J. Agric. & Env. Sci. (Damanhour University) 2025, 24(1): 112 - 141
Print: ISSN 1687-1464 Online: ISSN 2735-5098

ALLEVIATING SALINITY STRESS ON DIFFERENT GENOTYPES OF MAIZE (*Zea mays* L.) USING MYCORRHIZAE FUNGI

Ebrahim Shehata*, Hesham Kishar, Elsayed Abdelraouf, Heba Salim

Department of Natural Resources and Agricultural Engineering, Faculty of Agriculture, Damanhour University, Damanhour, Egypt

***Corresponding author:** ebrahim.shehata@agr.dmu.edu.eg

https://doi.org/10.21608/jaesj.2025.343505.1224

ABSTRACT

This study aimed to evaluate the response of different maize (Zea mays L.) genotypes to salinity stress under mycorrhizae inoculation. The experiment was conducted in pots sand culture, where plants were irrigated with modified Hoagland nutrient solution. The main plot consisted of three maize genotypes: Pioneer SC.3444, Hitech 2066, and Agrofood 168, while the sub-plot factor comprised eight treatments: four salinity levels (0, 25, 50, and 75 mM NaCl) with mycorrhizae and four others without mycorrhizae. Four weeks after sowing, plants were harvested, and the salinity effects were evaluated. The results demonstrated a significant reduction in plant growth, germination, and physiological parameters across all genotypes due to salinity stress. In cross-genotype comparisons, Agrofood was the most promising genotype for saline conditions, particularly when combined with mycorrhizae inoculation, offering significant potential for improving maize productivity in salt-affected areas due to superior water retention and osmotic adjustment mechanisms. Pioneer SC.3444 showed moderate tolerance, while Hitech 2066 was most affected by

salinity. Mycorrhizae inoculation improved the highest salinity tolerance and increase fresh weight, dry weight, shoot length, and chlorophyll content. Mycorrhizae helped retain RWC under stress. The enhanced performance with mycorrhizae aligns with recent research demonstrating that arbuscular mycorrhizae fungi improve plant growth and stress tolerance through enhanced nutrient uptake, improved water relations, and modulation of plant hormonal balance. For saline soils, inoculation recommended, especially for resilient genotypes like Agrofood. These findings emphasize the importance of mycorrhizae fungi as a sustainable solution to mitigate salinity stress and enhance crop performance in adverse environments.

Keywords: Germination Parameters, maize, salinity stress, mycorrhizae.

INTRODUCTION

Salinity is a pervasive environmental stressor that significantly influences plant growth and development. It is estimated that over 20% of the world's cultivated land and nearly half of all irrigated lands are affected by salinity, which poses a serious threat to global food security (**Munns and Tester, 2008**). The detrimental effects of salinity are observed at various stages of plant development, from seed germination to maturity. Salinity primarily affects plants through two main mechanisms: osmotic stress and ion toxicity. Osmotic stress arises from high salt concentrations in the soil, which reduce the soil water potential, making it difficult for plants to absorb water. Ion toxicity occurs due to the excessive accumulation of sodium (Na^+) and chloride ($Cl^−$) ions within plant tissues, disrupting cellular homeostasis and enzyme activities (**Shrivastava and Kumar, 2015**).

These stresses lead to various physiological and biochemical changes in plants. Salinity stress significantly affects the germination of seeds, high salt concentrations in the soil create an osmotic barrier that inhibits water uptake, delaying germination and reducing the germination rate. Key germination parameters affected by salinity include the Coefficient of Velocity of Germination (CVG), Final Germination Percentage (FGP), Germination Index (GI), and Germination Time (GT). Arbuscular mycorrhizae have the capacity to increase seedling growth and germination by biosynthesizing and releasing hormones which stimulate root growth (**Li *et al.*, 2012; Han and Yang, 2015; Adeoyo *et al.*, 2019; Wang *et al.*, 2022**). Salinity stress negatively affects various growth parameters of plants, including root and shoot growth, leaf area, and biomass accumulation. Salinity reduces plant length due to impaired cell division and elongation (**Zhou *et al.*, 2024**) and decreases the number of leaves due to reduced leaf initiation and expansion (**Vennam *et al.*, 2024**). Additionally, salinity adversely affects root branching, limiting the root system's ability to absorb water and nutrients. Physiological parameters such as photosynthesis, water relations, nutrient uptake, and oxidative stress are also affected by salinity. High salt levels cause stomatal closure, reducing CO_2 uptake and limiting photosynthesis (**Xu *et al.*, 2016**).

Salinity can greatly impair the uptake of vital nutrients in plants, resulting in nutritional imbalances and shortages. High salt levels in soil or water present various obstacles to plant growth and nutrient absorption (**Marschner, 2011**). Salinity interferes with the uptake of essential nutrients, leading to nutrient imbalances and deficiencies (**Acosta-Motos *et al.*, 2017**). Salinity-induced oxidative stress generates ROS, damaging cellular membranes (**Munns and Tester, 2008**). Maize (*Zea mays* L.) is particularly sensitive to salinity, affecting its growth and productivity. Salinity stress impairs seed germination and early seedling growth, leading to poor stand establishment and weakened plant vigor (**Farooq *et al.*, 2015**).

Physiological stress caused by salinity leads to reduced photosynthetic efficiency and overall plant growth (**Gorham *et al.*, 2016**). Given the negative impacts of salinity on maize, several strategies have been proposed to mitigate these effects, including breeding for salinity tolerance, effective irrigation management, soil amendments, and the use of mycorrhizae, which enhance nutrient uptake and resistance to environmental stresses (**Hashem *et al.*, 2018**). This research study aims to determine the extent of the possibility of reducing the negative impact of salinity on maize genotypes through mycorrhizae inoculation.

MATERIALS AND METHODS

A pot experiment under field conditions was conducted in the Agriculture Faculty field experiments area (36R 255085 3436670). The experiment commenced in April 2023. A randomized complete block design (RCBD) in a split-plot arrangement with three replications was used. The main plot factor comprised three maize genotypes (Pioneer SC.3444, Hitech 2066, and Agrofood 168), while the sub-plot factor included eight treatments: four salinity levels (0, 25, 50, and 75 mM NaCl) with mycorrhizae (2 g/pot) and four others without mycorrhizae.

Arbuscular mycorrhizae fungi (AMF) (Glomus sp.) were obtained from the Agricultural Research Center (ARC), Giza Governorate, Egypt. Four seeds of each maize genotype were sown in pots (12 cm inside diameter and 14 cm depth with drainage holes at the bottom) containing 0.9 kg of sand soil with a size fraction between 0.25 and 1 mm, as described by **Abdelraouf (2017)**. Each pot was irrigated three times per week with 150 mL of irrigation solution. The irrigation solution contained one-tenth strength modified Hoagland and Arnon nutrient solution (**Hewitt, 1966**) and the tested salt levels (0, 25, 50, or 75 mM NaCl).

The number of plants per pot was reduced to two after germination. The experiment continued for four weeks from its beginning. The experiment compared mycorrhizae-inoculated plants to non-inoculated ones by assessing germination parameters, growth parameters, physiological parameters, and plant nutritional status. Starting from the beginning of the experiment and continuing until plant collection, germination parameters were monitored through daily observations.

Germination parameters as Coefficient of Velocity of Germination (CVG) (**Maguire, 1962**), Final Germination Percentage (FGP) (**Tanveer *et al.*, 2010**), Germination Index (GI) (**Scott *et al.*, 1984**), and germination time (GT) (**Irik and Bikmaz, 2024**). Growth parameters (Shoot length, Root length, and Leaf Area) (**Radford, 1967**). Physiological parameters as Relative Water Content (RWC) (**Silva *et al.*, 2010**). Total Chlorophyll was measured spectrophotometrically (**Wintermans and de-Mots, 1965**). Plant nutritional status through the analysis of nitrogen (N) (**Bremner, 1965**), phosphorus (P) (**Olsen and Sommers, 1982**), potassium (K) and sodium (Na) (**Chapman and Pratt, 1961**). The Infection rate of arbuscular Mycorrhizae fungi calculated as reported by (**Muta *et al.*, 2022**). The results were statistically assessed by LSD at a 5% significance level calculated using Costat software (version 6.4).

RESULTS AND DISCUSSION

Germination parameters

For Pioneer, the Coefficient of Velocity of Germination (CVG) without mycorrhizae (Pio -) declines gradually from around 0.17 at 0 mM NaCl to approximately 0.15 at 75 mM NaCl. With mycorrhizae inoculation (Pio +), the CVG values are slightly higher, ranging from about 0.19 at 0 mM NaCl to 0.17 at 75 mM NaCl, indicating that mycorrhizae support nutrient uptake and osmotic balance under salinity stress. Notably, at 25 mM NaCl, Pioneer with mycorrhizae shows the highest CVG (approximately 0.21) compared to other genotypes at this level of salinity, Fig (1). This is attributed to the synergistic effect of mycorrhizae fungi enhancing phosphorus availability, ionic balance, and osmotic regulation under moderate stress, coupled with the genotype's physiological adaptability. The moderate stress at 25 mM NaCl may have triggered adaptive mechanisms, such as improved root development and accumulation of osmolytes, further supported by mycorrhizae symbiosis (**Evelin *et al.*, 2019**). In Hitech, CVG without mycorrhizae (Hit -) starts at approximately 0.17 at 0 mM NaCl and decreases to around 0.14 at 75 mM

NaCl, showing significant sensitivity to salinity. When inoculated with mycorrhizae (Hit +), Hitech shows improved resilience, with CVG ranging from about 0.19 at 0 mM NaCl to 0.13 at 75 mM NaCl, illustrating the benefits of mycorrhizae association in mitigating salinity stress by enhancing nutrient uptake and osmotic stability.

For Agrofood, CVG without mycorrhizae (Agr -) remains relatively stable, starting around 0.19 at 0 mM NaCl and declining slightly to approximately 0.16 at 75 mM NaCl. With mycorrhizae (Agr +) support, CVG values are even more stable, from about 0.20 at 0 mM NaCl to 0.18 at 75 mM NaCl, highlighting both the genotype's natural tolerance to salinity and the additional resilience conferred by mycorrhizae inoculation. AMF inoculation can improve CVG under salt stress by increasing water and nutrient intake, particularly phosphorus, necessary for early seedling development. This results in faster and more coordinated germination. AMF reduces the osmotic and ionic stress-induced salinity, allowing seeds to absorb water more efficiently and begin the metabolic processes required for germination **(Evelin *et al.*, 2009).**

The current study confirms prior findings that Arbuscular mycorrhizae can improve seedling development and germination. Increase seedling growth and germination by producing and releasing hormones that encourage root growth **(Li *et al.*, 2012; Han and Yang, 2015; Adeoyo *et al.*, 2019; Wang *et al.*, 2022).**

J. Agric. & Env. Sci. (Damanhour University) **2025, 24(1): 112 - 141**
Print: ISSN 1687-1464 **Online: ISSN 2735-5098**

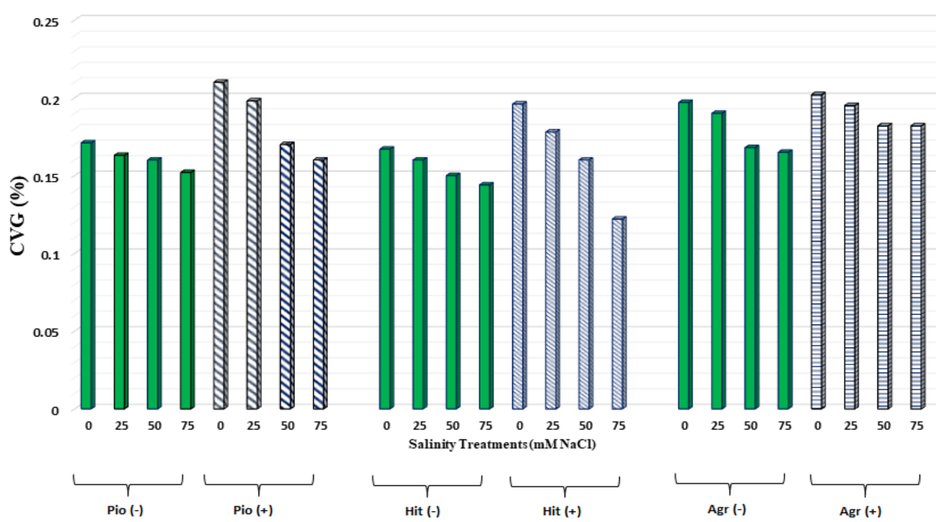

Figure (1): The Coefficient of Velocity of Germination (CVG) in different genotypes with or without mycorrhizae under salinity stress.

Pioneer genotype without mycorrhizae (Pio -) shows a steady decline in Germination Index (GI) from 1.0 at 0 salinity to 0.6 at 75 salinity (Fig. 2). With mycorrhizae (Pio +), it exhibits a dramatic increase in GI, peaking at 2.7 for 25 salinity, but then decreases to 0.7 at 75 salinity, still outperforming the non-mycorrhizae condition. Hitech genotype without mycorrhizae (Hit -) displays a gradual decrease from 1.0 to 0.7 as salinity increases. With mycorrhizae (Hit +), it shows improved GI values, maintaining around 1.2 up to 50 salinity before declining to 0.7 at 75 salinity. Agrofood genotype without mycorrhizae (Agr -) demonstrates the highest initial GI of 1.4 at 0 salinity, increasing to 1.5 at 25 salinity, and then declining to 0.8 at 75 salinity. With mycorrhizae (Agr +), it shows the most stable performance across all salinity levels, maintaining GI values between 2.2 and 1.5. Comparing genotypes, Agrofood exhibits the highest overall salinity tolerance, especially when inoculated with mycorrhizae, followed by Pioneer, while Hitech shows the least improvement with mycorrhizae inoculation.

J. Agric. & Env. Sci. (Damanhour University) 2025, 24(1): 112 - 141
Print: ISSN 1687-1464 Online: ISSN 2735-5098

AMF usually enhances the GI, indicating a higher germination rate and uniformity under salinity stress. This related to increased nutrient availability and stress reduction. AMF increases the availability of important minerals such as phosphorus and zinc, which are required for enzyme activity during germination **(Al-Karaki, 2006)**. The enhanced performance with mycorrhizae aligns with recent research demonstrating that arbuscular mycorrhizae fungi improve plant growth and stress tolerance through enhanced nutrient uptake, improved water relations, and modulation of plant hormonal balance **(Chen *et al.,* 2017; Evelin *et al.,* 2019).**

The superior performance of Agrofood suggests it may possess genetic traits for better osmotic adjustment and ion homeostasis under salt stress **(Yang and Guo, 2018)**. Recommendations include: prioritizing Agrofood for breeding programs aimed at salinity tolerance, investigating the specific mycorrhizae strains most effective for each genotype, and conducting field trials to validate these results under diverse environmental conditions. The current study verifies the previous finding that Arbuscular mycorrhizae can boost seedling development and germination. Increase seedling growth and germination by biosynthesizing and releasing hormones that stimulate root growth. In conclusion, Agrofood emerges as the most promising genotype for saline conditions, particularly when combined with mycorrhizae inoculation, offering significant potential for improving maize productivity in salt-affected areas. **(Li *et al.,* 2012; Han and Yang, 2015; Adeoyo *et al.,* 2019; Wang *et al.,* 2022).**

J. Agric. & Env. Sci. (Damanhour University) 2025, 24(1): 112 - 141
Print: ISSN 1687-1464 Online: ISSN 2735-5098

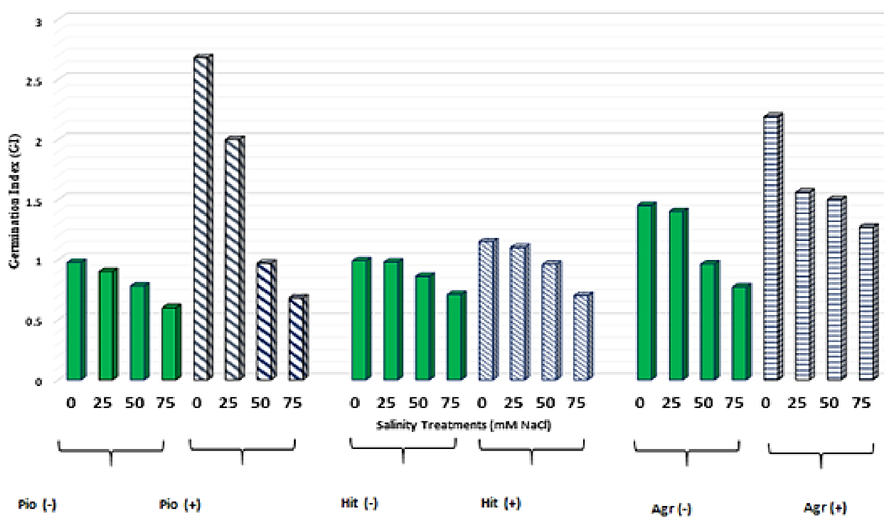

Figure (2): The Germination Index (GI) in different genotypes with or without mycorrhizae under salinity stress**.**

Figure (3) showed that the Pioneer demonstrated a notable response to mycorrhizal inoculation. Without mycorrhizae, the Final Germination Percentage (FGP) decreased from about 90% at 0 mM NaCl to 58% at 75 mM NaCl. This decline underscores how salinity negatively affects germination, likely due to osmotic stress and ion toxicity. However, with mycorrhizal associations, the FGP improved, ranging from 100% to 67%. This improvement highlights the role of mycorrhizae in enhancing nutrient uptake and maintaining plant vigor under saline conditions.

AMF frequently boosts FGP under salinity stress by counteracting the inhibitory effects of salt on seed germination. The fungi improve the plant's ability to withstand oxidative stress and preserve cellular balance. AMF lowers harmful ion accumulation (Na^+ and Cl^-) and enhances osmolyte production, such as proline, to protect cellular structures and enzymes **(Zuccarini and Okurowska, 2008)**. Mycorrhizae fungi play a critical role in improving plant resistance to salinity stress by facilitating nutrient uptake and enhancing root development **(Razvi *et al.,* 2023)**. Hitech exhibited an even sharper decline without mycorrhizae, with FGP dropping from 90% to 58%. This significant reduction indicates its sensitivity to salinity, which may be attributed to limited root development and nutrient uptake capacity under stress. Conversely, when paired with mycorrhizae, FGP started at 100% and decreased to 74%, confirming the buffering effect of mycorrhizae in mitigating the adverse impacts of salinity. This is supported by the findings of **Hashem *et al.,* (2016)** who noted that the presence of mycorrhizae could significantly buffer the negative effects of salt stress on plant germination and growth. In contrast, Agrofood emerged as the most tolerant genotype, with FGP decreasing moderately from 100% to 74% without mycorrhizae. This relatively small decline suggests inherent resilience to saline conditions, possibly due to physiological and biochemical adaptations. Notably, with mycorrhizae, it maintained high germination rates, ranging from 100% to 90%. This resilience reflects both the genotype's natural tolerance and the additional enhancement provided by mycorrhizae inoculation.

According to **Mardukhi *et al.,* (2011)**, Genetic variation in salt tolerance among maize genotypes can be enhanced by beneficial mycorrhizae associations, which improve water and nutrient uptake. Overall, mycorrhizae improve FGP across all tested genotypes, particularly in Pioneer and Hitech. Agrofood, in combination with mycorrhizae, is particularly recommended for optimal performance in saline soils, as it exhibits the highest salinity tolerance among the genotypes studied. The current research confirms the same result that arbuscular mycorrhizae have the capacity to increase seedling growth and germination. **(Li *et al.,* 2012; Han and Yang, 2015; Adeoyo *et al.,* 2019; Wang *et al.,* 2022).**

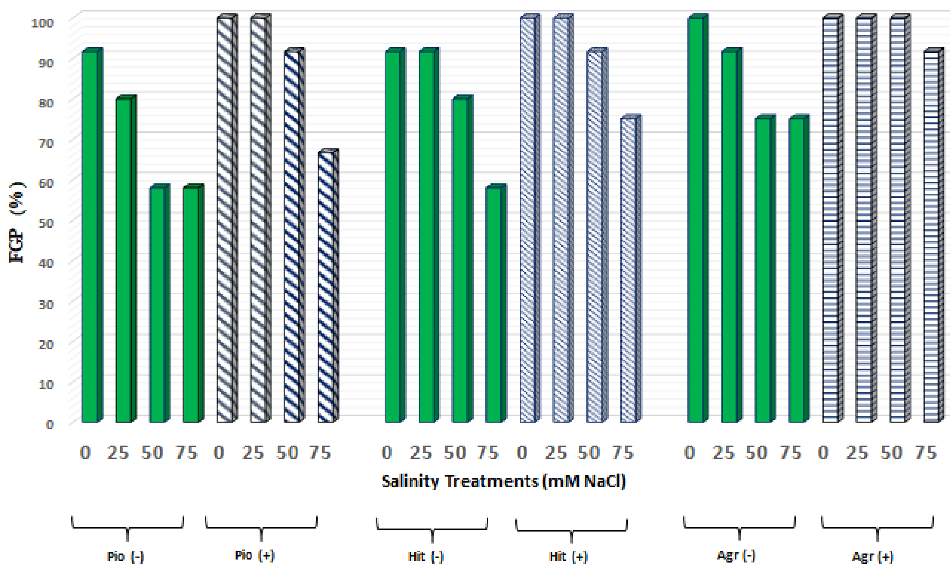

Figure (3): The Final Germination Percentage (FGP %) in different genotypes with or without mycorrhizae under salinity stress.

Pioneer showed a significant increase in germination time (GT) with rising salinity levels, especially under non-mycorrhizae conditions, but mycorrhizae inoculation helped reduce GT. AMF can reduce GT under saline stress by speeding up the metabolic processes necessary for germination. This accomplished by increased water absorption and nutrient mobilization. AMF improves the plant's ability to maintain turgor pressure and enzyme activity, which are necessary for breaking seed dormancy and commencing growth **(Porcel *et al.*, 2012)**. Hitech was highly sensitive, with GT spiking at 75 mM NaCl arrived in 8 days without mycorrhizae, yet mycorrhizae reduced GT across salinity levels, indicating improved ion balance and water absorption **(Hashem *et al.*, 2018; Zhu 2016).**

Agrofood showed moderate GT increases under salinity without mycorrhizae but remained stable with inoculation, reflecting resilience due to enhanced water and nutrient uptake **(Al-Karaki *et al.,* 2014; Shrivastava and Kumar, 2015)**. Across genotypes, Agrofood (Fig. 4) had the highest salinity tolerance, maintaining the lowest GT under stress with and without mycorrhizae, followed by Pioneer with moderate tolerance, while Hitech was most sensitive. These findings align with studies showing genetic and symbiotic adaptations that enhance stress resilience **(Evelin *et al.,* 2019; Saxena *et al.,* 2019)**. For saline soils, integrating mycorrhizae inoculation recommended, especially for resilient genotypes like Agrofood, to boost salinity tolerance **(Evelin *et al.,* 2019)**. Research results confirmed what scientists **(Li *et al.,* 2012; Han and Yang, 2015; Adeoyo *et al.,* 2019; Wang *et al.,* 2022)** had extended which shows that the increase in germination is due to the production of hormones by mycorrhizae.

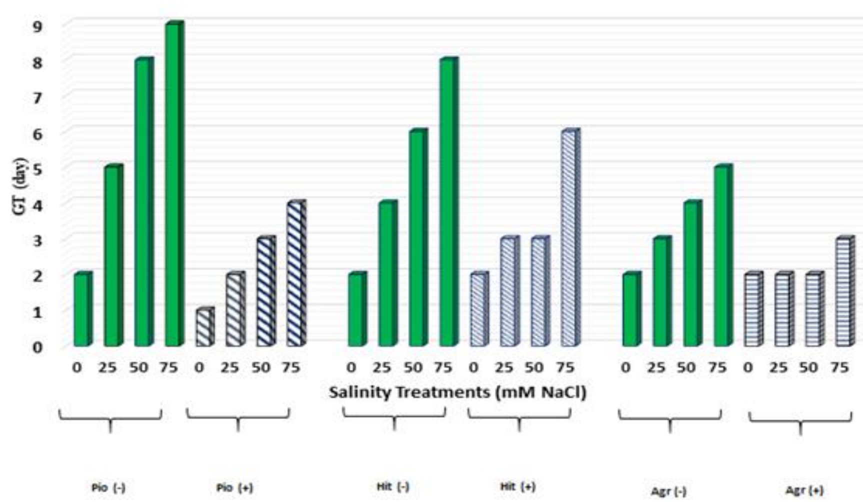

Figure (4): The Germination Time (GT) in different genotypes with or without mycorrhizae under salinity stress.

J. Agric. & Env. Sci. (Damanhour University) 2025, 24(1): 112 - 141
Print: ISSN 1687-1464 Online: ISSN 2735-5098

Vegetative characteristics

For Pioneer, without mycorrhizae, fresh weight decreased from 4.145 g to 2.1 g and dry weight from 1.26 g to 0.56 g at 75 mM salinity as presented in Table 1. It is also noted that there are no significant differences between these weights in mycorrhizae inoculation treatments. Hitech showed greater sensitivity, with fresh weight dropping from 4.622 g to 1.977 g and dry weight from 0.45 g to 0.089 g, but mycorrhizae increased fresh weight from 4.958 g to 2.85 g and dry weight from 0.597g to 0.191g.

Agrofood performed best, with fresh weight declining from 5.181 g to 2.963 g without mycorrhizae but improving from 6.476 g to 4.703 g with mycorrhizae. Dry weight improved similarly, showing the highest salinity tolerance, especially with mycorrhizae. **Zare-Maivan *et al.,* (2017)** showed that mycorrhizae plants had significantly higher dry and fresh weight than plants grown in sterilized soil. This shows a moderate improvement under mycorrhizae conditions, likely due to enhanced nutrient uptake **(Al-Karaki *et al.,* 2014).** Overall, mycorrhizae enhanced performance under salinity stress, with Agrofood showing the greatest resilience, likely due to superior water retention and osmotic adjustment mechanisms **(Shrivastava & Kumar, 2015).**

J. Agric. & Env. Sci. (Damanhour University) 2025, 24(1): 112 - 141
Print: ISSN 1687-1464 Online: ISSN 2735-5098

Table (1): The vegetative characteristics of the maize genotypes with or without mycorrhizae under different salinity levels.

Mycorrhizae	Salinity	Pioneer		Hitech		Agrofood	
		Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)
Without Mycorrhizae (-)	0	4.145^{cdef}	1.26^{a}	4.622^{bcd}	0.45^{fghi}	5.18^{b}	0.796^{cde}
	25	3.067^{efij}	0.6998^{cdef}	4.112^{cdefg}	0.225^{ghij}	4.01^{bcde}	0.612^{def}
	50	2.517^{ijkl}	0.51^{fgh}	4.10^{cdefg}	0.211^{hij}	3.9^{cdef}	0.541^{efg}
	75	2.1^{kl}	0.56^{efg}	1.977^{l}	0.089^{j}	2.963^{hijk}	0.25^{hij}
With Mycorrhizae (+)	0	4.197^{cdef}	1.21^{ab}	4.958^{bc}	0.597^{efg}	6.476^{a}	0.845^{cd}
	25	3.48167^{efgh}	0.98^{bc}	4.42^{cde}	0.46^{ghi}	4.291^{bcde}	0.597^{defg}
	50	2.727^{hijkl}	0.755^{ghi}	4.2^{cdef}	0.408^{fghi}	4.044^{defg}	0.429^{fghi}
	75	2.08^{kl}	0.443^{fghi}	2.85^{jkl}	0.19^{ij}	4.703^{bcd}	0.473^{fgh}

It was noted in Table (2) that the Pioneer experienced a notable decline in shoot length under salinity stress, dropping from 20.27 cm at 0 mM salinity without mycorrhizae to 11.8 cm at 75 mM. However, when treated with mycorrhizae, the reduction was less severe; with shoot length, decreasing from 20.78 cm to 12.77 cm. AMF promotes shoot growth in maize during salt stress by increasing nutrient uptake and water absorption. These results to improved osmotic adjustment and lower oxidative stress, which promotes shoot elongation. This highlights the potential of mycorrhizae in mitigating the effects of salinity stress **(Munns and Tester, 2008).**

Hitech exhibited a range of shoot lengths, from 25.6 cm at 0 mM salinity without mycorrhizae to 16.57 cm at 75 mM. When mycorrhizae were present, shoot length remained higher, at 26.5 cm at 0 mM and 17.8 cm at 75 mM. In terms of root length, Hitech performed exceptionally well but it is decreased with increasing soil salinity in the presence or absence of mycorrhizae, showing the highest root length of 34.95 cm at 0 mM and 18.75 cm at 75 mM without mycorrhizae, with root length consistently high when mycorrhizae were used (35.417 cm at 0 mM and 19.18 cm at 75 mM). Pioneer showed a decrease in root length from 21.58 cm to 18.4 cm without mycorrhizae, and from 29.25 cm to 19.7 cm with mycorrhizae. Agrofood maintained moderate root lengths, ranging from 27.7 cm to 23.7 cm without mycorrhizae, and from 29.58 cm to 26.5 cm with mycorrhizae. AMF greatly improves root growth under salinity stress by improving root architecture and increasing root surface area, resulting in greater nutrient and water intake.

Fungi help maintain ion homeostasis, lowering the harmful effects of Na^+ and Cl^- ions **(Zhu *et al.*, 2010)**. Regarding leaf area, Pioneer showed a sharp decrease, from 14.73 cm² at 0 mM to 5.66 cm² at 75 mM without mycorrhizae. With mycorrhizae, the leaf area ranged from 14.9 cm² to 2.86 cm². Hitech also demonstrated a reduction in leaf area, from 17.8 cm² at 0 mM to 8.01 cm² at 75 mM without mycorrhizae, and from 18.5 cm² to 6.25

J. Agric. & Env. Sci. (Damanhour University) 2025, 24(1): 112 - 141
Print: ISSN 1687-1464 Online: ISSN 2735-5098

cm² with mycorrhizae. Agrofood showed the best performance in leaf area, maintaining the highest values, from 15.65 cm² to 9.1 cm² without mycorrhizae, and from 19.45 cm² to 12.6 cm² with mycorrhizae. AMF enhances leaf area in maize under salt stress by improving photosynthetic efficiency and lowering harmful ion buildup in the leaves. This leads to improved carbon assimilation and overall plant growth **(Talaat and Shawky 2014).**

This indicates the plant's strong ability to maintain its photosynthetic capacity under salinity stress **(Porcel *et al.,* 2012)**. The Hitech variety is characterized by greater shoot and root length and leaf area than Pioneer and Agrofood. However, with increasing salt concentration, shoot and root length and leaf area decreased significantly. Overall, Agrofood proved to be the most adaptable, thriving under high salinity stress, especially when aided by mycorrhizae symbiosis. AMF reduces the negative effects of salt stress in maize by increasing shoot length, root length, and leaf area. These gains are mostly due to increased nutrient intake, improved water relations, and decreased oxidative stress.

Table (2): The shoot length (Sh.L), root length (R.L), and leaves area (L.A) of the maize genotypes with or without mycorrhizae under different salinity levels.

Mycorrhizae	Salinity	Pioneer			Hitech			Agrofood		
		Sh.L (cm)	R.L (cm)	L.A (cm^2)	Sh.L (cm)	R.L (cm)	L.A (cm^2)	Sh.L (cm)	R.L (cm)	L.A (cm^2)
Without Mycorrhizae (-)	0	20.2^{ab}	21.58^{d}	14.73^{b}	25.6^{b}	34.95^{a}	17.8^{ab}	21.42^{cd}	27.7^{b}	15.65^{c}
	25	14^{cde}	21.0^{d}	9.28^{d}	20.45^{de}	26.8^{cd}	15.1^{c}	20.68^{cd}	26.8^{bc}	12.42^{d}
	50	12.97^{de}	19.92^{de}	6.5^{e}	20.02^{e}	24.4^{de}	12.6^{e}	16.8^{efg}	25.5^{c}	8.89^{g}
	75	11.8^{e}	18.4^{e}	5.66^{e}	16.57^{de}	18.75^{fg}	8.01^{g}	16.78^{ef}	23.7^{d}	9.1^{f}
With Mycorrhizae (+)	0	20.78^{a}	29.25^{a}	14.9^{b}	26.5^{a}	35.42^{a}	18.5^{a}	24.02^{a}	29.58^{a}	19.45^{a}
	25	15.88^{c}	27.0^{b}	11.7^{c}	22.6^{cd}	29.4^{bc}	16.2^{b}	23.47^{ab}	29.28^{a}	18.4^{ab}
	50	13.78^{de}	26.52^{bc}	6.8^{e}	21^{de}	25.7^{cd}	12.7^{e}	17.6^{ef}	28.2^{ab}	11.18^{de}
	75	12.77^{de}	19.7^{de}	2.86^{f}	17.8^{fg}	19.18^{f}	6.25^{hi}	23.72^{ab}	26.5^{bc}	12.6^{d}

Total chlorophyll content and RWC

Pioneer without mycorrhizae showed decreasing chlorophyll content as salinity increased, with the lowest value at 75 mM NaCl (19.8 mg/g), but mycorrhizae increased chlorophyll content at each salinity level, reaching 26.29 mg/g at 0 mM NaCl as found in Table 3. **Zare-Maivan *et al.* (2017)** confirmed that mycorrhizae plants had chlorophyll content significantly higher than plants grown in sterilized soil. AMF has been proven to improve overall chlorophyll content in maize during salinity stress.

Salinity stress normally reduces chlorophyll content due to oxidative damage and poor nutrient uptake; however, AMF can counteract these effects via a variety of mechanisms **(Evelin *et al.,* 2019)**. Pioneer RWC was highest at 0 mM NaCl without mycorrhizae (94.79%), declining with salinity, though mycorrhizae helped retain RWC under stress, aligning with findings by **Moreira *et al.* (2020)**. Hitech also, exhibited declining chlorophyll content without mycorrhizae, reaching 18.23 mg/g at 75 mM NaCl, but mycorrhizae maintained higher chlorophyll contents, especially at moderate salinity, indicating enhanced salinity tolerance, consistent with the osmotic adjustments reported by **Sheng *et al*. (2008)**. Hitech RWC was highest at 0 mM NaCl without mycorrhizae (95.28%) and remained relatively stable with mycorrhizae under moderate salinity. Agrofood showed high baseline chlorophyll contents under all salinity levels without mycorrhizae (23.69 mg/g at 75 mM NaCl), suggesting inherent tolerance, which mycorrhizae further enhanced, and reaching 28.65 mg/g at 0 mM NaCl. However, its RWC values were lower at high salinity, suggesting limitations in water retention under extreme salinity stress **(Molazem *et al.,* 2011).** AMF has been demonstrated to increase the Relative Water Content (RWC) of maize plants under salinity stress. Salinity stress often causes osmotic stress, which limits plants' ability to absorb water, lowering RWC **(Porcel *et al.,* 2012).** In cross-genotype comparisons, Agrofood exhibited the highest natural chlorophyll content under salinity, while Pioneer and Hitech showed significant improvements in chlorophyll content and RWC

J. Agric. & Env. Sci. (Damanhour University) 2025, 24(1): 112 - 141
Print: ISSN 1687-1464 Online: ISSN 2735-5098

with mycorrhizae inoculation, likely due to enhanced nutrient uptake and osmotic stability **(Begum *et al.,* 2019)**.

Table (3): The total chlorophyll content (mg/g) and RWC (%) of the maize genotypes with or without mycorrhizae under different salinity levels.

Mycorrhizae	Salinity	Total Chlorophyll (mg/g)			RWC (%)		
		Pioneer	Hitech	Agrofood	Pioneer	Hitech	Agrofood
Without Mycorrhizae (-)	0	25.1^{bcde}	24.42^{bcde}	27.26^{abc}	94.79^{a}	95.28^{a}	92.8^{ab}
	25	24.1^{cdef}	22.75^{defg}	26.45^{abcd}	94.87^{a}	94.26^{a}	89.96^{bc}
	50	21^{fghi}	21.83^{efgh}	24.29^{cdef}	91.1^{ab}	93.23^{ab}	89.83^{bc}
	75	19.8^{hi}	18.23^{i}	23.69^{defg}	90.18^{b}	91.12^{b}	84.16^{d}
With Mycorrhizae (+)	0	26.29^{abcd}	26.62^{abcd}	28.65^{a}	95.78^{a}	97.14^{a}	91.18^{ab}
	25	24.81^{bcde}	25.15^{bcde}	27.9^{ab}	95.03^{a}	96.99^{a}	86.71^{cd}
	50	21.5^{defg}	24.57^{bcde}	26.43^{abcd}	92.92^{ab}	94.2^{ab}	88.13^{bc}
	75	20.5^{ghi}	22.68^{defg}	27.43^{abc}	92.61^{ab}	94.16^{ab}	91.95^{ab}

Nutrients content

The nutrients content (N, P & K) of three maize genotypes was showed in Table (4). Among the three maize genotypes, Agrofood showed the highest salinity tolerance, maintaining stable nitrogen (N), phosphorus (P), and potassium (K) levels, particularly with mycorrhizae inoculation, where N peaked at 7.9%, P at 2.79%, and K at 2.34 % under control conditions. Pioneer displayed moderate tolerance, with mycorrhizae improving nutrient retention, especially at 25–50 mM NaCl, where P and K levels remained relatively high. Hitech was the most sensitive genotype, with significant nutrient depletion under salinity stress but improved resilience when inoculated with mycorrhizae, particularly in N and K uptake.The nutritional content of maize under salt stress is significantly increased by AMF. Because it disrupts nutrient uptake, causes ion toxicity, and induces osmotic stress, salinity stress has a deleterious impact on plant growth. AMF can counteract these effects, though, by enhancing the plant's absorption of vital minerals like potassium (K), phosphorus (P), and nitrogen (N) **(Wahab *et al.,* 2023).**

J. Agric. & Env. Sci. (Damanhour University) 2025, 24(1): 112 - 141
Print: ISSN 1687-1464 Online: ISSN 2735-5098

Table (4): The nutrients content (N, P & K) of three maize genotypes with or without mycorrhizae under different salinity levels.

Mycorrhizae	Salinity treatments	Pioneer			Hitech			Agrofood		
		N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Without Mycorrhizae (-)	0	4.173ab	1.163bc	1.714c	4.463c	1.3bc	1.45de	6.53b	1.42bc	1.82cd
	25	2.83cd	0.81cd	1.071gh	3.86d	0.95c	0.37l	4.79c	1.07c	1.29g
	50	1.47e	0.553f	0.94 hi	2.37e	0.69cd	0.28mn	4.03cd	0.81cd	0.98h
	75	0.89f	0.18h	0.72k	1.67f	0.317d	0.13p	2.3e	0.437e	0.77i
With Mycorrhizae (+)	0	5.63a	2.53a	2.04a	6.05a	2.67a	2.03a	7.9a	2.79a	2.34a
	25	4.193ab	1.73 b	1.75c	4.787c	1.87b	1.49de	6.3b	1.99ab	1.98c
	50	2.997cd	1.09 bc	1.24f	3.57d	1.23bc	0.73 i	5.6bc	1.35bc	1.72d
	75	0.697fg	0.717d	0.91hi	1.67f	0.613cd	0.28mn	6b	1.77ab	1.96c

Overall, Agrofood emerged as the most salt-tolerant genotype and is highly recommended for cultivation in saline soils, particularly with mycorrhizae inoculation to maximize productivity. Hitech, given its high susceptibility to salinity, requires further improvement through breeding programs or agronomic interventions. By facilitating the plant's access to nitrogen in the soil, AMF can improve maize's uptake of nitrogen while it is under salt stress. Beyond the root zone, AMF hyphae provide the plant with access to nitrogen sources that it would not otherwise have **(Evelin *et al.* 2019).** AMFs are very effective at improving phosphorus uptake because they secrete organic acids and phosphatases that dissolve fixed phosphorus in the soil. AMF's vast hypha network also enables for investigation of a larger soil volume, resulting in increased phosphorus acquisition **(Porcel *et al.,* 2012).**

Salinity stress can cause potassium shortage due to competing with sodium (Na^+) ions. AMF improves potassium uptake by regulating ion transporters and decreasing sodium uptake, resulting in a balanced K^+/Na^+ ratio **(Abdel Latef and Chaoxing, 2014)**. These findings emphasize the importance of mycorrhizae fungi as a sustainable solution to mitigate salinity stress and enhance crop performance in adverse environments **(Diao *et al.,* 2021; Chandrasekaran, 2022)**. AMF inoculation enhances the nutrient content (N, P, and K) of maize under salt stress by increasing nutrient intake, maintaining ion homeostasis, and minimizing the negative impacts of salinity. This makes AMF an exciting option for sustainable agriculture in saline-affected soils.

The mycorrhizae infection rate

Figure (5) shows the effect of maize varieties under different concentrations of salinity on the rate of infection with mycorrhizae. Starting with Pioneer, the percentage of mycorrhizae inoculation was highest at 0 mM NaCl, around 60%, but it declined progressively with increasing salinity, reaching its lowest point at 75 mM NaCl. Hitech followed a similar pattern, although it maintained slightly higher mycorrhizae inoculation percentages at 25 mM NaCl compared to Pioneer. However, both genotypes exhibited a sharp decrease in inoculation rates at higher salinity levels, with the lowest at 75 mM NaCl. In contrast, Agrofood showed the highest mycorrhizae inoculation rates across all salinity treatments. Its inoculation percentage peaked at 0 and 25 mM NaCl, staying significantly higher than that of the other genotypes, even under the 75 mM NaCl treatment. This trend suggests that Agrofood is more resilient to salinity stress when inoculated with mycorrhizae, which aligns with studies indicating that mycorrhizae fungi enhance nutrient uptake and tolerance to stress **(Chandrasekaran, 2022).** The sharp decline in inoculation percentages for Pioneer and Hitech at higher salinity levels likely reflects their reduced physiological adaptation under stress; whereas Agrofood is superior, performance under salinity stress indicates its better tolerance.

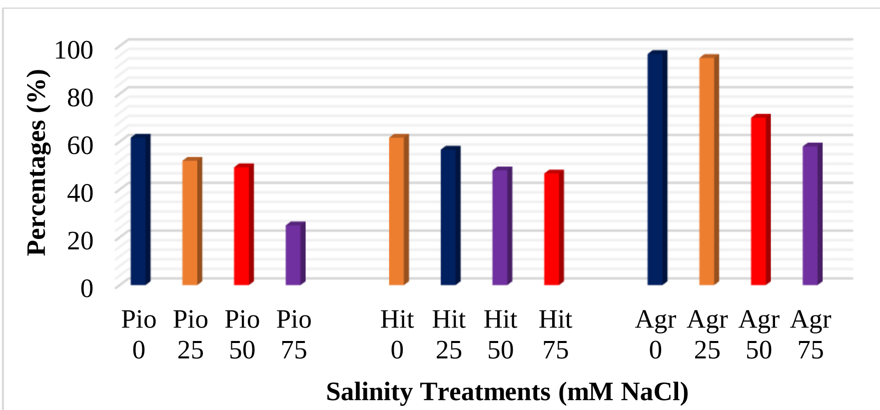

Figure (5) The Percentages of mycorrhizae inoculation in different genotypes under different salinity levels.

CONCLUSION

Agrofood emerges as the most salt-tolerant genotype among the three maize genotypes studied, followed by Hitech, with Pioneer showing the least tolerance. Mycorrhizal inoculation played a significant positive role across all genotypes, particularly in enhancing salt tolerance. The higher Growth Index (GI), improved Germination tolerance (GT), and better nutrient uptake (especially P and K) in mycorrhizae-inoculated plants under saline conditions evidence this. Mycorrhizae have the capacity to increase seedling growth and germination. Mycorrhizae symbiosis appears to have mitigated the negative effects of salt stress, likely through improved water relations, enhanced nutrient acquisition, and possibly through modulation of plant stress responses. For future research, it is recommended to: (1) Conduct detailed transcriptomic and metabolomic analyses of Agrofood to uncover the molecular mechanisms underlying its superior salt tolerance ; (2) Investigate the specific mycorrhizal strains most effective in enhancing salt tolerance in maize and optimize inoculation methods for field applications; (3) Explore the potential of combining mycorrhizal inoculation with other beneficial microorganisms or biostimulants to further enhance salt tolerance ; and (4) Assess the long-term effects of mycorrhizal inoculation on soil health, crop productivity, and sustainability in salt-affected agricultural systems.

REFERENCES

Abdel Latef, A.A.H., **Chaoxing, H**. (2014). Does inoculation with *Glomus mosseae* improve salt tolerance in pepper plants? *Journal of Plant Growth Regulation*, 33, 644-653.

Abdelraouf, E.A., **Elgarhy, A.M. (2017).** Response of different soybean (*Glycine max* L.) genotypes grown in sand culture to salinity stress. *Alexandria Science Exchange Journal*, 38(October-December), 810-818.

Acosta-Motos, J.R., **Ortuño, M.F.**, **Bernal-Vicente, A.**, **Diaz-Vivancos, P.**, **Sanchez-Blanco, M.J.**, **Hernandez, J.A. (2017).** Plant responses to salt stress: Adaptive mechanisms. *Agronomy*, 7(1), 18. https://doi.org/10.3390/agronomy7010018

Adeoyo, O.R., Pletschke, B.I., Dames, J.F. (2019). Molecular identification and antibacterial properties of an ericoid associated mycorrhizal fungus. *BMC Microbiology*, 19, 1-8.

Al-Karaki, G.N. (2006). Nursery inoculation of tomato with arbuscular mycorrhizal fungi and subsequent performance under irrigation with saline water. *Scientia Horticulturae*, 109(1), 1-7.

Al-Karaki, G.N., McMichael, B., Zak, J. (2014). Field performance of mycorrhizal barley and corn under water stress. *Agricultural Water Management*, 68(1), 49-58.

Begum, N., Qin, C., Ahanger, M. A., Raza, S., Khan, M. I., Ashraf, M., Zhang, L. (2019). Role of arbuscular mycorrhizal fungi in plant growth regulation: Implications in abiotic stress tolerance. *Frontiers in Plant Science*, 10, 1068.

Bremner, J.M. (1965). Total nitrogen. In C. A. Black (Ed.), *Methods of Soil Analysis: Part 2. Chemical and Microbiological Properties* (pp. 1149-1178). American Society of Agronomy.

Chandrasekaran, M. (2022). Arbuscular mycorrhizal fungi mediated enhanced biomass, root morphological traits and nutrient uptake under drought stress: A meta-analysis. *Journal of Fungi*, 8(7), 660.

Chapman, H.D., Pratt, P.F. (1961). Methods of analysis for soils, plants, and waters. *University of California, Division of Agricultural Sciences*.

Chen, J., Zhang, H., Zhang, X., Tang, M. (2017). Arbuscular mycorrhizal symbiosis alleviates salt stress in black locust through improved photosynthesis, water status, and K+/Na+ homeostasis. *Frontiers in Plant Science*, 8, 1739. https://doi.org/10.3389/fpls.2017.01739.

Diao, F., Dang, Z., Xu, J., Ding, S., Hao, B., Zhang, Z., Guo, W. (2021). Effect of arbuscular mycorrhizal symbiosis on ion homeostasis and salt tolerance-related gene expression in halophyte *Suaeda salsa* under salt treatments. *Microbiological Research*, 245, 126688.

Evelin, H., Devi, T.S., Gupta, S., Kapoor, R. (2019). Mitigation of salinity stress in plants by arbuscular mycorrhizae fungi: Current understanding and future directions. *Frontiers in Plant Science*, 10, 470. https://doi.org/10.3389/fpls.2019.00470.

Evelin, H., Devi, T.S., Gupta, S., Kapoor, R. (2019). Mitigation of salinity stress in plants by arbuscular mycorrhizal symbiosis: Current understanding and new challenges. *Frontiers in Plant Science*, 10, 470.

Evelin, H., Kapoor, R., Giri, B. (2009). Arbuscular mycorrhizal fungi in alleviation of salt stress: A review. *Annals of Botany*, 104(7), 1263-1280.

Farooq, M., Hussain, M., Wakeel, A., Siddique, K.H.M. (2015). Salt stress in maize: Effects, resistance mechanisms, and management. *Agronomy for Sustainable Development*, 35, 461-481. https://doi.org/10.1007/s13593-015-0287-0.

Gorham, J., Lauchli, A., Leidi, E.O. (2016). Plant responses to salinity stress. In C. K. Hasegawa (Ed.), *Environmental Plant Physiology* (pp. 93-122). CRC Press. https://doi.org/10.1201/b13684-6.

Han, C., Yang, P. (2015). Studies on the molecular mechanisms of seed germination. *Proteomics*, 15(10), 1671-1679.

Hashem, A., Abd_Allah, E.F., Alqarawi, A.A., Al-Huqail, A.A., Wirth, S., Egamberdieva, D. (2016). The interaction between arbuscular mycorrhizal fungi and endophytic bacteria enhances plant growth of *Acacia gerrardii* under salt stress. *Frontiers in Microbiology*, 7, 1089.

Hashem, A., Abd_Allah, E.F., Alqarawi, A.A., Al-Huqail, A.A., Wirth, S., Egamberdieva, D. (2018). Arbuscular mycorrhizal fungi mitigates NaCl-induced adverse effects on *Solanum lycopersicum* L. *Saudi Journal of Biological Sciences*, 25(4), 851-858. https://doi.org/10.1016/j.sjbs.2018.02.005.

Hewitt, E.J. (1966). *Sand and Water Culture Methods Used in the Study of Plant Nutrition* (2nd ed.). Commonwealth Bureau of Horticulture and Plantation Crops.

Irik, H.A., **Bikmaz, G. (2024).** Effect of different salinity on seed germination, growth parameters and biochemical contents of pumpkin (Cucurbita pepo L.) seeds cultivars. *Scientific Reports, 14*(1), 6929.

Li, S.X., **Gu, H.B.**, **Mao, Y.**, **Yin, T.M.**, **Gao, H.D**. (2012). Effects of tallowtree seed coat on seed germination. *Journal of Forestry Research, 23*, 229-233.

Maguire, J. D. (1962). Seed of germination-aid in selection and evaluation for seedling emergence and vigor. *Crop Science, 2*, 176-177.

Mardukhi, B., **Rejali, F.**, **Daei, G.**, **Ardakani, M.R.**, **Malakouti, M.J.**, **Miransari, M. (2011).** Arbuscular mycorrhizas enhance nutrient uptake in different wheat genotypes at high salinity levels under field and greenhouse conditions. *Comptes Rendus. Biologies, 334*(7), 564-571.

Marschner, H. (Ed.). (2011). *Marschner's mineral nutrition of higher plants*. Academic Press.

Molazem, D., **Azimi, J.**, **Branch, A. (2011).** Effect of different levels of salinity on leaf characteristics and chlorophyll content of commercial varieties of maize (Zea mays L.). *Australian Journal of Basic and Applied Science, 5*, 1718-1722.

Moreira, H., **Pereira, S.I.**, **Vega, A.**, **Castro, P.M.**, **Marques, A.P. (2020).** Synergistic effects of arbuscular mycorrhizal fungi and plant growth-promoting bacteria benefit maize growth under increasing soil salinity. *Journal of Environmental Management, 257*, 109982.

Munns, R., **Tester, M. (2008).** Mechanisms of salinity tolerance. *Annual Review of Plant Biology, 59*, 651-681. https://doi.org/10.1146/annurev.arplant.59.032607.092911.

Muta, K., **Takata, S.**, **Utsumi, Y.**, **Matsumura, A.**, **Iwamura, M.**, **Kise, K. (2022).** TAIM: tool for analyzing root images to calculate the infection rate of arbuscular mycorrhizal fungi. *Frontiers in Plant Science, 13*, 881382.

Olsen, S.R., **Sommers, L.E. (1982).** Phosphorus. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties* (2nd ed., pp. 403-430). American Society of Agronomy.

Porcel, R., **Aroca, R.**, **Ruiz-Lozano, J.M. (2012).** Salinity stress alleviation using arbuscular mycorrhizal fungi. A review. *Agronomy for Sustainable Development, 32*(1), 181-200. https://doi.org/10.1007/s13593-011-0029-x.

Porcel, R., **Aroca, R.**, & **Ruiz-Lozano, J. M.** (2012). Salinity stress alleviation using arbuscular mycorrhizal fungi. A review. *Agronomy for Sustainable Development, 32*, 181-200.

Radford, P.J. (1967). Growth analysis formulae their use and abuse. *Crop Science, 7*, 171-175.

Ramon Acosta-Motos, J., **Fernanda Ortuno, M.**, **Bernal-Vicente, A.**, **Diaz-Vivancos, P.**, **Jesus Sanchez-Blanco, M.**, **Antonio Hernandez, J. (2017).** Plant responses to salt stress: Adaptive mechanisms. *Agronomy-Basel, 7*(1).

Razvi, S.M., **Singh, N.**, **Mushtaq, A.**, **Shahnawaz, D.A.R.**, **Hussain, S. (2023).** Arbuscular mycorrhizal fungi for salinity stress: Anti-stress role and mechanisms. *Pedosphere, 33*(1), 212-224.

Saxena, R., **Kumar, M.**, **Tomar, R.S. (2019).** Plant responses and resilience towards drought and salinity stress. *Plant Arch, 19*(Suppl 2), 50-58.

Scott, S.J., **Jones, R.A.**, **Williams, W.A. (1984).** Review of data analysis methods for seed germination. *Crop Science, 24*(6), 1192–1199. https://doi.org/10.2135/cropsci1984.0011183X002400060043x.

Sheng, M., Tang, M., Chen, H., Yang, B., Zhang, F., Huang, Y. (2008). Influence of arbuscular mycorrhizae on photosynthesis and water status of maize plants under salt stress. *Mycorrhiza, 18*(6-7), 287–296. https://doi.org/10.1007/s00572-008-0180-7.

Shrivastava, P., Kumar, R. (2015). Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. *Saudi Journal of Biological Sciences, 22*(2), 123-131.

Silva, E.D., Ribeiro, R.V., Ferreira-Silva, S.L., Viégas, R.A., Silveira, J. A.G. (2010). Comparative effects of salinity and water stress on photosynthesis, water relations and growth of Jatropha curcas plants. *Journal of Arid Environments, 74*(10), 1130-1137.

Talaat, N.B., Shawky, B.T. (2014). Protective effects of arbuscular mycorrhizal fungi on wheat (Triticum aestivum L.) plants exposed to salinity. *Environmental and Experimental Botany, 98*, 20-31.

Tanveer, A., Rehman, A., Javaid, M.M., Abbas, R.N., Sibtain, M., Ahmad, A., Zamir, M.S., Chaudhary, K.M., Aziz, A. (2010). Allelopathic potential of *Euphorbia helioscopia* L. against wheat (Triticum aestivum L.), chickpea (Cicer arietinum L.), and lentil (Lens culinaris Medic.). *Turkish Journal of Agriculture and Forestry, 34*, 75-81.

Vennam, R.R., Bheemanahalli, R., Reddy, K.R., Dhillon, J., Zhang, X., Adeli, A. (2024). Early-season maize responses to salt stress: Morpho-physiological, leaf reflectance, and mineral composition. *Journal of Agriculture and Food Research, 15*, 100994.

Wahab, A., Muhammad, M., Munir, A., Abdi, G., Zaman, W., Ayaz, A., Reddy, S.P.P. (2023). Role of arbuscular mycorrhizal fungi in regulating growth, enhancing productivity, and potentially influencing ecosystems under abiotic and biotic stresses. *Plants, 12*(17), 3102.

Wang, L., Chen, X., Wang, S., Du, Y., Zhang, D., Tang, Z. (2022). Effects of arbuscular mycorrhizal symbiosis on the growth and reproduction of cherry tomato can be persistent to the next generation. *European Journal of Soil Biology, 112*, 103429.

Wintermans, J.F.G.M., **de Mots, A. (1965).** Spectrophotometric characteristics of chlorophylls a and b and their pheophytins in ethanol. *Biochimica et Biophysica Acta, 109*(2), 448-453. https://doi.org/10.1016/0926-6585(65)90170-6.

Xu, Z., **Jiang, Y.**, **Jia, B.**, **Zhou, G. (2016).** Elevated-CO_2 response of stomata and its dependence on environmental factors. *Frontiers in Plant Science, 7*, 657. https://doi.org/10.3389/fpls.2016.00657.

Yang, Y., **Guo, Y. (2018).** Unraveling salt stress signaling in plants. *Journal of Integrative Plant Biology, 60*(9), 796-804. https://doi.org/10.1111/jipb.12689.

Zare-Maivan, H., **Khanpour-Ardestani, N.**, **Ghanati, F. (2017).** Influence of mycorrhizal fungi on growth, chlorophyll content, and potassium and magnesium uptake in maize. *40*(14). https://doi.org/10.1080/01904167.2017.1353842.

Zhou, H., **Shi, H.**, **Yang, Y.**, **Feng, X.**, **Chen, X.**, **Xiao, F.**, **Guo, Y. (2024).** Insights into plant salt stress signaling and tolerance. *Journal of Genetics and Genomics, 51*(1), 16-34.

Zhu, J.K. (2016). Salt and drought stress signal transduction in plants. *Annual Review of Plant Biology, 53*, 247-273. https://doi.org/10.1146/annurev.arplant.53.091401.143329.

Zhu, X., **Song, F.**, **Xu, H. (2010).** Influence of arbuscular mycorrhiza on lipid peroxidation and antioxidant enzyme activity of maize plants under temperature stress. *Mycorrhiza, 20*, 325-332.

Zuccarini, P., **Okurowska, P. (2008).** Effects of mycorrhizal colonization and fertilization on growth and photosynthesis of sweet basil under salt stress. *Journal of Plant Nutrition, 31*(3), 497-513.

J. Agric. & Env. Sci. (Damanhour University) 2025, 24(1): 112 - 141
Print: ISSN 1687-1464 Online: ISSN 2735-5098

الملخص العربى

تخفيف الإجهاد الملحي على اصناف مختلفة من الذرة (*Zea mays L.*) باستخدام فطريات الميكوريزا

إبراهيم شحاته ، هشام كيشار، السيد عبد الرؤوف، هبة سالم

***قسم الموارد الطبيعية والهندسة الزراعية، كلية الزراعة، جامعة دمنهور، دمنهور، مصر**

الملخص

هدفت هذه الدراسة إلى تقييم استجابة اصناف مختلفة من الذرة (*Zea mays L.*) للإجهاد الملحي تحت تلقيح فطريات الميكوريزا. أجريت التجربة في مزرعة رملية، حيث تم ري النباتات بمحلول مغذي هوجلاند Hoagland المعدل. تتكون التجربة من ثلاثة أصناف من الذرة تمثل العامل الرئيسى وهى : Pioneer SC.3444 و Hitech 2066 و Agrofood 168، بينما العوامل الثانوية تتكون من ثماني معاملات: أربعة مستويات من الملوحة (0 و 25 و 50 و 75 مليمولار كلوريد الصوديوم) مع فطريات الميكوريزا وأربعة أخرى بدون فطريات الميكوريزا. بعد أربعة أسابيع من الزراعة، تم حصاد النباتات، وتقييم تأثيرات الملوحة. أظهرت النتائج انخفاضًا كبيرًا في نمو النبات وإنباته والمعايير الفسيولوجية في جميع الجينات بسبب الإجهاد الملحي. في مقارنات بين الاصناف المختلفة، كان Agrofood هو النمط الصنف الأكثر تحملا لظروف الملوحة، وخاصةً عند التلقيح بفطريات الميكوريزا ، مما يوفر إمكانات كبيرة لتحسين إنتاجية الذرة في المناطق المتأثرة بالملح بسبب الإحتفاظ العالي للماء وآليات التنظيم الاسموزية. أظهر Pioneer SC.3444 تحملًا معتدلاً، بينما كان Hitech 2066 الأكثر تأثرًا بالملوحة. حسنت التلقيح بفطريات الميكوريزا تحمل الملوحة وزادت الوزن الطازج والوزن الجاف وطول المجموع الخضري ومحتوى الكلوروفيل. ساعدت فطريات الميكوريزا في الاحتفاظ بالمحتوى المائي للنبات تحت الاجهاد. يتماشى الأداء المحسن مع فطريات الميكوريزا مع الأبحاث الحديثة التي توضح أن فطريات الميكوريزا الجذرية تحسن نمو النبات وتحمل الإجهاد من خلال زيادة امتصاص العناصر الغذائية وتحسين العلاقات المائية وتعديل التوازن الهرموني للنبات. بالنسبة للتربة المالحة، يوصى بالتلقيح، وخاصة للأنماط الجينية المرنة مثل Agrofood. وتؤكد هذه النتائج على أهمية فطريات الميكوريزا كحل مستدام للتخفيف من إجهاد الملوحة وتعزيز أداء المحاصيل في البيئات المعاكسة.

J. Agric. & Env. Sci. (Damanhour University) 2025, 24(1): 112 - 141
Print: ISSN 1687-1464 Online: ISSN 2735-5098

الكلمات الدالة : صفات الإنبات، الذرة، إجهاد الملوحة، الميكوريزا