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Synergistic effect of arbuscular mycorrhizal fungi and poultry manure to significantly increase proximal structure and physiological parameters of *Cucurbita maxima* and *Telfairia occidentalis* under soil salinity

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Abstract

This research was carried out to assess the potential impacts of arbuscular mycorrhizal fungi (AMF) complex (*Glomus geosporum* and *Rhizophagus irregularis*) synergy with poultry manure (PM) on the survival of *Cucurbita maxima* and *Telfairia occidentalis* grown under salt stress conditions. This experiment was set up in a completely randomized design with all treatments replicated thrice for both test plants. Analysis of the saline and garden soils used in this study revealed significant ($P \leq 0.05$) variations in their soil physico-chemical parameters. Increase in parameters such as pH (7.75 for saline soil; 6.78 for garden soil), EC (SS 7.80 $dS.m.^{-1}$; GS 0.32) and Ex Na+ (SS 8.81 $cmol.kg^{-1}$; GS 0.4181 $cmol.kg^{-1}$) was observed in the saline soil while there was a decrease in organic carbon, total nitrogen and available phosphorus in saline soil. Proximate analysis of *C. maxima* and *T. occidentalis* leaves revealed that fiber, carbohydrate, and caloric value were slightly reduced in saline soil treatments while ash, protein and lipids contents were slightly increased. AMF inoculation and PM application had significant effect on proximate composition of these plant leaves but caloric value which was significantly ($P \leq 0.05$) increased in non-saline soil treatments. Physiological parameters such as leaf turgid weight (LTW), leaf relative water content (LRWC), vigor index (VI), and salt tolerance index (STI) were significantly reduced by salinity, while electrolyte leakage (EL) was higher in saline soil treatments than non-saline soil treatments. However, inoculation with AMF in combination with PM amendment significantly increased LTW, LRWC, VI, and STI in both saline and non-saline soil treatments above single treatment with mycorrhizal species and poultry manure. However, EL reduced with mycorrhizal inoculation. The results of this work have shown that AMF and PM can enhance plants ability to tolerate salinity possibly through some morphological and physiological changes which improved water and nutrients uptake.

Introduction

Soil salinity is a term used to describe the amount of mineral salts present in soil (Shan 2009). The mineral salts constitute a mixture of electrolytes. The major cations in saline soils include Na^+, Ca^{2+}, Mg^{2+}, and K^+. The major anions include Cl^-, SO_4^{2-}, HCO^{3-}, CO_3^{2-}, and NO^{3-}. These constituents are usually reported in units of mg/L (ppm), $mmol.L^{-1}$ or mmol $charge.L^{-1}$ ($meq.L^{-1}$) in solution extracted from a soil saturated with water (Tanji 2002). Salinity is often measured as electrical conductivity (EC), a measure of the ability of a substance to conduct electricity. The natural factors contributing to salinization of soils include weathering of rocks, deposition of oceanic salts, topographical factor, groundwater table fluctuation, salt lake, scald, fallow period, and flood water. However, the major contributors to soil salinization are weathering of parental rocks, oceanic salt deposition, and groundwater table fluctuation. Rocks are mostly rich in sodium and other salts (Saxena *et al.* 2017). The most common man-made factors contributing to salinization are the irrigational water and the use of chemical fertilizers and pesticides. Irrigation is an important factor in the crop productivity. Therefore, the use of high salt-containing water for crop irrigation and poor management practices for appropriate leaching of salts lead to the accumulation of salts and deteriorate the crop fields (Zhu 2007).

Salinity not only decreases the agricultural production of most crops, but also, as a result of its effect on soil physicochemical properties, adversely affects the associated ecological balance of the area. The harmful impacts of salinity include: low agricultural production, low economic returns due to high cost of cultivation, reclamation management, soil erosion due to high dispersibility of soil, ecological imbalance due to halophytes and marine life forms from fresh water to brackish water, poor human health due to toxic effects of elements such as B, F, and Se (Hu and Schmidhalter 2002; Ashok *et al.* 2012). Crop species show a spectrum of responses to salt, although all have their growth, and eventually, their yield reduced by salt. Salt effects are the combined result of the complex interaction among different morphological, physiological, and biochemical processes (Ashok *et al.* 2012). Salinity may directly or indirectly inhibit cell division and enlargement and finally the growth of the whole plant. In addition to these factors, some other factors like water deficit (drought stress), ion toxicity, ion imbalance and soil compaction may cause growth reduction, injury of foliage, nutrient deficiencies, destruction of soil structure which ultimately hampers the growth of the plant. Some above ground visible morphological symptoms of plants are marginal yellowing/browning of foliage, premature fall of leaves, twig and branch die back, loss of vigor and stunted growth (Ashok *et al.* 2012).

The high concentration of salts in soil may induce three types of stresses: osmotic, ionic or oxidative, which drastically affect plant growth and productivity (Saxena *et al.* 2017). Osmotic stress leads to altered water potential, thereby reducing the water use efficiency of plant due to induction of physiological drought conditions (Saxena *et al.* 2017). Ionic stress causes disruption of ion homoeostasis at both cellular and whole-plant levels, oxidative stress elicits release of reactive oxygen species, which inhibit cell growth and plant metabolism. Experiments carried out to understand AMF-salinity interaction revealed that mycorrhizal fungi reduce negative effects of these stresses and promote plant growth (Wu *et al.* 2006; Zuccarini and Okurowska 2008; Evelin *et al.* 2009; Wu *et al.* 2010a, 2010b).

Plants encounter a variety of biotic and abiotic stresses, which cause significant structural and functional changes that will result in decreased yield and vegetative traits (plant height, shoot length, number of branches, fresh and dry biomass, etc.) (Agha *et al.* 2021; Matrood and Rhouma 2021; Sofy *et al.* 2021a). In the other hand, salinity is among the most significant threats hindering global food security. Arbuscular mycorrhizal fungi and poultry manure (practice alone or in combination) were commonly used for agricultural production for their abilities to improve plant health to salinity stress (Solaiman *et al.* 2020; Zhang *et al.* 2020; Sallam *et al.* 2021; Sofy *et al.* 2021a, 2021b).

Arbuscular mycorrhizal (AM) fungi are among the most common soil fungi and the majority of plant species have associations with AM fungal species (Selvaraj and Chellappan 2006). It is thought that about 80 % of vascular plants form AM associations (Hodge 2000). Mycorrhizal fungi can help plants to survive and grow under different environmental conditions, and also help plants increase their reproductive output (Bolandnazar *et al.* 2007). The basic elements of the symbiosis are that the plant provides the mycorrhiza with carbohydrates while the fungi enhance the plant's uptake of certain nutrients needed for growth

(Selvaraj and Chellappan 2006). It has been estimated that in compensation for the additional nutrients and water provided by mycorrhizas, a plant must provide 20 % of its fixed carbon to the roots for mycorrhizal establishment and maintenance of the association (Ebrahim 2014).
Little information is available about the influence of combination poultry manure/arbuscular mycorrhizal fungi on yield and quality of cucurbits. Elmer and Pignatello (2011) and Blackwell *et al.* (2015) pointed out that poultry manure application and arbuscular mycorrhizal fungi could serve as a sustainable nutrient alternative to chemical fertilizer. This is due to the potential of the fungi to utilize unavailable organic nutrients and increase the efficiency use of nutrients through improved nutrients uptake, which might enhanced plant growth and yield (Elmer and Pignatello 2011; Blackwell *et al.* 2015). Earlier researchers have clearly documented the positive effect of organic amendments in combination with arbuscular mycorrhizal fungi (Hammer *et al.* 2014, 2015) on plant growth and improve nutrients uptake (Abdullahi *et al.* 2015; Solaiman *et al.* 2019). Solaiman *et al.* (2020) pointed out that the cucumber growth responses to poultry manure application and arbuscular mycorrhizal symbiosis showed better plant growth and yield of cucumber and reduced the negative impact of stress salinity. This combination also improved the nutrient uptake and soil fertility of sandy soils (Mickan *et al.* 2016; Paymaneh *et al.* 2018; Solaiman *et al.* 2020). This research was undertaken to investigate the effect of salt stress on the proximate composition and physiological parameters of two different Cucurbits (*Telfairia occidentalis* and *Cucurbita maxima*) and determine ways of ameliorating its effect using arbuscular mycorrhizal species and poultry manure.

Experimental

Study area

Saline soil and salt water were collected from the saline ecosystem of Iwuochang, Ibeno Local Government Area (Latitude 4.56°N and Longitude 7.57°E), Akwa Ibom State, Nigeria, with an annual rainfall of about 4,021 mm and mean temperature variation of 22 – 31 ºC. The experiment was set up in a safe and secured environment at Mbioto 1, Etinan Local Government Area (Latitude 4.51°N and Longitude 7.50°E), Akwa Ibom State, Nigeria, with an annual rainfall of about 4,000 mm and mean temperature variation of 26 – 36 ºC (AKSG 2008). Non-saline soil for the control and non-saline treatments was obtained from a farmland in Mbioto 1, Etinan Local Government Area; fresh water was used for watering the non-saline and control treatments. A map showing the saline water/soil collection and experimental set-up locations is presented in Fig. 1.

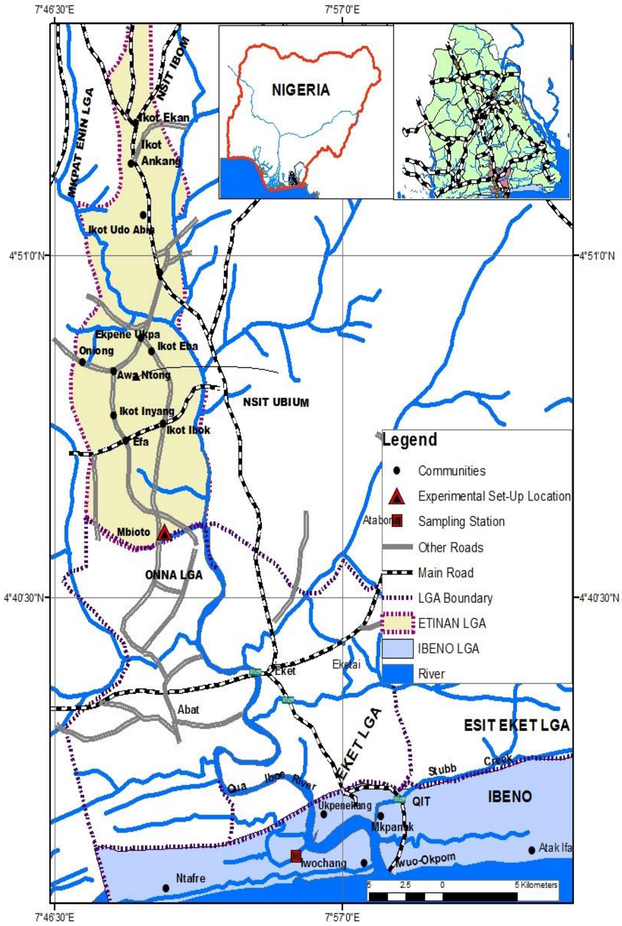

Fig. 1. Map showing saline water/soil collection and experimental set-up locations (Source: Field Data).

Experimental design

This experiment was set up in a randomized complete block design and arranged in three blocks of 108 pots each for each species of cucurbits (*C. maxima* and *T. occidentalis*). This gave a total of 12 treatments (Table 1) for each species with nine replicates totaling 108 combinations for each species of cucurbits. This experiment was carried out in 1 March 2020 in a greenhouse.

Table 1. Experimental design.

Treatments	Meaning
S- M- P-	- Salinity, - Mycorrhiza, - Poultry
S+ M- P-	+ Salinity, - Mycorrhiza, - Poultry
S+ M+ P- (*Gg*)	+ Salinity, + Mycorrhiza (*G. geosporum*), - Poultry
S+ M+ P- (*Ri*)	+ Salinity, + Mycorrhiza (*R. irregularis*), - Poultry
S+ M- P+	+ Salinity, - Mycorrhiza, + Poultry
S+ M+ P+ (*Gg*)	+ Salinity, + Mycorrhiza (*G. geosporum*), + Poultry
S+ M+ P+ (*Ri*)	+ Salinity, + Mycorrhiza (*R. irregularis*), + Poultry
S- M+ P- (*Gg*)	- Salinity, + Mycorrhiza (*G. geosporum*), - Poultry
S- M+ P- (*Ri*)	- Salinity, + Mycorrhiza (*R. irregularis*), - Poultry
S- M+ P+ (*Gg*)	- Salinity, + Mycorrhiza (*G. geosporum*), + Poultry
S- M+ P+ (*Ri*)	- Salinity, + Mycorrhiza (*R. irregularis*), + Poultry
S- M- P+	- Salinity, - Mycorrhiza, + Poultry

Planting

The experimental soils were steam sterilized in the oven in bits for 2 h at 100 ºC to kill weed seeds and soil microorganisms and sieved through a 2 mm mesh to remove pebbles. The poultry manure used in this research consists of moisture (39.69 %), N (2.47 %), P_2O_5 (2.84 %), K_2O (1.84 %). Treatments consisted of 1 kg of poultry manure per pot. AM fungi *Glomus geosporum* and *Rhizophagus irregularis* (60 – 65 spores per 5 g) were purchased from International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. Matured seeds of *Cucurbita maxima* and *Telfairia occidentalis* were obtained from Akwa Ibom State Agricultural Development Project (AKADEP) in Etinan. The obtained seeds were selected to eliminate infected seeds. Five seeds each of *C. maxima* and *T. occidentalis* were sown in each of the pots filled with about 10 kg of sterilized soils. Arbuscular mycorrhiza fungi were inoculated by placing 25 g of soil/root fragments containing 60 – 65 spores per 5 g in planting hole at 15 cm depth, before planting the *C. maxima* and *T. occidentalis*. Following seedling emergence, the plants inoculated were allowed to establish for up to 15 d before being treated with the first dose of saline water. This was to ensure the establishment of AM colonization and avoid sudden plant death due to salinity shock. The roots treatment with saline water (100 mL) using an Erlenmeyer flask (250 mL) on the two cucurbits species was performed 1 d after the establishment of the mycorrhizal symbiosis and the treatments were spaced every 3 d until the end of the trial (30 June 2020). Assessments were conducted 90 d after the treatment (with poultry manure and AM Fungi). At the end of trial (30 June 2020), 27 plants (3 plants × 9 replicates) per treatment and per block were assessed for each cucurbit species (*C. maxima* and *T. occidentalis*).

Physico-chemical properties of experimental soils

Soil samples were taken using a 7-cm-diameter soil auger. A total of 108 samples per block were collected in sterile polythene bags. For each block, samples were mixed together into a single one. Nine soil samples (500 g) per block (3 blocks) and per replicate (3 replicates) were collected from each treatment after and before the trials and brought to the laboratory. The soil samples were taken and air-dried at room temperature and ground in a wooden mortar to pass through a 2 mm mesh sieve and stored in labelled bags. Sub-samples were taken from each soil sample and analysed for physico-chemical properties of the soil. Soil samples were analysed following the standard procedures outlined by the Association of Official Analytical Chemist (AOAC 2005) procedure for wet acid digestions (Rhouma *et al.* 2019). Soil physicochemical properties (pH, Total Nitrogen (%), Available Phosphorus (mg.kg^{-1}), Silt (%), Clay (%), Sand (%), Ex. Ca (cmol.kg^{-1}), Ex. Mg (cmol.kg^{-1}), Ex. Na. (cmol.kg^{-1}), Ex. K. (cmol.kg^{-1}), Organic Carbon (%), Exchangeable acidity (meq/100 g), ECEC (cmol.kg^{-1}), Base saturation

(%) and Electrical conductivity (EC) ($dS.m^{-1}$) were determined for each samples (Rhouma *et al.* 2019).

Analysis of water samples

Nine water samples (1,000 mL) per replicate (3 replicates) were collected from saline (water used in treatment) and freshwater). A total of 27 samples were collected in sterile glass bottles (2,000 mL) and brought to the laboratory. Water pH, electrical conductivity, and total dissolved solid (TDS was measured using portable pH/EC/TDS/Temperature combined (HI 991301, Hanna Instruments Ltd., Leighton, UK). Dissolved oxygen was measured using digital portable analyzer JPB-607A Portable Dissolved Oxygen Analyzer (Tech Instrumentation Inc., Elizabeth, USA). Biological oxygen demand (BOD5), total alkalinity, acidity, chloride, calcium, nitrate, sulphate, phosphate, magnesium, sodium and potassium concentration was determined by the conventional method of the Association of Official Analytical Chemists (AOAC 2005). Salinity was determined using digital salt meter, which measures the salinity of seawater in parts per thousand (Rhouma *et al.* 2017).

Determination of proximate content

The determination of ash, lipid, carbohydrate and crude fibre was carried out using the standard methods described by Cella and Watson (2000) and Adeola *et al.* (2010). Caloric value was determined using a bomb calorimeter.

Physiological parameters

Electrolyte leakage was calculated using the formula (Shi *et al.* 2006): EC1/EC2. Values of FW, TW, and DW were used to calculate LRWC using the formula (Eq. 1; Kaya *et al.* 2003):

$$\text{LRWC (\%)} = \frac{(\text{FW} - \text{DW})}{\text{TW} - \text{DW}} \times 100 \qquad (1)$$

To determine the turgid weight (TW), leaves were soaked in distilled water inside a closed Petri dish. Leaf samples were weighed periodically after gently wiping the water from the leaf surface with tissue paper until a steady state was achieved. The turgid weight of the leaves was determined by weighing the soaked leaves on a weighing balance and weight recorded (Kaya *et al.* 2003).
Plant vigor index in each treatment was calculated using the formula (Eq. 2; Maisuria and Patel 2009):

Vigor index = Root length + Shoot length × percentage emergence (%) (2)

Plant salt tolerance index (PSTI) was calculated using the formula of Jaarsma *et al.* (2013) (Eq. 3):

$$\text{PSTI} = \frac{\text{Fresh weight salt treatment}}{\text{Fresh weight control}} \qquad (3)$$

Statistical analysis

All data in the present study were subjected to analysis of variance (ANOVA) using Statistical package for Social Sciences (SPSS) and data are presented as standard error of mean (± SEM) of triplicate experiments. The student's t-test was used to determine the significant difference between means of the soil and water parameters analyzed. The differences between the means were separated and compared using the Duncan's multiple range tests. However, a probability level of $P \leq 0.05$ was considered statistically significant.

Results and Discussion

Analysis of the saline and garden soils used in this study revealed significant variations in their soil physico-chemical parameters ($P \leq 0.05$). Significant increase in parameters such as pH (7.75), EC (7.80 $dS.m^{-1}$) and Ex Na^+ (8.81 $cmol.kg^{-1}$) was observed in the saline soil while there was a decrease in organic carbon (1.61 %), total nitrogen (0.49 %) and available phosphorus (24.66 $mg.kg^{-1}$) in saline soil ($P \leq 0.05$) (Table 2 and 3). This observation is in line with the work of Miller and Gardiner (2007) who reported an increase in pH and EC in saline soils in New Jersey due to salt stress. Deleke and Akomolafe (2013) also made similar findings as they observed an increase in pH, EC and Ex Na^+ in saline soils and a decrease in organic carbon, organic matter, total nitrogen and phosphorus in salinity influenced soils in Nigeria. Soil organic carbon content is influenced by two opposing factors: reduced plant inputs and reduced rates of decomposition (Garg and Manchanda 2008). This might be responsible for the significant decrease in the soil OC, Total N and P observed in this work. High concentrations of salts in soil, especially Na^+ ions drastically affect the basic structure of soil (Garg and Manchanda 2008). The presence of Na^+ ions in the cation exchange complex makes the soil compact and subsequently decreases soil porosity and aeration, which hampers plant growth and hinders their productivity (Garg and Manchanda 2008). The presence of the salts of calcium and magnesium forms a white crust on the soil surface that changes soil water osmotic potential; therefore, plants growing in saline soils face salt-induced physiological drought conditions. Salinity impairs plant's major processes such as photosynthesis, protein and lipid metabolism, nutrient acquisition, and ion homeostasis. Indeed, water moves out of the plant due to salt-induced osmotic stress, which makes the plant dehydrated and eventually leads to the death of the plant (Evelin *et al*. 2011).

Table 2. Physicochemical properties of the experimental soils.

S/No.	Parameters	Soil before treatment with saline water	Soil after treatment with saline water
1.	pH	6.78^b	7.75^a
2.	Total Nitrogen [%]	2.27^a	0.49^b
3.	Available P. [mg.kg^{-1}]	36.31^a	24.66^b
4.	Silt [%]	4.00^b	5.60^a
5.	Clay [%]	4.20^b	12.00^a
6.	Sand [%]	92.04^a	82.40^b
7.	Ex. Ca [cmol.kg^{-1}]	5.25^a	2.97^b
8.	Ex. Mg [cmol.kg^{-1}]	4.36^a	3.80^b
9.	Ex. Na [cmol.kg^{-1}]	0.41^b	8.81^a
10.	Ex. K. [cmol.kg^{-1}]	6.98^a	1.48^b
11.	Organic Carbon (%)	5.61^a	1.61^b
12.	Exchangeable acidity (meq/100g)	3.56^a	3.20^b
13.	ECEC [cmol.kg^{-1}]	20.56^a	20.26^b
14.	Base saturation [%]	82.68^b	84.20^a
15.	EC. (dS.m^{-1})	0.32^b	7.80^a

* Significant at $P \leq 0.05$, Ex – Exchange, ECEC – Effective cation exchange capacity, EC – Electrical conductivity.

Table 3. Water analysis of the experimental irrigation water.

S/No.	Parameters	Saline water (water used in treatment)	Fresh water
1.	pH	7.70^a	6.70^b
2.	EC [µS.cm^{-1}]	3080.00^a	27.70^b
3.	TDS	1021.00^a	11.00^b
4.	Acidity [mg.L^{-1} as CaCo$_3$]	80.00^b	95.40^a
5.	Alkalinity [mg.L^{-1} as CaCo$_3$]	138.00^a	53.20^b
6.	DO [mg.L^{-1}]	6.40^b	7.60^a
7.	BOD [mg.L^{-1}]	3.20^b	2.80^a
7.	Sulphate [mg.L^{-1}]	102.31^a	1.91^b
9.	Phosphate [mg.L^{-1}]	0.09^a	0.04^b
10.	Nitrate [mg.L^{-1}]	0.06^b	2.82^a
11.	Cl^- [mg.L^{-1}]	2560.13^a	55.23^b
12.	Ca^{2+} [mg.L^{-1}]	55.71^b	106.20^a
13.	Mg^{2+} [mg.L^{-1}]	120.20^b	232.81^a
14.	Na^+ [mg.L^{-1}]	1027.00^a	0.11^b
15.	K^+ [mg.L^{-1}]	6.42^b	8.40^a
16.	Salinity [ppt]	33.21^a	0.32^b

* Significant at $P \leq 0.05$, EC – Electrical conductivity, DO – Dissolved oxygen, BOD – Biological oxygen demand, TDS – Total dissolved solids.

Proximate analysis of *C. maxima* and *T. occidentalis* leaves revealed that fibre, carbohydrate and caloric value were slightly reduced in saline soil treatments while ash, protein and lipids contents were slightly increased (Table 4 and 5). AMF inoculation of *C. maxima* and *T. occidentalis* and poultry manure application had some significant effect on proximate composition of these plant leaves but caloric value which was significantly increased in non-saline soil treatments ($P \leq 0.05$) (Table 4 and 5). Proximate composition of *C. maxima* and *T. occidentalis* such as carbohydrate, caloric value and fibre were significantly reduced with salinity, while ash, protein and lipids increased in saline soil treatments compared to non-saline soil treatments. However, inoculation of *C. maxima* and *T. occidentalis* with arbuscular mycorrhizal fungi (AMF) (*R. irregularis* and *G. geosporum*) in conjunction with soil amelioration with poultry manure (PM) increased some proximate composition of *C. maxima* and *T. occidentalis*. Proximate analysis of *C. maxima* and *T. occidentalis* leaves increased dramatically for the plants treated with *G. geosporum*+manure poultry (ash 18.48 – 17.09 %, respectively; fibre 15.20 – 20.11 %, respectively; protein 8.81 – 8.21 %, respectively; lipid 8.38 – 6.88 %, respectively; CHO 49.12 – 47.71 %, respectively; caloric value 297.60 – 281.41 Kcal, respectively) and *R. irregularis* + manure poultry (ash 17.54 – 17.02 %, respectively; fibre 14.67 – 19.82 %, respectively; protein 8.22 – 8.41 %, respectively; lipid 6.94 – 6.66 %, respectively; CHO 50.03 – 48.09 %, respectively; caloric value 318.71 – 289.00 Kcal, respectively) even in the presence of salinity (Table 4 and 5).

It can be concluded from the results of this study that *C. maxima* plants tolerate better the salinity when treated with *G. geosporum*+manure poultry. We concluded that the addition of *R. irregularis* in combination with poultry manure to soil optimally improved the studied parameters of *T. occidentalis* in water stress conditions (Table 4 and 5).

Increase in ash, protein and lipids have also been reported by Uddin *et al.* (2017) in *Clinacanthus nutans* with increasing salinity. The findings in this study agree with the results of Ali *et al.* (2014) on *Portulaca oleracea*, *Hibiscus sabdariffa* and *Sorghum bicolor*, Kekere (2014) in *A. hypogea*, Uzun *et al.* (2013) and Kapoor and Srivastava (2010) who reported that increasing salinity levels tended to enhance crude protein synthesis. The increase in crude lipid content of *C. maxima* and *T. occidentalis* in response to salinity may be because plants have some level of tolerance at these salinity levels or due to accumulation of compatible solutes (Uddin *et al.* 2017). These results agree with those previously reported on *P. oleracea* by Teixeira and Carvalho (2009) and *Oenothera biennis* by Heuer *et al.* (2002). They observed increased total fat content in plants exposed to moderate saline environment.

Table 4. Effects of arbuscular mycorrhizal fungi (AMF) inoculation on the proximate composition of *C. maxima* grown in saline soil and ameliorated with poultry manure.

Treatments	Ash [%]	Fibre [%]	Protein [%]	Lipid [%]	CHO [%]	Caloric value [Kcal]
S- M- P-	*16.06 ± 0.66[b]	16.11 ± 0.38[a]	8.95 ± 0.21[b]	6.54 ± 0.15[b]	52.33 ± 4.55[a]	314.73 ± 10.51[c]
S+ M- P-	0.00 ± 0.00[c]	0.00 ± 0.00[b]	0.00 ± 0.00[c]	0.00 ± 0.00[c]	0.00 ± 0.00[c]	0.00 ± 0.00[g]
S+ M+ P- (Gg)	18.65 ± 1.24[a]	16.21 ± 0.33[a]	10.71 ± 1.61[a]	8.22 ± 0.25[a]	46.21 ± 3.42[b]	242.71 ± 8.41[f]
S+ M+ P- (Ri)	18.40 ± 0.71[a]	15.72 ± 0.61[a]	9.20 ± 0.75[a]	8.61 ± 0.34[a]	48.07 ± 3.11[b]	257.10 ± 8.11[e]
S+ M- P+	19.06 ± 1.62[a]	15.68 ± 0.46[a]	11.24 ± 1.22[a]	8.68 ± 0.29[a]	45.34 ± 2.05[b]	239.12 ± 6.34[f]
S+ M+ P+ (Gg)	18.48 ± 1.44[a]	15.20 ± 0.51[a]	8.81 ± 0.61[b]	8.38 ± 0.41[a]	49.12 ± 4.12[a]	297.60 ± 6.81[d]
S+ M+ P+ (Ri)	17.54 ± 1.34[a]	14.67 ± 0.25[a]	8.22 ± 0.57[b]	6.94 ± 0.38[b]	50.03 ± 4.48[a]	318.71 ± 9.66[c]
S- M+ P- (Gg)	16.76 ± 0.84[b]	15.49 ± 0.35[a]	7.97 ± 0.43[b]	6.61 ± 0.31[b]	53.17 ± 4.33[a]	320.12 ± 10.67[c]
S- M+ P- (Ri)	16.24 ± 0.69[b]	16.01 ± 0.42[a]	7.77 ± 0.64[b]	6.58 ± 0.50[b]	53.40 ± 4.37[a]	322.50 ± 10.81[c]
S- M+ P+ (Gg)	15.45 ± 0.51[b]	14.81 ± 0.29[a]	8.96 ± 0.72[b]	6.62 ± 0.34[b]	54.16 ± 4.71[a]	332.13 ± 12.12[b]
S- M+ P+ (Ri)	16.28 ± 0.75[b]	14.77 ± 0.32[a]	8.06 ± 0.76[b]	6.48 ± 0.34[b]	54.41 ± 4.21[a]	351.00 ± 14.32[a]
S- M- P+	16.79 ± 0.65[b]	14.58 ± 0.45[a]	8.09 ± 0.59[b]	7.92 ± 0.51[b]	51.02 ± 3.55[a]	298.30 ± 9.42[d]

*Mean of three replicates ± SEM. Means within of each column followed by different letters are significantly different at $P < 0.05$ according to Duncan's Multiple Range Test. S- (No salinity), M- (No mycorrhiza), P- (No poultry manure), S+ (Plus salinity), M+ (Plus mycorrhiza), P+ (Plus poultry droppings), (Gg) – *Glomus geosporum*, (Ri) – *Rhizophagus irregularis*, 0.00 (means the plants were dead).

Table 5. Effect of arbuscular mycorrhizal fungi (AMF) inoculation on the proximate composition of *T. occidentalis* grown in saline soil and ameliorated with poultry manure.

Treatments	Ash [%]	Fibre [%]	Protein [%]	Lipid [%]	CHO [%]	Caloric value [Kcal]
S- M- P-	*17.20 ±1.51[b]	20.17 ± 2.78[a]	8.74 ± 0.15[a]	6.81 ± 0.57[a]	47.08 ± 3.58[a]	298.16 ± 6.45[b]
S+ M- P-	21.43 ± 1.91[a]	23.11 ± 2.88[a]	8.67 ± 0.31[a]	8.27 ± 0.66[a]	38.52 ± 2.94[b]	197.14 ± 4.88[f]
S+ M+ P- (Gg)	18.96 ± 0.52[b]	21.22 ± 1.94[a]	8.21 ± 0.25[a]	7.08 ± 0.4[a]	45.45 ± 3.42[a]	246.30 ± 6.12[d]
S+ M+ P- (Ri)	17.47 ± 0.78[b]	21.43 ± 1.81[a]	8.87 ± 0.38[a]	6.71 ± 0.49[a]	45.52 ± 3.64[a]	275.28 ± 5.14[c]
S+ M- P+	22.00 ± 1.24[a]	21.77 ± 1.57[a]	8.77 ± 0.42[a]	8.25 ± 0.67[a]	39.21 ± 3.11[b]	202.11 ± 3.88[e]
S+ M+ P+ (Gg)	17.09 ± 0.64[b]	20.11 ± 1.45[a]	8.21 ± 0.33[a]	6.88 ± 0.35[a]	47.71 ± 3.31[a]	281.41 ± 5.74[c]
S+ M+ P+ (Ri)	17.02 ± 0.45[b]	19.82 ± 1.39[a]	8.41 ± 0.47[a]	6.66 ± 0.42[a]	48.09 ± 4.01[a]	289.00 ± 6.14[c]
S- M+ P- (Gg)	16.42 ± 0.64[b]	18.76 ± 1.43[a]	7.91 ± 0.51[a]	6.21 ± 0.29[a]	50.70 ± 3.69[a]	301.10 ± 7.22[b]
S- M+ P- (Ri)	16.53 ± 0.51[b]	18.64 ± 0.84[a]	7.61 ± 0.39[a]	6.11 ± 0.43[a]	51.11 ± 4.12[a]	307.42 ± 7.31[a]
S- M+ P+ (Gg)	17.06 ± 0.48[b]	18.65 ± 1.44[a]	7.66 ± 0.45[a]	6.06 ± 0.28[a]	51.57 ± 4.24[a]	309.40 ± 6.48[a]
S- M+ P+ (Ri)	16.22 ± 0.33[b]	18.70 ± 0.87[a]	7.25 ± 0.42[a]	6.21 ± 0.57[a]	51.62 ± 4.1[a]	311.10 ± 7.24[a]
S- M- P+	17.03 ± 0.66[b]	19.76 ±1.46[a]	7.84 ± 0.37[a]	5.29 ± 0.61[a]	50.08 ± 3.82[a]	299.90 ± 6.75[b]

*Mean of three replicates ± SEM. aMeans within of each column followed by different letters are significantly different at $P < 0.05$ according to Duncan's Multiple Range Test. S- (No salinity), M- (No mycorrhiza), P- (No poultry manure), S+ (Plus salinity), M+ (Plus mycorrhiza), P+ (Plus poultry droppings), (Gg) – *Glomus geosporum*, (Ri) – *Rhizophagus irregularis*, 0.00 (means the plants were dead).

Measured physiological parameters of *C. maxima* and *T. occidentalis* such as leaf turgid weight (LTW), leaf relative water content (LRWC), salt tolerance index (STI) and vigor index (VI) were significantly reduced in saline soil treatments when compared to the control, while electrolyte leakage increased in saline soil treatments ($P \le 0.05$) (Table 6 and 7). Amelioration of the saline soil with poultry manure alone also enhanced the physiological parameters of *C. maxima* and *T. occidentalis*. Inoculation with AMF alone or together with poultry manure amelioration significantly increased performance of the physiological parameters in the two test plants both in saline and non-saline soil treatments during the first and second cropping seasons ($P \le 0.05$) (Table 6 and 7).

LTW, LRWC, STI and VI were all significantly higher in AMF inoculated and poultry manure ameliorated *C. maxima* plants grown in non-saline soil ($P \le 0.05$) (Table 6 and 7).

Table 6. Effects of arbuscular mycorrhizal fungi (AMF) on the physiological parameters of *C. maxima* grown in saline soil ameliorated with poultry manure.

Treatments	Leaf Turgid Weight (LTW) [g]	Leaf Relative Water Content (LRWC) [%]	Salt Tolerance Index [STI]	Vigour Index (VI) [%]	Electrolyte Leakage (EL) [dS.m^{-1}]
S- M- P-	*0.67 ± 0.06[b]	38.00 ± 2.51[c]	1.00 ± 0.01[a]	7481.00 ± 7.04[h]	0.81 ± 0.24[c]
S+ M- P-	0.00 ± 0.00[d]	0.00 ± 0.00[d]	0.00 ± 0.00[d]	0.00 ± 0.00[l]	0.00 ± 0.00[d]
S+ M+ P- (Gg)	0.26 ± 0.11[c]	36.00 ± 1.24[c]	0.36 ± 0.08[c]	1,303.00 ± 6.06[i]	2.22 ± 0.67[a]
S+ M+ P- (Ri)	0.23 ± 0.20[c]	36.36 ± 1.66[c]	0.29 ± 0.06[c]	956.00 ± 8.13[j]	2.31 ± 0.38[a]
S+ M- P+	0.21 ± 0.09[c]	30.00 ± 1.02[c]	0.28 ± 0.12[c]	856.00 ± 4.90[k]	2.52 ± 0.44[a]
S+ M+ P+ (Gg)	0.68 ± 0.12 [b]	44.78 ± 2.42[b]	0.71 ± 0.33[b]	8,037.00 ± 9.02[f]	1.66 ± 0.14[b]
S+ M+ P+ (Ri)	0.69 ± 0.34 [b]	42.65 ± 1.57[b]	0.71 ± 0.24[b]	7,897.00 ± 8.37[g]	1.51 ± 0.16[b]
S- M+ P- (Gg)	0.70 ± 0.30[b]	44.93 ± 3.10[b]	1.04 ± 0.67[a]	9,465.00 ± 9.53[c]	0.72 ± 0.20[c]
S- M+ P- (Ri)	0.69 ± 0.27[b]	45.59 ± 1.67[b]	1.03 ± 0.75[a]	8,378.00 ± 8.86[d]	0.91 ± 0.48[c]
S- M+ P+ (Gg)	0.74 ± 0.61[b]	45.21 ± 2.01[b]	1.06 ± 0.54[a]	10,088.00 ± 10.75[b]	0.85 ± 0.44[c]
S- M+ P+ (Ri)	0.93 ± 0.84[a]	51.09 ± 3.44[a]	1.14 ± 0.68[a]	10,583.00 ± 12.15[a]	0.67 ± 0.28[c]
S- M- P+	0.68 ± 0.22[b]	44.78 ± 1.97[b]	1.01 ± 0.24[a]	8,099.00 ± 7.14[e]	0.83 ± 0.41[c]

*Mean of three replicates ± SEM. aMeans within of each column followed by different letters are significantly different at $P < 0.05$ according to Duncan's Multiple Range Test. S- (No salinity), M- (No mycorrhiza), P- (No poultry manure), S+ (Plus salinity), M+ (Plus mycorrhiza), P+ (Plus poultry droppings), (Gg) – *Glomus geosporum*, (Ri) – *Rhizophagus irregularis*, 0.00 (means the plants were dead).

Table 7. Effects of arbuscular mycorrhizal fungi (AMF) on the physiological parameters of *T. occidentalis* grown in saline soil ameliorated with poultry manure.

Treatments	Leaf Turgid Weight (LTW) [g]	Leaf Relative Water Content (LRWC) [%]	Salt Tolerance Index [STI]	Vigour Index (VI) [%]	Electrolyte Leakage (EL) [dS.m^{-1}]
S- M- P-	*0.89 ± 0.51[a]	56.58 ± 3.11[b]	1.00 ± 0.01[c]	11,984.00 ±3.68[f]	0.51 ± 0.24[c]
S+ M- P-	0.51 ± 0.20[c]	37.78 ± 1.05[d]	0.28 ± 0.08[g]	662.00 ± 3.80[k]	2.06 ± 0.97[a]
S+ M+ P- (Gg)	0.66 ± 0.32[b]	49.09 ± 1.57[c]	0.48 ± 0.10[f]	8,784.00 ± 2.09[i]	1.91 ± 0.11[b]
S+ M+ P- (Ri)	0.71 ± 0.55[b]	47.37 ± 1.22[c]	0.50 ± 0.25[f]	9,265.00 ± 6.00[h]	1.76 ± 0.21[b]
S+ M- P+	0.63 ± 0.19[b]	52.73 ± 1.67[b]	0.61 ± 0.33[e]	8,265.00 ± 4.33[j]	2.01 ± 0.40[a]
S+ M+ P+ (Gg)	0.83 ± 0.22[a]	57.75 ± 2.15[b]	0.88 ± 0.51[d]	10,602.00 ± 7.09[g]	1.27 ± 0.22[b]
S+ M+ P+ (Ri)	0.85 ± 0.46[a]	60.27± 1.97[a]	1.02 ± 0.66[c]	12,169.00 ± 2.64[e]	1.14 ± 0.31[b]
S- M+ P- (Gg)	0.88 ± 0.75[a]	63.38 ± 2.28[a]	1.21 ± 0.58[b]	13,248.00 ± 4.64[h]	0.47 ± 0.26[c]
S- M+ P- (Ri)	0.91 ± 0.69[a]	66.67± 2.11[a]	1.23 ± 0.64[b]	13,665.00 ± 1.95[c]	0.49 ± 0.34[c]
S- M+ P+ (Gg)	0.95 ± 0.56[a]	68.49 ± 3.15[a]	1.37 ± 0.69[a]	13,901.00 ± 2.84[b]	0.52 ± 0.58[c]
S- M+ P+ (Ri)	0.99 ± 0.87[a]	70.67 ± 3.47[a]	1.40 ± 0.81[a]	14,183.00 ± 8.28[a]	0.48 ± 0.61[c]
S- M- P+	0.89 ± 0.61[a]	57.89 ± 2.30[b]	1.07 ± 0.55[c]	12,201.00 ± 7.38[l]	0.53 ± 0.42[c]

*Mean of three replicates ± SEM. [a]Means within of each column followed by different letters are significantly different at $P < 0.05$ according to Duncan's Multiple Range Test. S- (No salinity), M- (No mycorrhiza), P- (No poultry manure), S+ (Plus salinity), M+ (Plus mycorrhiza), P+ (Plus poultry droppings), (Gg) – *Glomus geosporum*, (Ri) – *Rhizophagus irregularis*, 0.00 (means the plants were dead).

EL was however, highest in sole poultry manure ameliorated saline soil treatments. A similar trend was observed in *T. occidentalis*, except for EL which was highest in pure saline soil non-fertilized with poultry manure and uninoculated with AMF in the first cropping (Table 6 and 7).

The symbiotic association of *G. geosporum*+manure poultry applied on *C. maxima* and *T. occidentalis* plants allows better leaf turgid weight (0.68 – 0.83 g, respectively), leaf relative water content (44.78 – 57.75 %, respectively), salt tolerance index (0.71 – 0.88, respectively), vigour index (8,037 – 10,602 %, respectively), and electrolyte leakage (1.66 – 1.27 ds.m^{-1}, respectively) underwater stress conditions; whose *T. occidentalis* plants are more tolerant to water salinity. Also, the highest value of leaf turgid weight (0.69 – 0.85 g, respectively), leaf relative water content (42.65 – 60.27 %, respectively), salt tolerance index (0.71 – 1.02, respectively), vigour index (7,897 – 12,169 %, respectively), and electrolyte leakage (1.51 – 1.14 ds.m^{-1}, respectively) was obtained when the *C. maxima* and *T. occidentalis* plants are treated with *R. irregularis*+manure poultry under water stress conditions; whose *T. occidentalis* plants are more tolerant to water salinity (Table 6 and 7).

Foliar Na^+ accumulation in of *C. maxima* and *T. occidentalis* had corresponding significant reduction on some physiological parameters such as leaf turgid weight (LTW), leaf relative water content (LRWC), salt tolerance index (STI), vigour index (VI) and Electrolyte leakage (EL) of *C. maxima* and *T. occidentalis* ($P \leq 0.05$) (Fig. 2 and 3). Amelioration with poultry manure showed some improvements in these physiological parameters in the two test plants. Inoculation of *C. maxima* and *T. occidentalis* with AMF in non-saline soil treatments showed significant increase in physiological parameters when compared to the control and saline treatments ($P \leq 0.05$) (Fig. 2 and 3). LTW, LRWC, STI, VI and EL were improved when the plants were treated with *G. geosporum*+manure poultry and *R. irregularis*+manure poultry underwater stress conditions. We can conclude that these treatments enhanced the studied parameters of *T. occidentalis* in water stress conditions (Fig. 2 and 3).

Physiological parameters of *C. maxima* and *T. occidentalis* such as leaf turgid weight (LTW), leaf relative water content (LRWC), vigour index (VI) and salt tolerance index (STI) were significantly reduced by salinity, while electrolyte leakage (EL) was higher in saline soil treatments than non-saline soil treatments. However, inoculation of *C. maxima* and *T. occidentalis* with AMF (*R. irregularis* and *G. geosporum*) in conjunction with poultry manure amendment significantly increased their leaf turgid weight

(LTW), leaf relative water content (LRWC), vigor index (VI) and salt tolerance index (STI) in both saline and non-saline soil treatments above single treatment with mycorrhizal species and poultry manure ($P \leq 0.05$). However, electrolyte leakage (EL) reduced with mycorrhizal inoculation.

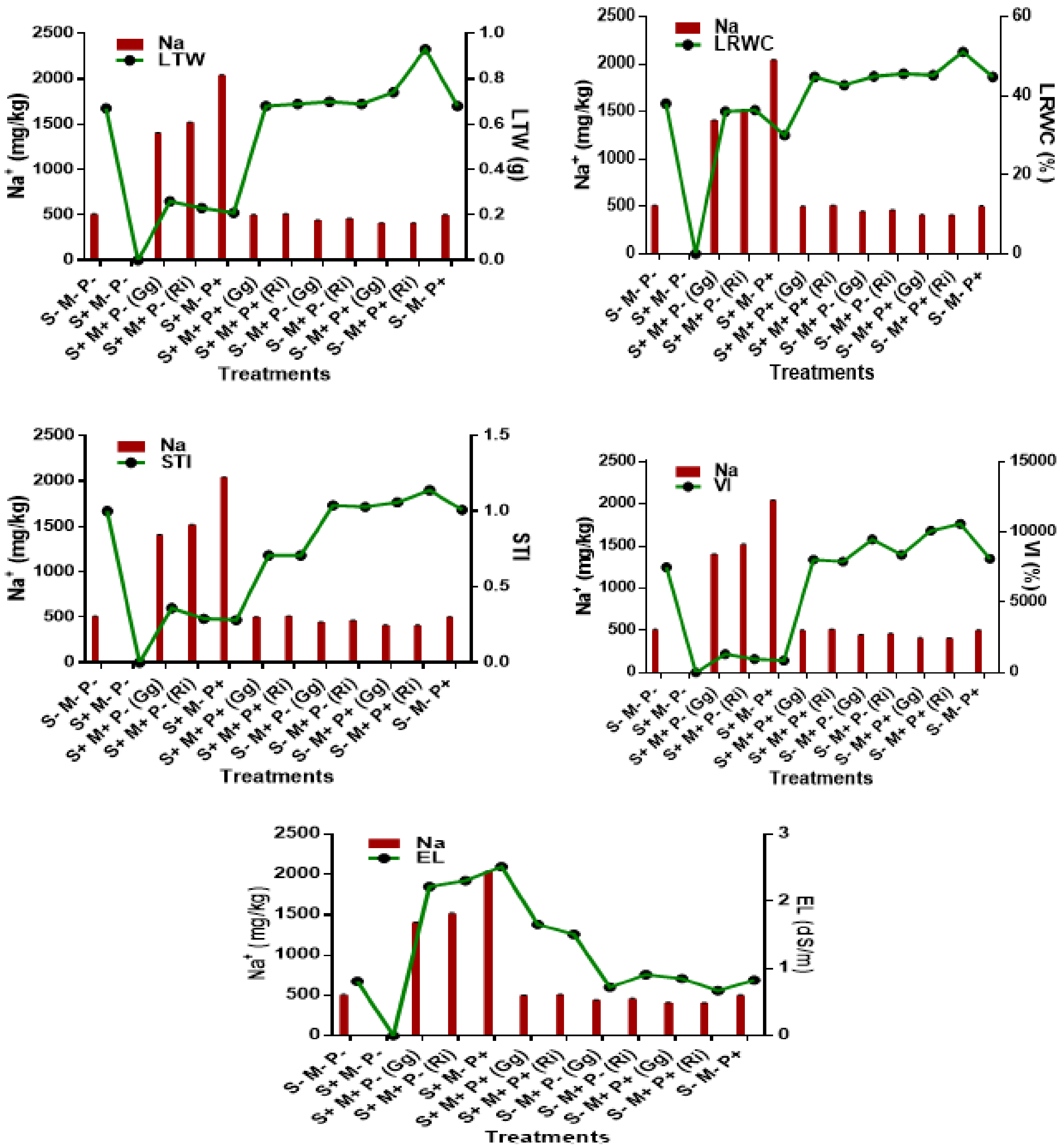

Fig. 2. Comparative assessment of the influence of foliar Na^+ accumulation on leaf turgid weight, leaf relative water content, salt tolerance index, vigour index and electrolyte leakage of *C. maxima*.

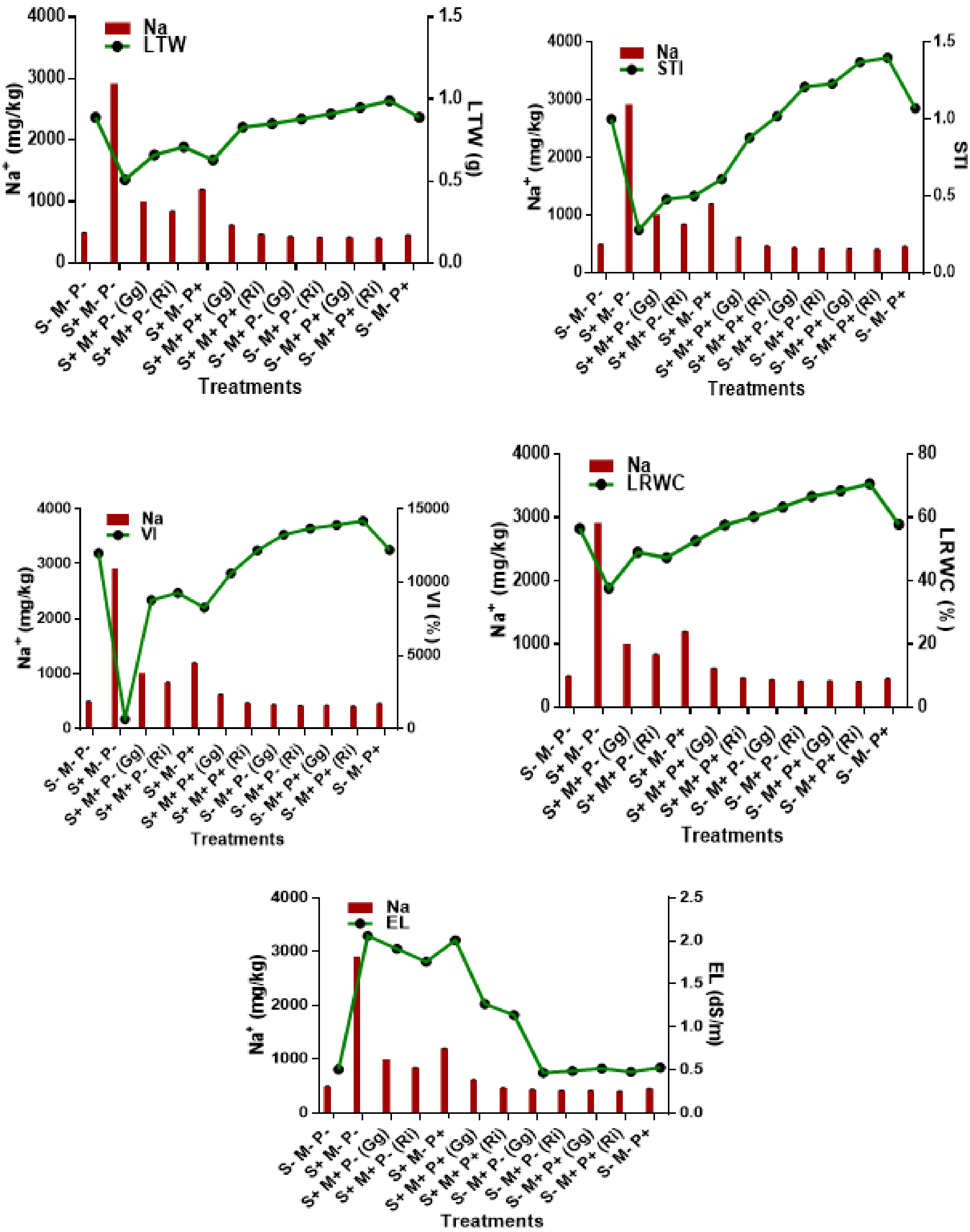

Fig. 3. Comparative assessment of the influence of foliar Na^+ accumulation on leaf turgid weight, leaf relative water content, salt tolerance index, vigour index and electrolyte leakage of *T. occidentalis*.

The increasing of the studied parameters in the cucurbit plants with application of arbuscular mycorrhizal fungi and poultry manure could be attributed to two processes: (i) through increased nutrient transport found in the poultry manure through the arbuscular mycorrhizal fungi and (ii) direct connection between cucurbits plant and mycorrhizal hyphal network. Arbuscular mycorrhizal fungi and poultry manure application are widely claimed to be able to aid plants under soil salinity conditions. Cyril *et al.* (2014), and Adebisi and Adewole (2019) showed that organic manures particularly poultry manure, mixed with arbuscular mycorrhizal fungi had positive effects in increasing red amaranth yield and improving crop quality under saline conditions. Abusuwar (2018) reported that the arbuscular mycorrhizal fungi coupled with poultry manure enhanced leaf area, number of leaves per plant, plant height, fresh and dry biomass, yield and nutritive value of forage crops grown in saline soils and irrigated with saline water. Mickan *et al.* (2016) poultry manure applied to the agricultural soils with the presence of AM fungi stimulated growth of extra-radical hyphae in soil and increased mycorrhizal colonization of roots. Based on the understanding of these interactions, it has been claimed that AM fungi can be more important to plant growth and yield than poultry manure (Mickan *et al.* 2016; Solaiman *et al.* 2019, 2020; Zhang *et al.* 2020).

Over the last couple of decades, the universal symbiosis between arbuscular mycorrhizal fungi and cucurbits is such an old tie that, perhaps, enabled the establishment of plants in land (Rouphael *et al.* 2015; Chen *et al.* 2017) by boosting photosynthesis, plant growth, nutrient acquisition and decreasing membrane leakage and reactive oxygen species under condition of salinity stress (Cavagnaro *et al.* 2015; Liu *et al.* 2016; Sofy *et al.* 2021a). This symbiosis had been reported 400 million years ago (Selosse *et al.* 2015). Several research studies have reported the efficiency of AM fungi to impart growth and yield enhancement in plants under salinity stress (Abdel Latef and Chaoxing 2014; Talaat and Shawky 2014). Wang *et al.* (2018) have noted considerable improvement in fresh and dry biomass, and N concentration of root and shoot due to mycorrhizal inoculation under saline conditions. Chen *et al.* (2017) revealed that the stem diameter, plant height, dry weight, root to shoot ratio of cucumber seedlings inoculated with *Glomus* sp., and *Rhizophagus* sp. were improved greatly compared with the non-inoculated control. The same authors showed that *Glomus* sp., and *Rhizophagus* sp. increase the nutrient concentration, net photosynthetic rate, chlorophyll content, root activity, light saturated rate of the CO_2 assimilation, maximum carboxylation rate and maximum ribulose-1,5-bis-phosphate regeneration rate. Moreover, arbuscular mycorrhizal fungi can significantly improve plant nutrient uptake and resistance to several abiotic stress factors particularity salinity stress (Sun *et al.* 2018; Begum *et al.* 2019). Liu *et al.* (2016) documented that the AM fungi inoculation could effectively enhance the cucumber growth and other cucurbit crops, which is closely associated with the secondary metabolism in plants. Notably, Yang *et al.* (2014) and He *et al.* (2017) showed a positive stimulatory effect of *Glomus* spp., and *Rhizophagus* spp. on peanut and tomato in terms of photosynthetic characteristics, growth and hormone status. Yadav *et al.* (2013) found that the inoculation of *Gloriosa superba* with *Glomus* sp. can interact synergistically and maximize benefits, resulting in root length, higher leaf area and colchicine content. It is widely believed that arbuscular mycorrhizal fungi have been considered as an alternative to inorganic fertilizers in the near future (Ortas 2012), which is probably why AM fungi enhanced plant tolerance to abiotic factors (Plassard and Dell 2010). Qiu *et al.* (2019) documented that the soil application of arbuscular mycorrhizal fungi could improve the chemical and biological properties of soil and enhance their nutrient levels and enzymatic activities. A prominent role of such AM fungi application is to transfer nutrients, (organic carbon in the form of sugars and lipids) (Jiang *et al.* 2017; Luginbuehl *et al.* 2017). Amiri *et al.* (2017) revealed that AM fungi-*Pelargonium graveolens* symbiosis increased the concentrations of N, P, and Fe under drought stress. Gomez-Bellot *et al.* (2015) reported the levels of P, Ca, and K in *Euonymus japonica* have been enhanced under salinity stress due to instant AM fungi attachment. In addition, AM fungi application improved P and N contents in plant tissues of *Chrysanthemum morifolium* (Wang *et al.* 2018) and increased seedling biomass by enhancing intercellular CO_2, P, and N contents and water content in *Leymus chinensis* (Jixiang *et al.* 2017). Furthermore, Hashem *et al.* (2018) documented that the synthesis of jasmonic acid, salicylic acid, and several important inorganic nutrients and the total concentrations of P, Ca^{2+}, N,

Mg^{2+}, and K^+ were higher in the arbuscular mycorrhizal fungi-treated *Cucumis sativus* plants compared with those in the un-inoculated plants under salt stress conditions. Ali and Hassan (2014) reported that under salt stress because of inadequate water uptake, RWC was significantly decreased in relation to salinity in chamomile herb. Shou-Jun *et al.* (2014) also reported that under no saline condition, leaf relative turgidities in non-mycorrhizal and mycorrhizal plants remained at comparatively steady-state level from 53.75 % to 54.56 % throughout the experiment. Mycorrhizal inoculation led to relatively higher leaf turgidity compared to non-mycorrhizal plants in this study. The phenomenon is ascribed to improved hydraulic conductivity of plants with a longer root and an altered root system morphology induced by AM fungi (Shou-Jun *et al.* 2014). Sheng *et al.* (2008) reported that plants inoculated with AMF maintain relatively higher water content compared with uninoculated plants. Inoculation with AMF often results in increased nutrient uptake, accumulation of an osmo-regulator, an increase in photosynthetic rate and water use efficiency, suggesting that salt stress alleviation by AMF results from a combination of nutritional, biochemical and physiological effects (Evelin *et al.* 2009). Sofy *et al.* (2021a) proved that the combination of arbuscular mycorrhizal and organic amendment is the most effective in decreasing the damaging impacts of salt on spinach plants by increasing the up-regulation of antioxidants, morphological and physiological parameters (shoot and root length, fresh and dry biomass, membrane stability index, relative water content, mineral contents, chlorophyll content, total soluble protein content and endogenous phytohormones (auxin, abscisic acid, gibberellins, salicylic acid and jasmonic acid)) and decreasing membrane leakage and reactive oxygen species. Mumtaz *et al.* (2013) reported that electrolyte leakage was enhanced with increasing salinity levels as compared to the control in salt sensitive cucumber plants as compared to the salt tolerant cultivar. This observation has been reported by other investigators in cucumber (Kaya *et al*. 2001), rice (Lutts *et al*. 1996), tomato (Atilla 2014) and sugar beet (Ghoulam *et al*. 2002). Agha *et al.* (2021) and Sofy *et al.* (2021b) documented that the bacteria combination was the most efficient in reducing the harmful effects of salt on soybean and pea plants by boosting antioxidant up-regulation and lowering membrane leakage and reactive oxygen species.

A major effect of environmental stress (i.e., salt, drought) on plant is membrane modification, which results in cell membrane perturbed function or total dysfunction. Changes in membrane leakage and injury can be measured by the extent of EL (Electrolyte Leakage) in tissues (Atilla 2014). The positive effects of AM fungi inoculation may result in improving integrity, vigour and stability of the membrane since the membrane permeability has been found to be reduced by AM fungi inoculation. Plants inoculated with AMF have been shown to maintain a lower electrolyte concentration than the non-mycorrhizal ones and hence maintain membrane stability (Garg and Manchanda 2008; Ali and Hassan 2014).

Poultry manure has been widely used as fertilizers for centuries. This manure contains not only the basic nutrients required by crops, but also trace elements. It is rich in mineral elements, essential nutrients N, P, and K, and other nutrients that can stimulate microbial activity and healthy plants, ameliorate seed germination, increase vegetative traits, reduce the negative impact of salinity, increase the percent root colonization of arbuscular mycorrhizal fungi, improve the physical and chemical properties of the soil (structure, texture, porosity, etc.), maintain the balance of soil nutrient, improve nutrient absorption, increase root vitality, increase fertilizer retention, enhance yields, and participate in the addition of organic matter to organically-deficient soils (Mufwanzala and Dikinya 2010; Revell *et al.* 2012; Awad 2016; Pandian *et al.* 2016; Sikder *et al.* 2019; Sistani *et al.* 2019; Solaiman *et al.* 2020; Zhang *et al.* 2020; Sallam *et al.* 2021). Hirzel *et al.* (2018) showed that the highest values of available P and exchangeable K, S, Ca and Mg were obtained using poultry manure in saline soil, whereas pH and salinity (electrical conductivity) reported the lowest values. Adeleye *et al.* (2010) documented that poultry manure application enhanced soil physico-chemical properties by decreasing soil bulk density and temperature, and increasing exchangeable Ca, Mg, K, total porosity, soil moisture retention capacity, total N, soil organic matter, available P and lowered exchange acidity under salinity conditions.

Conclusion

Soil salinity is one of the most severe abiotic stresses affecting plant establishment, growth and production worldwide as observed in this study. Results of this study revealed that salt stress negatively affected physicochemical properties of the saline soil when compared to the garden soil, thus resulting in negative effects on growth parameters, proximate composition and physiological parameters of *C. maxima* and *T. occidentalis*. The effects of mycorrhizal symbiotic association on *C. maxima* and *T. occidentalis* showed improvements on the growth of the test plants. Using different mechanisms *C. maxima* and *T. occidentalis* by itself or in association with arbuscular mycorrhizal fungi and poultry manure can tolerate or survive soil salinity. However, in the presence of the fungi, plant ability to resist the stress increases as a result of morphological and physiological changes and improved vigour, extensive network of the mycorrhizal plant roots and enhanced nutrient uptake are all among the processes that made the mycorrhizal inoculated plants to survive under salt stress. *T. occidentalis* showed better salt tolerance indices on individual parameters and overall salt tolerance index. Given the importance of these strategies, arbuscular mycorrhizal fungi/poultry manure application has important implications under pot experiments. Hence, field and greenhouse trials aimed at understanding the effectiveness, efficiency and durability of these strategies are suggested for future studies.

Conflict of Interest

The authors declare that they have no conflict of interest.

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