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Mitigating Impact of Soil Salinization on Growth, Yield and Fruit Nutritional Quality of *Abelmoschus esculentus* L. (Okra) Using Arbuscular Mycorrhiza Fungus (*Glomus clarum*)

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ABSTRACT: Soil salinity is a severe environmental stress that limits crop growth and productivity. Mycorrhizal fungi association has the potential to minimize environmental stress like soil salinization in some plant species. Hence, an experiment was conducted to examine the potential of an Arbuscular mycorrhiza (AM), *Glomus clarum*, to reduce salt stress in *Abelmoschus esculentus* L. (okra). Seedlings of *A. esculentus* were raised in perforated plastic pots filled with 3 kg top soil; treated with 0 (control), 35, 70, 140, 280 or 560 mM NaCl solution; and grouped into two. Each pot in the first group was inoculated with 20 g of AM spawn while pots in the second group were not inoculated with the mycorrhizal fungus. The experiment was laid out in a completely randomized design with each treatment replicated 5 times. Growth parameters in plants without AM including plant height, stem girth, leaf area and number of leaves decreased significantly with increasing salt concentration compared to the control. Salinity also reduced the growth parameters in plants with AM but did not differ significantly from the control. Fresh and dry weight of plant parts, total biomass, number of fruits, fruit fresh and dry weights as well as leaf total chlorophyll were reduced by salinity, but significant differences were recorded only in plants without inoculation with AM. Salinity with or without AM did not significantly affect fruit nutritional and proximate composition of *A. esculentusn* except Na^+ that increased with increasing soil salinity. Inoculation of saline sites with arbuscular mycorrhizal fungus, *Glomus clarum*, could serve as a sustainable and environmentally safe treatment to enhance salinity tolerance in okra for improved productivity.

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Salt accumulation in the soil is a threat facing crop production worldwide (Nasim, 2010). Soil salinity is one of the most severe environmental stresses that limit crop yield and productivity; and it has been estimated that more than 6% of the total land area of the world is affected by salinity (Munns and Tester, 2008). Salinity is a serious land degradation problem and is increasing steadily in many parts of the world, particularly in arid and semi-arid areas (Giri, 2003). It has been reported that 7% of the global land surface is exposed to high soil salinity levels and according to some estimates, 77 million hectares of irrigated land have been severely affected by salinity, markedly reducing the agricultural potential of 5% of the world's land (Munns *et al.,* 1999). Semi-arid and arid areas around the globe are most affected by soil salinity, with consequent reductions in crop productivity (Giri *et al.,* 2003). It is expected that with global warming, the salinity problem will spread further to affect half of the world's cultivated areas (Gamalero *et al.,* 2009). According to some estimation, increased salt accumulation of arable land will result in 30% land loss within the next 25 years, and up to 50% within the next 40 years (Porcel *et al.,* 2012). It is not only plants that are affected by salinity; populations of soil microorganisms can be damaged and soil properties can also be negatively and severely affected (Gamalero *et al.,* 2009). Soil salinity is characterized by an excessive accumulation of salt ions, namely Na^+, K^+, Mg^{2+},Ca^{2+}, Cl^- and NO_3^- (Meybodi and Ghareyazi, 2002). A number of factors are responsible for this problem, including irrigation using groundwater with a high salt content, excessive application of fertilizers and high evaporation rates due to rising temperatures (Juniper and Abbott, 1993). Accumulating salt beyond certain critical levels can cause many physiological and biological problems to plants (Taiz and Zeiger, 2006). For example, salt stress can cause changes in the photosynthetic rate (Lovelock and Ball, 2002). Salinity can affect plant growth through the production of ethylene (Shibli *et al.,* 2007). It can also lower quality and productivity of plants (Cerda *et al.,* 1990). Leaf area and diameter can be significantly reduced under salinity stress (Sumer

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et al., 2004). Salinity may affect plants indirectly by increasing the alkalinity of the soil, making it harder for plants to absorb nutrients (Pankhurst *et al.,* 2001). There has been a growing interest in identifying new plants that can cope with salinity, and at the same time be suitable as new crop plants for human and animal consumption (Gallagher, 1985). Another approach is to breed existing crop plants specifically to develop varieties that can withstand salt stress (Guartero and Fernandez-Munoz, 1999). Genetic engineering has also taken on an important role in overcoming salinity by designing plants with genes that enable adaptation to high salinity conditions (Wei-Feng *et al.,* 2008). Also, several mechanical methods had been adopted to combat the setback of soil salinity. These include using chemicals to leach excessive salts from soil, and the use of desalination machines to remove salts from irrigation water (Muralev *et al.,* 1997). However, conventional methods for reducing soil salinity are expensive, and most farmers cannot afford the financial burden especially in the developing countries like Nigeria (Cantrell and Linderman, 2001). Arbuscular mycorrhiza (AM) fungi are present in many saline environments where they help plants to conquer salinity stress (Aliasgharzadeh *et al*., 2001). Different researches have shown that AM fungi can support plants in overcoming salinity stress (Rabie, 2005). One of the mechanisms by which these fungi assist plants is by increasing nutrient absorption (Asghari *et al*., 2005). AM fungi live symbiotically with the roots of 80% of terrestrial plants (Smith and Read, 1997) and are able to increase plant growth and crop productivity under salt stress (Barea *et al*., 2013). AM fungi help to maintain a balanced K^+/Na^+ ion concentration inside the plant tissues, which is important for protection under salinity stress (Giri *et al*., 2003). Additionally, higher chlorophyll content in the leaves of mycorrhizal plants can give protection against the side effects of salinity (Giri and Mukerji, 2004). Furthermore, AM fungi enhance the synthesis of the amino acid, proline, which helps in maintaining osmotic balance during stress (Delauney and Verna, 1993). AM fungi also benefit plants by stimulating the production of growth regulating substances, increasing photosynthesis, improving osmotic adjustment under salinity stress and increasing resistance to pest and soil borne diseases (Al-karaki, 2006). Therefore, the aim of this study was to investigate the effect of AM fungus (*Glomus clarum)* on growth and yield performance of *A. esculentus* under salinity stress.

MATERIALS AND METHOD

Experimental Location: This experiment was carried out at the screen house of Plant Science and Biotechnology Department, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria (latitude $7^0 37^i$N and longitude $5^0$44E).

Planting Material: Viable seeds of *A. esculentus* were obtained from the Agricultural Development Agency (ADP) office, Oka-Akoko, Ondo State, Nigeria.

Source of Soil for Planting: Top soil used for the experiment was collected from the experimental farm of Plant Science and Biotechnology Department, Adekunle Ajasin University, Akungba Akoko. The soil physicochemical properties had earlier been determined (Kekere *et al*., 2019).

Source of Sodium Chloride: Sodium chloride (NaCl) salt was obtained from the laboratory of Plant science and Biotechnology Department, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria.

Source of Mycorrhiza Fungus (Glomus clarum): This was obtained from the Agronomy Department, University of Ibadan, Oyo State. Nigeria.

Experimental Set-up: Seedlings of *A. esculentus* were raised in perforated plastic pots filled with 3 kg top soil; treated with 0 (control), 35, 70, 140, 280 or 560 mM NaCl solution; and grouped into two. Each pot in the first group was inoculated with 20 g of *Glomus clarum* spawn while pots in the second group were not inoculated with the mycorrhizal fungus. The experiment was laid out in a completely randomized design with each treatment replicated 5 times. Salinity treatment began by 35 mM increments until the highest level was reached to avoid osmotic shock. Each pot received 250 ml of the salt solution twice/week for 8 weeks till fruit maturity. Salt build-up in the soil was avoided by saturating the pots with tap water and allowed to drain once per week.

Data Measurement and Plant Analyses: Plant height was measured from the stem base to the apical bud using meter rule while stem girth was measured using a digital Vernier caliper (model 0-200 mm) at the 5 cm point from the base of the stem. The leaves were counted and leaf area determined by Eze (1965) method. The relative growth was calculated using the formula: In mass2-In mass1/Time (days) where mass1= total biomass at the commencement of the experiment, mass 2= total biomass at the end of the experiment, and time = the period interval between the two biomass determinations in days. Fresh and dry mass of plant parts were measured.

The leaf total chlorophyll content was determined using Arnon (1949) method and calculated using the formula: Total chlorophyll= [(20.2 × D645) + (8.02 ×

D665)] × [50/1000] × [100/5] × ½ where D645= absorbance of the extract at 645 wave length (nm), 663= absorbance of the extract at 663 wave length (nm). Dried fruit samples were digested using 10 ml of 20% sulphuric acid. Na^+ and K^+ were analyzed by flame photometry while Mg^{2+} and Ca^{2+} were determined by EDTA titration (AOAC, 1990). The proximate composition was also assayed using the standard laboratory procedures by AOAC (1990). Data were subjected to One-way ANOVA and means were separated with Tukey HSD test at 95% level of probability using SPSS 24.0 version.

RESULTS AND DISCUSSION

Salinity caused reduction in the growth of *A. esculentus* in terms of plant height, number of leaves, leaf area and stem girth (Tables 1 and 2). Generally, plants grown in saline soil without arbuscullar mycorrhiza fungus (AM) were more affected than those with it. For example, when compared with the control, reduction in leaf area by salinity was not significant in plants with AM except 560 mM NaCl concentration (Table 1) while it was significant at both 280 mM and 560 mM concentrations when AM was not applied (Table 2). Likewise, the non-significant reduction in stem girth due to salt stress with AM inoculation was significant at 140-280 Mm NaCl concentrations when AM was not added to the soil (Table 1). In the same vein, the relative growth rate of the plant was significantly reduced by salinity (Figure 1). In other words, the growth rate of plants subjected to salt-stressed soil inoculated with *Glomus clarum* was higher than those grown without it.

Table 1: Growth parameters of *Abelmoschus esculentus* (okra) grown in saline soil inoculated with arbuscular mycorrhizal fungus, *Glomus clarum*

Growth parameter	Salinity (mM NaCl)					
	0	35	70	140	280	560
Plant height (cm)	74.24^{a}	67.48^{a}	61.62^{a}	54.62^{ab}	49.64^{ab}	48.62^{ab}
Number of leaves/plant	7.80^{a}	7.00^{a}	6.70^{a}	6.40^{a}	6.60^{a}	6.80^{a}
Leaf area (cm^2)	192.1^{a}	182.60^{a}	167.20^{a}	158.90^{a}	181.70^{a}	132.50^{b}
Stem girth (cm)	9.60^{ab}	8.80^{ab}	8.20^{ab}	8.20^{ab}	8.20^{ab}	6.80^{a}

Each value is a mean ± standard error of five replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at P ≥ 0.05 (Tukey HSD test).

Table 2: Growth parameters of *Abelmoschus esculentus* (okra) grown in saline soil without inoculation with arbuscular mycorrhizal fungus, *Glomus clarum*

	Salinity (mM NaCl)					
Growth parameter	**0**	**35**	**70**	**140**	**280**	**560**
Plant height (cm)	65.96^{a}	63.06^{a}	50.32^{a}	51.26^{a}	44.06^{ab}	31.54^{b}
Number of leaves/plant	7.20^{a}	7.80^{a}	7.00^{a}	6.40^{a}	6.00^{a}	6.20^{a}
Leaf area (cm^2)	180.30^{a}	175.80a	165.20^{ab}	164.50^{ab}	150.80^{b}	134.60^{b}
Stem girth (cm)	8.80^{a}	8.20^{a}	8.60^{a}	6.80^{b}	6.80^{b}	$6.40b^{b}$

Each value is a mean ± standard error of five replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at P ≥ 0.05 (Tukey HSD test).

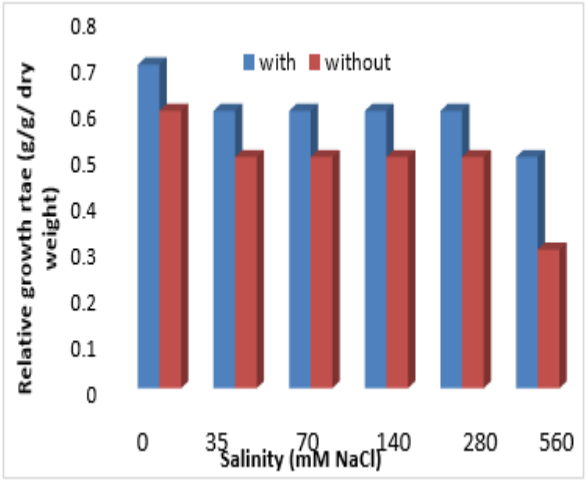

Fig 1: Relative growth rate of *Abelmoschus esculentus* (okra) grown in saline soil with or without inoculation with arbuscular mycorrhizal fungus, *Glomus clarum*. Each bar is a mean of five replicates.

The reduction in plant height, number of leaves per plant, stem girth and growth rate by salinity stress concurs with that of Sumer *et al.* (2004) who stated that plant growth in terms of leaf area and leaf diameter can be significantly reduced under salinity stress. Growth reduction in this study can be due to physiological disorder. Shibli *et al.* (2007) confirmed that salinity can affect plant growth through production of ethylene, a growth regulating hormone. Pankhurst *et al.* (2001) reported that salinity may affect plants indirectly by increasing the alkalinity of the soil, making it harder for plants to absorb nutrients.

Many studies have proven that salinity can reduce plant growth through several mechanisms including damage of enzymes and plasma membranes (Hasegawa *et al.,* 2000). This fact can be corroborated by the report that plants growing in saline soil are subjected to distinct physiological stresses: the toxic

effect of specific ions such as sodium and chloride prevalent in saline soils; disruption of the structure of enzymes and other macromolecules; damage to cell organelles; disruption of photosynthesis and respiration; inhibition of protein synthesis; and inducement of ion deficiencies (Juniper and Abbott, 1993). The insignificant reduction in growth parameters of plants grown in salt-stressed soil inoculated with AM fungus observed in this research did not differ from an earlier report that AM can help plants overcome salinity stress (Rabie, 2005) and that AM could enhance the ability of plants to cope with salt stress (Jahromi *et al*., 2008) by improving mineral nutrient absorption (Cantrell and Linderman, 2001), maintaining ion balance (Giri *et al*. 2007), protecting enzyme activities, and facilitating water uptake (Colla *et al.,* 2008). Bolandnazar *et al*. (2007) found that AM fungi can help plants to survive and grow under different environmental conditions, and also help plants increase their reproductive output. This result reveals the efficacy of the arbuscular mycorrhizal fungus, *Glomus clarum*, in mitigating the negative effect of soil salinity to the okra plant.

Reduction in root dry mass that was significant at 280-560 mM NaCl in the presence of AM (Table 3) became significant at 140-560 mM concentrations in its absence (Table 4). Also, shoot dry mass reduction by salinity with AM in the soil was significant at 280-560 mM NaCl (Table 3) while significant differences were recorded between 35 and 560 mM NaCl concentrations in the absence of AM (Table 4). Similarly, total biomass was reduced by sanity significantly at 280-560 mM concentration when AM was added to the soil (Table 3), but when the mycorrhiza was not added, significant reduction was obtained at concentrations of 70-560 mM (Table 4). This confirms the fact that salinity is a severe environmental stress that adversely affects crop growth and biomass yield. Decrease in the values of biomass by salinity agrees with that of Pitman and Lauchli (2002) who revealed that soil salinity inhibits the photosynthetic ability of plants, resulting in decrease in plant growth and biomass accumulation. Also, decreased plant biomass, leaf area, and growth of different vegetable crops under salt stress have earlier been confirmed (Zribi *et al.* 2009). Results of negative impact of soil salinity on *A. esculentus* dry mass of plant parts and total biomass by addition of mycorrizal fungus is consistent with an earlier one by Yano-Melo *et al.* (2003). They stated that inoculation of banana plants with AM fungus (*G. clarum*) resulted in higher salt tolerance and greater biomass and leaf area than the non-mycorrhizal controls. It was also found that using mycorrhizal inoculant for neem tree (*Azadirachta indica*) over a range of different salinity levels increased dry matter biomass compared with non-mycorrhizal controls (Pande and Tarafdar, 2002).

Table 3: Dry mass and root/shoot ratio of *Abelmoschus esculentus* (okra) grown in saline soil inoculated with arbuscular mycorrhizal fungus, *Glomus clarum*

Dry matter	Salinity (mM NaCl)					
	0	**35**	**70**	**140**	**280**	**560**
Root dry mass (g)	26.73^{a}	23.88^{a}	20.94^{a}	19.18^{ab}	12.53^{b}	12.52^{b}
Shoot dry mass (g)	115.84^{a}	105.47^{ab}	110.54^{ab}	110.54^{ab}	97.26^{b}	97.02^{b}
Total biomass (g)	142.57^{bc}	139.79^{a}	129.61^{b}	131.48^{b}	109.35^{b}	108.57^{bc}
Root/shoot ratio	0.230^{a}	0.2264^{b}	0.1894^{b}	0.1735^{b}	0.1288^{b}	0.1290^{b}

Each value is a mean ± standard error of five replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at P ≥ 0.05 (Tukey HSD test).

Table 4: Dry mass and root/shoot ratio of *Abelmoschus esculentus* (okra) grown in saline soil without inoculation with arbuscular mycorrhizal fungus, *Glomus clarum*

Dry matter	Salinity (mM NaCl)					
	0	**35**	**70**	**140**	**280**	**560**
Root dry mass (g)	25.83^{a}	16.28^{ab}	10.54^{b}	11.28^{b}	9.62^{b}	7.82^{b}
Shoot dry mass (g)	102.67^{a}	$98.92a^{b}$	65.04^{b}	60.63^{b}	57.36^{b}	42.58^{b}
Total biomass (g)	128.67^{a}	115.20^{a}	74.58^{b}	69.91^{b}	67.98^{b}	49.40^{c}
Root/shoot ratio	0.2516^{a}	0.1646^{b}	0.1621^{b}	0.186^{b}	0.1677^{b}	0.1837^{b}

Each value is a mean ± standard error of five replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at P ≥ 0.05 (Tukey HSD test).

The leaves total chlorophyll content of the plant was significantly reduced by salinity (Figure 2). The figure shows that the total chlorophyll content of plants grown in salt-stressed soil inoculated with *Glomus clarum* was higher than those grown without it. This concurs with that obtained by Tsang and Maun (1999) that addition of mycorrhiza to wild bean (*Strophostyles helvola* L.) increased the chlorophyll content and the amount of water in the plant, which in turn, made it more resistant to salinity. Feng *et al.* (2002) likewise found that inoculating maize (*Zea mays* L.*)* plants under saline conditions with a mycorrhizal fungus, *G. mosseae*, resulted in higher chlorophyll content, more soluble sugars and higher electrolyte concentration in the roots, which helped the plant to overcome salt stress (Feng *et al*., 2002).

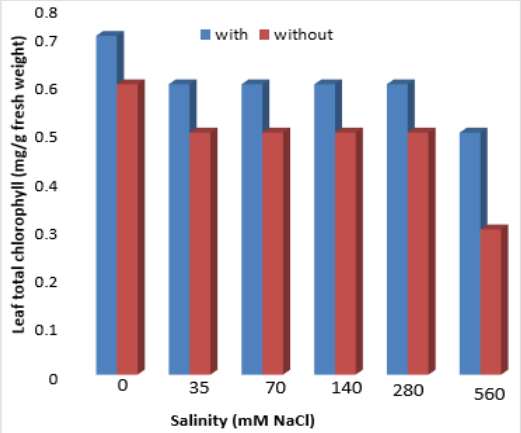

Fig 2: Leaf total chlorophyll content of *Abelmoschus esculentus* (okra) grown in saline soil with or without inoculation with arbuscular mycorrhizal fungus, *Glomus clarum*. Each bar is a mean of five replicates.

Murkute *et al.* (2010) likewise observed that increasing salinity can decrease chlorophyll concentrations in the plant due to deficiency in particular enzymes that produce photosynthetic pigments, leading to a reduction of carbohydrate supply and the size of the plant (Murkute *et al*., 2010).

It was also found that higher chlorophyll content in the leaves of mycorrhizal plants can give protection against the side effects of salinity (Giri and Mukerji, 2004). Furthermore, plant yield declined under soil salinity; when AM was applied to the soil, no significant differences were obtained between the control and plants exposed to soil salinity in number fruits as well as fresh and dry weight of fruits (Table 5). However, a significant reduction was obtained at 560 mM NaCl fruit fresh and dry weight in plants with AM inoculation (Table 6). However, salinity caused loss in yield compared with the control even when mycorrhiza fungus (*Glomus clarum*) was added to the soil. This is in agreement with a previous study by Evelin *et al.* (2000) who pointed out that soil salinity affects the establishment, growth and development of plants leading to huge losses in productivity (Evelin *et al*., 2009). Reduction in crop yield by salinity in this study is similar to what was recorded on pepper grass (*Lepidium latifolium*) in which seed yield was reduced by 29% at the high salinity site (Leininger and Foin, 2009). Another study on sunflower revealed reduced seed yield under salinity stress above 4 dS/m, and the reduction of oil concentration inside the seeds was the main reason (Francois, 1996).

Table 5: Yield parameters of *Abelmoschus esculentus* (okra) grown in saline soil inoculated with arbuscular mycorrhizal fungus, *Glomus clarum*

	Salinity (mM NaCl)					
Yield parameter/plant	**0**	**35**	**70**	**140**	**280**	**560**
Number of fruits	23.70^{a}	16.67^{a}	17.61^{a}	18.00^{a}	19.24^{a}	18.00^{a}
Fruit fresh weight	16.69^{a}	14.06^{a}	11.07^{a}	8.59^{a}	8.19^{a}	11.05^{a}
Fruit dry weight	2.00^{a}	1.56^{a}	1.86^{a}	1.09^{a}	1.62^{a}	1.41^{a}

Each value is a mean ± standard error of five replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at P ≥ 0.05 (Tukey HSD test).

Table 6: Yield parameters of *Abelmoschus esculentus* (okra) grown in saline soil without inoculation with arbuscular mycorrhizal fungus, *Glomus clarum*

	Salinity (mM NaCl)					
Yield parameter/plant	**0**	**35**	**70**	**140**	**280**	**560**
Number of fruits	24.50^{b}	13.50^{ab}	14.76^{ab}	16.50^{ab}	16.80^{ab}	12.50^{a}
Fruit fresh weight (g)	19.27^{b}	15.04^{ab}	13.70^{ab}	14.90^{ab}	13.00^{ab}	13.08^{a}
Fruit dry weight (g)	3.29^{b}	2.08^{ab}	1.83^{ab}	2.33^{ab}	1.56^{a}	1.19^{a}

Each value is a mean ± standard error of five replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at P ≥ 0.05 (Tukey HSD test).

Mitigation of the effects of salinity on crop yield by mycorrhizal inoculation might be due to the indirect effect of microorganisms whereby the mycorrhizal fungus and phosphorus soluble microorganisms act in the direction of the dietary requirements of plant nutrients such as nitrogen, phosphorus and potassium, and it improves the growth and yield of crops (Sharpley *et al.,* 2015). Soil salinity generally did not have significant impact on the fruit nutrition and proximate composition of *A. esculentus* in comparison with the control even when AM was added to the soil (Tables 7 and 8). Increased Na^{+} in the fruits of okra as obtained in this study corroborates the fact that chloride ions in soil irrigation solution are absorbed by plants and stored in plant tissues particularly the storage organs (Grieve and Suarez, 1997) which is the fruit in this case. However, the insignificant effect of salinity on plant nutrient obtained in this research is in contrast with an earlier finding that percentage ash, lipid, fibre and protein increased in *Portulaca oleracea* across salt treatment levels in comparison with the control. It was found that mycorrhizal roots of salt grass plant (*Distichis* spicata) had higher Na, K and P concentrations than non-mycorrhizal roots. Also, concentrations of Ca, Mg and Zn in onion plants inoculated with *Glomus fasiculatum* increased in saline conditions and improved the nutritional status (Ojala *et al.,* 1983). The improved growth and nutrient

acquisition (P and K) in tomato demonstrated the potential of AM fungi for protecting plants against salt stress in arid and semiarid areas (Al-Karaki and Hammad, 2001). Meanwhile, the variation observed in this research might be due to differences that exist among plant species in their responses to salinity stress and the underlying environmental conditions such as soil type.

Table7: Nutritional and proximate composition of fruits produced by okra grown in saline soil inoculated with arbuscular mycorrhizal fungus, *Glomus clarum*

Nutritional/Proximate composition	Salinity (mM NaCl)					
	0	**35**	**70**	**140**	**280**	**560**
N (%)	2.54[a]	2.56[a]	2.56[a]	2.55[a]	2.54[a]	2.49[a]
P (%)	0.18[a]	0.19[a]	0.19[a]	0.19[a]	0.18[a]	0.16[a]
K (%)	1.09[a]	1.10[a]	1.09[a]	1.09[a]	1.08[a]	1.08[a]
Ca (%)	0.91[a]	0.93[a]	0.93[a]	0.92[a]	0.91[a]	0.91[a]
Mg (%)	0.36[a]	0.37[a]	0.36[a]	0.36[a]	0.35[a]	0.34[a]
Na (%)	0.07[a]	1.05[b]	1.06[b]	1.07[b]	1.08[b]	1.16[b]
Ash (%)	9.01[a]	9.18[a]	9.18[a]	11.07[a]	11.11[a]	10.78[a]
Fibre (%)	18.89[a]	18.96[a]	18.93[a]	18.36[a]	18.95[a]	18.44[a]
Protein (%)	15.88[a]	15.90[a]	15.89[a]	15.89[a]	15.88[a]	15.88[a]
Lipid (%)	12.87[a]	12.98[a]	12.98[a]	12.07[a]	12.11[a]	11.78[a]
NFE (%)	56.05[a]	57.60[a]	56.98[a]	56.71[a]	56.48[a]	55.98[a]

Each value is a mean ± standard error of three replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at P ≥ 0.05 (Tukey HSD test).

Table 8: Nutritional and proximate composition of fruits produced by okra grown in saline soil without inoculation with arbuscular mycorrhizal fungus, *Glomus clarum*

Nutritional/Proximate composition	**Salinity (mM NaCl)**					
	0	**35**	**70**	**140**	**280**	**560**
N (%)	2.61[a]	2.47[a]	2.49[a]	2.55[a]	2.51[a]	2.53[a]
P (%)	0.19[a]	0.18[a]	0.17[a]	0.18[a]	0.17[a]	0.18[a]
K (%)	1.08[a]	1.08[a]	1.07[a]	1.06[a]	1.05[a]	1.06[a]
Ca (%)	0.88[a]	0.89[a]	0.87[a]	0.89[a]	0.88[a]	0.89[a]
Mg (%)	0.36[a]	0.35[a]	0.36[a]	0.34[a]	0.35[a]	0.33[a]
Na (%)	0.07[a]	1.06[a]	1.07[a]	1.08[a]	1.09[a]	1.08[a]
Ash (%)	8.76[a]	8.91[a]	9.03[a]	10.01[a]	9.98[a]	9.79[a]
Fibre (%)	20.03[a]	19.49[a]	18.01[a]	19.83[a]	18.45[a]	18.77[a]
Protein (%)	15.69[a]	15.44[a]	15.56[a]	15.14[a]	15.31[a]	15.02[a]
Lipid (%)	12.71[a]	11.78[a]	11.24[a]	10.87[a]	11.98[a]	12.04[a]
NFE (%)	45.51[a]	44.40[a]	44.16[a]	43.35[a]	43.28[a]	42.89[a]

Each value is a mean ± standard error of three replicates. For each value, means with the same letter(s) in superscript on the same row are not significantly different at P ≥ 0.05 (Tukey HSD test).

Conclusion: Addition of arbuscular mycorrhizal fungus, *Glomus clarum*, to soil could serve as a sustainable and environmentally safe treatment to enhance salinity tolerance in okra for improved productivity.

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