b]	8.11[c]	13.12[c]	1.39[b]

3.2 Tuber Initiation

The interactive effect of water regimes, AMF, and NaCl on tuber initiation (Table 6) showed that all the treatments did not significantly affect the initiation of the tuber. The result in Table 7, showed that plants watered daily had the highest number of tubers initiated (1.00), though there was no significant difference with plants watered twice a week, there was a significant difference with plants watered once in two weeks.

The effect of salinity on tuber initiation (Table 7) shows that plant treated with 80 mM initiated more tubers (0.79) compared to the control (0.33) though there were no significant differences among the treatments. Plants inoculated with AMF initiated more tubers (0.69) than plants without AMF (0.42) but did not significantly differ from each other.

Table 6: Interactive Effect of Water Regimes, NaCl and AMF on Tuber Initiation

Source of variation	Df	Tuber initiation
Water Regimes	3	2.04[ns]
AMF	1	1.39[ns]
NaCl	2	1.26[ns]
Water regime × AMF	3	0.17[ns]
Water regime × NaCl	6	0.69[ns]
AMF × NaCl	2	0.35[ns]
Water regime × AMF × NaCl	6	0.40[ns]
Error	48	
Total	72	
Corrected total	71	

Note df= Degree of freedom, ns=not significant

Table 7: Effect of Water Regimes, Sodium Chloride and AMF on Tuber Initiation of Cassava (TME 419) plant

Treatments	Variations	Tuber initiation
Water regimes	Daily watering	1.00[a]
	Watering twice/week	0.61[ab]
	Watering once/week	0.39[b]
	Watering once/two weeks	0.22[b]
NaCl	00 mM	0.33[a]
	80 mM	0.79[a]
	100 mM	0.54[a]
AMF	Without	0.42[a]
	With	0.69[a]

Means with the same letter in a column (for each treatment) did not differ significantly at $p<0.05$.

4. Discussion

Cassava is a crop with the ability to tolerate short term drought and mild salinity which cannot be tolerated by other plants. However, the result of this study, in Table 1 showed that cassava height, leaf area, the number of leaf and the number of leaves produced will decline at severe drought condition. This corroborates the findings of Nonami, (1998) and Alves and Setter, (2004) who reported that severe drought inhibits cell elongation in higher plants by mitigating water supply to the meristematic tissue. Drought also impairs cell division, elongation and enlargement (Hussain *et al.* (2008). At higher salinity, plant height, leaf area, number of leaves on plant and number of leaves produced also declined while the loss of leaf increased. Giri*et al.* (2003) reported that salinity renders plants unproductive and leads to a decline in growth and development. The decrease in plant height is linked with a decrease in cell enlargement and leaf loss. This finding is also in line with the reports of Bhatt and Srinivasa Rao (2005) who observed stunting in *Abelmoschusesculentus*subjected to water stress. The drastic decline in growth is indicated by reduced leaf area and growth stagnation (Läuchli and Epstein, 1990, Alves, 2002). Reduction in leaf area, despite being a mechanism for stress tolerance (Taiz & Zeiger, 2009) can also affect the rate of photosynthesis and dry matter production (Jaleel *et al*. 2008c).

But with daily watering, cassava can grow, produce leaves and have greater leaf area even at high salinity. This is possible because, daily application of water leaches out the accumulated salt within the soil and decrease the electric conductivity of the soil (Kara &Willardson, 2006). Apart from daily watering, plants treated with AMF were observed to grow better with a higher number of leaves. This finding is in tandem with the report of Oyetunji*et al.* 2007; Priyadharsini and Muthukumar, 2015 who reported that mycorrhizal association is capable of ameliorating all forms of stress and aid the formation of better vegetation in plants. However, the loss of leaves by both inoculated and non-inoculated plants could be due to leaf aging and mechanism for water conservation since the higher the number of leaves, the higher the rate of transpiration. This work is in line with the findings of Setter &Fregene (2007) and Vandegeeer*et al.* (2013) who also reported the loss of older leaves due to water deficit.

Severe drought and salt stress adversely affected plant growth as inferred from the plant shoot and root fresh and dry weight. Plants watered daily had the heaviest shoot and root dry and fresh weight but at prolonged water deficit, shoot and root fresh and dry weight drastically declined. This could be due to result of inhibition of leaf production, enlargement and resultantly low light absorption (Anjum *et al.* 2011). Water deficit gravely affected yield in plants by mitigating gaseous exchange thereby limiting the expansion of source and sink tissue, phloem loading, translocation of assimilates and alter dry matter partitioning (Farooq *et al.* 2009). Sever water stress is capable of halting photosynthesis, disrupting metabolism and ultimately death of plant (Jaleel *et al.* 2008c). The decrease in biomass at prolonged water stress condition could be as a result of the closure of the stomata which disrupt the exchange of raw materials for photochemical conversion.

Salinity also affected cassava shoot and root fresh and dry weight with an increase in salinity level, as plant subjected 100mM salinity had the least shoot and root fresh and dry weight compared to lower salinity level. This could be as a result of inhibition of water absorption by plants due to an increase in the electric conductivity of the soil and inhibition of the uptake of vital soil nutrients and disruption of metabolism. This result of this study is in line with the result of Gleadow*et al.* (2016) who reported that plant biomass of plants at 0mM was higher than that of plants in higher salinity levels 80-150mM. Even though salinity and drought severely affected plant biomass, AMF inoculated plants had greater shoot and root fresh and dry weight with a significant difference in shoot dry weight compared to non-treated plants. This could be as a result of the increase in the number of leaves due to better water absorption leading to the creation of large photosynthetic area resulting to higher dry matter content as reported by Oyetunji*et al.* (2007). However, according to Juniper and Abbott (2006) and Evelin et al. (2009), salinity limits the fungus' ability to produce extraradical hyphae, which may explain why the interaction of AMF x salinity and water regimes x AMF x NaCl had no influence on the shoot and root fresh and dry weight.

Cassava is a plant capable of tolerating diverse abiotic stress and still produces tuber even when growing in an unfavourable soil condition (El-Sharkawy, 1993; Jørgensen*et al.* 2005; Burns *et al.* 2010). Plants watered daily initiated more tubers than other treatments and as drought increases tuber initiation progressively decreased. This can be due to the low interception of light, as result of a reduction in the number of leaves, leaf area and loss of leaves. This corroborates the findings of Porto, 1983; El-Sharkawy and Cock, 1987; Calatayud*et al.* 2000; Alves and Setter, 2004b, who reported that at prolong drought, cassava captures less light by reducing its canopy, producing new leaves with a smaller area and dropping leaves. According to Connor *et al.* 1981; El-Sharkawy and Cock, 1987; Porto, 1983; El-Sharkawy*et al.* 1992; Alves, 2002, this adaptive mechanism even though it conserves water, results in a decline of plant productivity. This could be the reason why there is a positive and significant correlation between tuber initiation, root fresh weight, and root dry weight.

The effect of salinity at the different water regimes and AMF inoculation showed less tuber initiation in the control than in the salt-treated plants. This could be due to the dry matter partitioning in response to severe water stress so as to increase water absorption. This is in line with the report of Lahai*et al.*(2009) who stated that when assimilates are allocated to the roots, leaves and stem yield declines. Ekanayake*et al*. (1998), reported that cassava yield is determined by both assimilates synthesized and its distribution to the different parts of the plant. AMF inoculated plants initiated more tuber as compared with the control. This could be due to the higher number of leaves and larger leaf area in AMF inoculated plants. A similar report by Oyetunji and Osonubi (2007) assert that AMF inoculation increase tuber yield in cassava.

5. Conclusion

Cassava is an important crop with the ability to generate income and curbing hunger in many parts of the world especially Africa. Severe salinity and drought both affect the morphology and physiology of cassava. The effect of salinity even at higher concentration can be mitigated by the availability of soil water. Therefore, the survival and yield of cassava plants exposed to both drought and salt stress can be facilitated by the daily supply of water and AMF association.

6. Conflict of Interest

There is no conflict of interest among the authors of this article.

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