



## Effects of Salinity and Arbuscular Mycorrhizal Fungi Interactions on Morphology of 10 Varieties of Tomato (*Solanum lycopersicum* L.)

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### Authors' contributions

This work was carried out in collaboration between both authors. Author OJO designed the Study. Author OSO performed the statistical analysis. Authors OSO wrote the first draft of the manuscript. Authors OJO and OSO Managed the analyses of the study. Author OSO managed the literature searches. Both authors read and approved the final manuscript.

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### ABSTRACT

*Solanum lycopersicum* L. (Tomato) is one of the plants commonly grown for its edible fruits all over the world. It is an important component of the average Nigerian meal. The present study aimed at investigating the effects of salinity and arbuscular mycorrhizal fungi interactions on morphology of 10 varieties of *Solanum lycopersicum* L. Ten different varieties of tomato were exposed to three different treatments, salt and arbuscular mycorrhizal fungi treatment, arbuscular mycorrhizal fungi treatment and sterile soil treatment which served as the control. All data collected were subjected to Analysis of Variance (One way-ANOVA). The results of this study showed that effects of the interactions of salinity and arbuscular mycorrhizal fungi (AMF) differs across varieties of tomatoes with significant differences occurring in some varieties; low or no effect in others across other varieties when comparing growth parameters at  $p < 0.05$ . Tomato plants grown in salt + arbuscular mycorrhizal fungi had the highest plant height, leaf area, stem diameter, number of leaves, number of flowers and highest fresh weight of fruits across most of the varieties compared to other

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treatments. However, tomatoes subjected to only AMF treatment had the least performance across all the varieties. Thus, from the results of this study, it could be concluded that arbuscular mycorrhizal fungi has the potential to improve tomato plants tolerance to salinity.

**Keywords:** *Arbuscular mycorrhizal fungi; growth; salt; tolerance; tomato.*

## 1. INTRODUCTION

*Solanum lycopersicum* L. (Tomato) is one of the plants commonly grown for its edible fruits all over the world. Tomato farming is predominantly done in the northern part of Nigeria with farming done on large fields usually thousands of hectares in states like Kano, Jigawa, Plateau, Benue, Kaduna, Gombe, Bauchi, Sokoto, Kebbi, Nasarawa, Zamfara and Kogi. Tomato is also grown in South-Western Nigeria but in smaller quantities compared to the Northern states. Tomato production can improve the livelihoods of small-scale producers by creating jobs and serving as source of income for both rural and urban dwellers.

Plants, because of their sessile nature are often affected by fluctuations in their external environment and this affects their normal growth and development. Abiotic and biotic stress is engulfing the cultivated land at an alarming rate and among the abiotic stresses, salt stress is having a greater impact on farmlands worldwide [1]. Increase in soil salinity has restricted the cultivation of vegetables by farmers worldwide. Abiotic stresses such as salinity and water stress are capable of reducing the production of tomato plant and thus cause severe constraints to its growth. Salinity in soil, according to [2] can be defined as a condition when soluble salts get accumulated in the solution (soil or water) to a point whereby it has deteriorating and negative effects on the growth and development of plants.

The significance of soil salinity for agricultural yield is huge [3] as it affects the germination, establishment, growth and development of plants leading to losses in productivity and yield [4,5]. Salt stress causes physiological drought to plants, imbalance in nutrient composition and excessive toxicity due to Na and Cl ions thereby leading to reduction in osmotic potential of plants, disruption of cell organelles and their metabolism these ultimately affect plant growth and reduce the yield [6].

Plants have derived coping mechanisms to combat abiotic and biotic stresses over time. One

of these coping mechanisms is the establishment of mutualistic and beneficial relationship between the roots nodules of plants and some fungi known as arbuscular mycorrhizal fungi. Mycorrhizae are the intricate associations roots form frequently with specific fungal groups and represent the underground absorbing organs of most plants in nature [7]. Arbuscular mycorrhizal fungi (AMF) are the most common root fungal symbiosis and it can be found in most of the higher plants. There is a mutualistic symbiosis relationship between AMF and the roots of terrestrial plants [8]. AMF improves the absorption of the several nutrients, such as phosphorus, nitrogen, potassium, calcium and magnesium, copper and zinc, increases the content of antioxidants in inoculated plants and can also improve soil structures and protect host plants against the detrimental effects caused by the drought and salinity stress [9]. Arbuscular mycorrhizal symbiosis has been proven to improve plant performance under various environmental stresses, such as drought and salt stresses, and to change plant water relations in both well-watered and water-stressed conditions [10]. AMF have been shown to promote plant growth and salinity tolerance by many researchers. They promote salinity tolerance by employing various mechanisms, such as enhancing nutrient acquisition [11], producing plant growth hormones, improving rhizospheric and soil conditions [12], altering the physiological and biochemical properties of the host [13] and defending roots against soil-borne pathogens [14]. Arbuscular mycorrhizal fungi are found naturally in abundance in saline soil [6].

Thus, the aim of this experiment was to investigate the effect of salinity and arbuscular mycorrhizal fungi interactions on morphology of 10 varieties of *Solanum lycopersicum* L.

## 2. MATERIALS AND METHODS

### 2.1 Study Site

The study was conducted at the nursery of the Department of Botany, Faculty of Science, University of Ibadan. The study site lies between

latitude 7 30°N and longitude 3 53°E in Ibadan, Oyo state, Nigeria.

## 2.2 Source of Materials

Seeds of *Solanum lycopersicum* (Tomato) were collected from the seed bank of National centre for genetic resources and biotechnology (NACGRAB), Moor plantation, Ibadan, Oyo state, Nigeria; the ten varieties were labeled as NGB00692, NGB00696, NGB00714, NGB00716, NGB00718, NGB00722, NGB00724, NGB00734, NGB00737, and NGB00749.

Arbuscular mycorrhizal fungi (inoculants), *Glomus mosseae* was sourced from the Department of Botany, University of Ibadan. Industrial salt (NaCl) was obtained from the Department of Botany, University of Ibadan.

## 2.3 Soil Sample Collection

Soil sample was collected from the nursery of the Department of Botany, University of Ibadan. The soil was collected at a depth of 0 – 15 cm. The soil was sieved using a 2mm wire mesh sieve to get rid of debris and an electric soil sterilizer was used to sterilize the soil, this was done to kill microorganisms in the soil. The sterilized soil was then dried at room temperature.

## 2.4 Pot Preparation

Polythene bags were filled with 5kg of the sterilized soil. They were perforated for drainage of excess water and for proper aeration of the soil. The bags were properly labeled according to treatments.

## 2.5 Experimental Design

The experiment was carried out in a factorial arrangement consisting of 10 varieties of tomato, three treatments and three replicates laid out in a Completely Randomized Design (CRD). The three treatments were established as followed:

- a) Salt treatment + AMF (SA)
- b) AMF (A)
- c) Control

## 2.6 Arbuscular Mycorrhizal Fungi (AMF) Inoculation

Mycorrhizal inoculated treatments received 50g mycorrhizal inoculants (*Glomus mosseae*). This was mixed with the sterile soil in the polythene bags and the control received 0g of inoculant.

## 2.7 Sowing of the Seeds

Direct sowing of seeds of tomato was done for each of the accession. Each experimental bag was thinned down to one tomato stand per bag 3 weeks after planting. The study was done for 80days on field, from the time of planting to time of harvesting of fruits.

## 2.8 Salt Application

Salt treatment was started 3 weeks after planting. 5.6grams of NaCl was dissolved in 1000ml of water. 500ml of the solution was used to water the plant two times daily till the end of the experiment.

## 2.9 Data Collection

Data were collected for growth parameters that is, plant height (cm), leaf area (cm<sup>2</sup>), stem girth (mm), number of leaves on each tomato stand and number of flowers formed per tomato stand were recorded. Fresh weights of fruits were recorded on day of harvest (80<sup>th</sup> day).

## 2.10 Statistical Analysis

The data obtained from the study for various plant parameters was subjected to single univariate summary statistics such as the mean and standard deviation. The analysis of variance (ANOVA) was then used to compare the variability in the selected parameters due to the treatment application with the aid of the software MITAB Statistical analysis system (SAS) 9.3 version. Significant means were compared with Duncan multiple range test at the 95% probability level.

## 3. RESULTS AND DISCUSSION

### 3.1 Results

#### 3.1.1 Effects of salinity and arbuscular mycorrhizal fungi interaction on the morphological characters

Table 1 shows the effects of salinity and arbuscular mycorrhizal fungi interaction on plant height of 10 varieties of *Solanum lycopersicum* at 80<sup>th</sup> day after planting. Salinity and arbuscular mycorrhizal treatments (SA) had the highest plant height in 5 varieties, NGB00692, NGB00696, NGB00714, NGB00718, and NGB00734 (Table 1) compared to control treatment (C) which gave highest plant height across 5 varieties, NGB00716, NGB00722,

NGB00724, NGB00737, NGB00749 with no significant differences when compared with the salinity and AMF treated varieties. Arbuscular mycorrhizal fungi treatment (A) only gave the least plant height across all 10 varieties (Table 1).

Leaf area was recorded across the ten varieties in the 3 treatments (Table 2). Varieties NGB00692, NGB00696, NGB00714, NGB00716, NGB00718, NGB00734, NGB00737 and NGB00749 had the highest leaf areas in treatment SA (Table 2). Two varieties NGB00722 and NGB00724 had the highest leaf area in treatment C. Differences across treatments were significant to one another (Table 2).

Table 3 shows the diameter of the stem, that is, stem girth across the ten varieties of tomato in the 3 treatments. Treatment SA had highest stem girth across 6 varieties, NGB00696, NGB00714, NGB00718, NGB00722, NGB00734 and NGB00749 and treatment C had the highest stem girth across the remaining 4 varieties, NGB00692, NGB00716, NGB00724 and NGB00749 (Table 3).

Table 4 shows the number of leaves across the ten varieties of tomato in the 3 treatments. Treatment SA recorded highest number of leaves in 6 varieties, NGB00692, NGB00696, NGB00714, NGB00722, NGB00724 and NGB00734 (Table 4). Treatment C had the highest leaf numbers in 3 varieties, NGB00716, NGB00737 and NGB00749 (Table 4). Treatment Arbuscular mycorrhizal fungi only (A) had the highest number of leaves in just one variety NGB00718 (Table 4).

Table 5 shows the number of flowers for the ten varieties. Treatment SA recorded highest number of flowers in 5 varieties, NGB00696, NGB00714, NGB00724, NGB00734 and NGB00737 (Table 5). Treatment A had highest number of flowers in two varieties, NGB00718 and NGB00722 (Table 5). Treatment C recorded highest number of flowers in 3 varieties, NGB00692, NGB00716, and NGB00749 (Table 5).

Table 6 shows the fresh weight of fruits (g). Treatment SA recorded highest number of leaves in 6 varieties, NGB00718, NGB00722, NGB00724, NGB00734, NGB00737 and NGB00749 (Table 6). Treatment C had the highest leaf numbers in 3 varieties, NGB00692, NGB00696 and NGB00716 (Table 6). Treatment Arbuscular mycorrhizal fungi only (A) had the

highest number of leaves in just one variety NGB00714 (Table 6).

#### 4. DISCUSSION

The results of this study showed that effects of salinity and arbuscular mycorrhizal fungi differs across varieties with significant differences occurring in some varieties and low or no effect in others across growth parameters. Tomato plants grown in salt treatments and arbuscular mycorrhizal fungi had the highest plant height across 5 varieties. This can be an indicator that salts can cause a slight increase in vegetative growth. This was corroborated in the work of [15]. Low or moderate salt has the ability of increasing plant height with high concentration leading to decrease in plant height. This was also in accordance with report of [16], who showed a variety of mechanisms to determine how mycorrhizal ameliorate the effects of salinity stress on. Studies have shown that mycorrhizal colonization may increase nutrient acquisition of plants grown at high salinity which can in turn lead to increase in plant height [17,18]. Studies on AMF have shown that it has a positive influence on the composition of mineral nutrients of plants grown in salt-stress conditions by enhancing and/or selective uptake of nutrients [19].

The results of the growth parameters which showed that varieties of tomatoes treated with salt and AMF had better morphological characters than in other treatments in this study, these results are in line with the reports of other researchers who think that AMF can contribute to plants protection against salinity by reducing the oxidative stress caused by salinity. AMF has the ability to enhance salt tolerance of plants [20]. Ruiz-Lozano [21] reported that *Glomus sp.* protected plants from high salinity by stimulating root development, this in turn increase water use efficiency there by leading to increase in morphology parameters of plants. Under salt stress, plant growth and biomass can be drastically reduced. The reasons may be the non-availability of nutrients and the expenditure of energy to counteract the toxic effects of NaCl [6]. However, mycorrhization was found to increase the fitness of the host plant by enhancing its growth and biomass [6]. Several researchers have reported that AMF-inoculated plants grow better than non-inoculated plants under salt stress [17].

**Table 1. Plant height (cm) of the 10 varieties of *Solanum lycopersicum* grown in different treatments at 80<sup>th</sup> day after planting**

TRTS	Varieties									
	NGB00692	NGB00696	NGB00714	NGB00716	NGB00718	NGB00722	NGB00724	NGB00734	NGB00737	NGB00749
SA	45.75±6.55 <sup>a</sup>	54.03±11.46 <sup>a</sup>	57.70±17.50 <sup>a</sup>	56.43±9.72 <sup>ab</sup>	61.10±25.97 <sup>a</sup>	32.20±9.68 <sup>ab</sup>	45.92±8.86 <sup>b</sup>	56.00±3.85 <sup>a</sup>	47.73±10.87 <sup>a</sup>	44.13±10.89 <sup>a</sup>
A	23.67±6.49 <sup>b</sup>	33.20±9.23 <sup>b</sup>	41.95±18.75 <sup>b</sup>	37.70±2.91 <sup>b</sup>	55.37±18.62 <sup>a</sup>	25.20±9.53 <sup>b</sup>	34.50±2.40 <sup>c</sup>	43.20±2.38 <sup>ab</sup>	35.20±10.61 <sup>ab</sup>	33.20±13.41 <sup>b</sup>
C	44.20±2.69 <sup>a</sup>	51.27±7.14 <sup>ab</sup>	56.05±7.05 <sup>a</sup>	71.10±2.00 <sup>a</sup>	43.33±6.71 <sup>b</sup>	39.80±1.73 <sup>a</sup>	56.10±5.58 <sup>a</sup>	51.56±3.21 <sup>a</sup>	48.53±8.59 <sup>a</sup>	48.86±3.91 <sup>a</sup>

Means with different superscripts in each column are significantly different at  $P \leq 0.05$  according to Duncan multiple range test. TRTS: Treatments; SA: Salt treatment + AMF; A: AMF; C: Control

**Table 2. Leaf area (cm<sup>2</sup>) of 10 varieties of *Solanum lycopersicum* grown in different treatments at 80<sup>th</sup> Day after planting**

TRTS	Varieties									
	NGB00692	NGB00696	NGB00714	NGB00716	NGB00718	NGB00722	NGB00724	NGB00734	NGB00737	NGB00749
SA	135.42±1.25 <sup>a</sup>	104.65±0.57 <sup>a</sup>	92.86±2.20 <sup>a</sup>	78.88±0.68 <sup>a</sup>	56.70±0.52 <sup>a</sup>	57.99±0.87 <sup>c</sup>	80.76±1.03 <sup>b</sup>	115.15±0.66 <sup>a</sup>	57.40±1.52 <sup>a</sup>	95.91±0.88 <sup>a</sup>
A	67.14±1.24 <sup>c</sup>	96.62±0.41 <sup>ab</sup>	78.84±0.55 <sup>ab</sup>	65.99±1.82 <sup>ab</sup>	32.18±2.43 <sup>b</sup>	63.50±2.48 <sup>bc</sup>	51.67±0.49 <sup>c</sup>	78.45±1.96 <sup>b</sup>	54.18±1.43 <sup>ab</sup>	33.88±2.21 <sup>c</sup>
C	72.48±0.38 <sup>abc</sup>	92.74±0.83 <sup>b</sup>	65.83±0.35 <sup>b</sup>	76.80±0.80 <sup>a</sup>	41.00±0.74 <sup>ab</sup>	83.87±0.59 <sup>a</sup>	83.87±0.76 <sup>a</sup>	69.96±2.05 <sup>c</sup>	52.96±0.32 <sup>ab</sup>	51.62±1.02 <sup>b</sup>

Means with different superscripts in each column are significantly different at  $P \leq 0.05$  according to Duncan multiple range test. TRTS: Treatments; SA: Salt treatment + AMF; A: AMF; C: Control

**Table 3. Stem girth (mm) of 10 varieties of *Solanum lycopersicum* grown in different treatments at 80<sup>th</sup> day after planting**

TRTS	Varieties									
	NGB00692	NGB00696	NGB00714	NGB00716	NGB00718	NGB00722	NGB00724	NGB00734	NGB00737	NGB00749
SA	5.70±0.68 <sup>ab</sup>	6.74±1.29 <sup>a</sup>	6.64±0.53 <sup>a</sup>	6.04±0.16 <sup>a</sup>	4.58±1.33 <sup>a</sup>	6.15±1.34 <sup>a</sup>	5.92±1.23 <sup>b</sup>	7.65±0.50 <sup>a</sup>	6.18±1.57 <sup>a</sup>	5.59±1.25 <sup>ab</sup>
A	4.40±0.30 <sup>b</sup>	4.60±0.92 <sup>b</sup>	5.69±1.66 <sup>ab</sup>	6.22±0.64 <sup>a</sup>	3.81±1.19 <sup>ab</sup>	4.54±1.73 <sup>b</sup>	4.34±0.06 <sup>c</sup>	5.01±0.83 <sup>b</sup>	4.03±1.47 <sup>b</sup>	4.55±1.38 <sup>b</sup>
C	6.60±1.04 <sup>a</sup>	6.33±1.08 <sup>a</sup>	6.57±0.53 <sup>a</sup>	6.44±0.91 <sup>a</sup>	4.45±0.72 <sup>a</sup>	4.40±0.65 <sup>b</sup>	7.12±0.59 <sup>a</sup>	5.88±0.59 <sup>b</sup>	5.13±0.28 <sup>ab</sup>	7.29±1.09 <sup>a</sup>

Means with different superscripts in each column are significantly different at  $P \leq 0.05$  according to Duncan multiple range test; TRTS: Treatments; SA: Salt treatment + AMF; A: AMF; C: Control

**Table 4. Number of leaves of 10 varieties of *Solanum lycopersicum* grown in different treatments at 80<sup>th</sup> day after planting**

TRTS	Varieties									
	NGB00692	NGB00696	NGB00714	NGB00716	NGB00718	NGB00722	NGB00724	NGB00734	NGB00737	NGB00749
SA	16.00±8.00 <sup>a</sup>	26.00±6.43 <sup>a</sup>	16.00±5.00 <sup>a</sup>	20.67±5.92 <sup>b</sup>	29.67±10.71 <sup>abc</sup>	12.33±2.60 <sup>a</sup>	18.75±5.07 <sup>a</sup>	16.33±3.84 <sup>a</sup>	17.00±5.03 <sup>a</sup>	13.00±2.51 <sup>b</sup>
A	6.67±0.67 <sup>c</sup>	15.33±3.38 <sup>b</sup>	13.00±5.00 <sup>b</sup>	11.67±2.67 <sup>c</sup>	36.67±16.04 <sup>a</sup>	11.33±3.18 <sup>ab</sup>	8.00±0.57 <sup>c</sup>	11.00±2.08 <sup>b</sup>	11.33±1.76 <sup>b</sup>	11.33±3.48 <sup>c</sup>
C	10.67±0.67 <sup>b</sup>	23.00±4.16 <sup>ab</sup>	15.50±5.50 <sup>ab</sup>	25.00±1.00 <sup>a</sup>	16.00±1.53 <sup>c</sup>	11.00±1.00 <sup>ab</sup>	15.66±4.09 <sup>b</sup>	15.00±2.64 <sup>ab</sup>	17.66±5.69 <sup>a</sup>	18.33±5.81 <sup>a</sup>

Means with different superscripts in each column are significantly different at  $P \leq 0.05$  according to Duncan multiple range test; TRTS: Treatments; SA: Salt treatment + AMF; A: AMF; C: Control

**Table 5. Number of flowers of 10 varieties of *Solanum lycopersicum* grown in different treatments at 80<sup>th</sup> day weeks after planting**

		Varieties									
TRTS	NGB00692	NGB00696	NGB00714	NGB00716	NGB00718	NGB00722	NGB00724	NGB00734	NGB00737	NGB00749	
SA	7.50±0.50 <sup>d</sup>	12.67±2.60 <sup>a</sup>	10.00±5.00 <sup>a</sup>	9.33±2.33 <sup>ab</sup>	22.33±12.99 <sup>ab</sup>	4.33±2.60 <sup>b</sup>	10.50±2.72 <sup>a</sup>	11.66±0.33 <sup>a</sup>	8.00±4.00 <sup>a</sup>	4.33±1.20 <sup>b</sup>	
A	1.00±1.00 <sup>c</sup>	7.00±3.05 <sup>b</sup>	7.50±0.50 <sup>a</sup>	4.67±1.45 <sup>b</sup>	31.67±16.41 <sup>a</sup>	5.00±3.60 <sup>a</sup>	7.33±1.20 <sup>b</sup>	5.00±1.00 <sup>bc</sup>	4.00±2.08 <sup>bc</sup>	6.00±3.78 <sup>ab</sup>	
C	11.67±6.33 <sup>a</sup>	8.00±4.58 <sup>ab</sup>	6.00±1.00 <sup>a</sup>	11.50±4.50 <sup>a</sup>	8.67±0.88 <sup>b</sup>	5.00±1.53 <sup>a</sup>	7.33±3.28 <sup>b</sup>	8.66±2.85 <sup>b</sup>	5.00±1.15 <sup>b</sup>	7.33±3.71 <sup>a</sup>	

Means with different superscripts in each column are significantly different at  $P \leq 0.05$  according to Duncan multiple range test; TRTS: Treatments; SA: Salt treatment + AMF; A: AMF; C: Control

**Table 6. Fresh weight of fruits (g) of 10 varieties of *Solanum lycopersicum* grown in different treatments at 80<sup>th</sup> day after planting**

		Varieties									
TRTS	NGB00692	NGB00696	NGB00714	NGB00716	NGB00718	NGB00722	NGB00724	NGB00734	NGB00737	NGB00749	
SA	6.15±1.63 <sup>b</sup>	3.96±0.04 <sup>b</sup>	11.07±0.41 <sup>b</sup>	3.38±0.14 <sup>b</sup>	1.57±0.05 <sup>a</sup>	14.69±2.28 <sup>a</sup>	13.83±2.50 <sup>a</sup>	43.87±12.83 <sup>a</sup>	5.03±0.30 <sup>a</sup>	8.53±1.35 <sup>a</sup>	
A	0.00±0.00 <sup>c</sup>	1.18±0.21 <sup>c</sup>	18.03±1.23 <sup>a</sup>	2.05±0.33 <sup>c</sup>	0.86±0.08 <sup>b</sup>	2.11±0.92 <sup>c</sup>	6.25±1.89 <sup>b</sup>	2.54±0.19 <sup>c</sup>	4.01±0.22 <sup>c</sup>	4.42±0.25 <sup>c</sup>	
C	12.83±1.77 <sup>a</sup>	6.11±0.92 <sup>a</sup>	10.59±3.49 <sup>bc</sup>	14.56±3.38 <sup>a</sup>	0.78±0.07 <sup>c</sup>	5.09±2.82 <sup>b</sup>	4.12±0.67 <sup>bc</sup>	20.05±3.00 <sup>b</sup>	4.28±1.26 <sup>b</sup>	5.27±0.91 <sup>b</sup>	

Means with different superscripts in each column are significantly different at  $P \leq 0.05$  according to Duncan multiple range test; TRTS: Treatments; SA: Salt treatment + AMF; A: AMF; C: Control

Earlier studies found that the improved growth of mycorrhizal plants in saline conditions is highly related to mycorrhizal-mediated enhancement of host plant P nutrition [22]. The sustained growth of AMF+ plants under salinity is partially based on improved uptake of nutrients and maintaining favorable ionic ratios [23]. There was a higher shoot and root dry weight, fresh fruit yield, fruit weight and fruit number in a tomato plant inoculated with arbuscular mycorrhizal fungi than in one not inoculated this was observed by [17]. Increased growth of AMF inoculated plants has been partly attributed to enhanced nutrient acquisition by mycorrhizal [24].

## 5. CONCLUSION

The result of this study indicated that salt and arbuscular mycorrhizal fungi treated plants had higher and better morphological parameters and better weights of fruits across majority of the varieties tested. It is recommended that arbuscular mycorrhizal fungi be added to areas with high rate of salinity to ameliorate the effect of the high salt content on plants especially tomato plants.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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