Acta Scientific NUTRITIONAL HEALTH (ISSN:2582-1423)

Volume 8 Issue 8 August 2024

Research Article

The Effects of Salinity on *Mycorrhizal* Association and Corn Growth

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DOI: 10.31080/ASNH.2024.08.1414

Received: June 14, 2024

Published: July 26, 2024

Abstract

Salinity is a significant problem regarding plant growth. Salinity hinders plant reproduction and growth by impeding nitrogen uptake and interfering with a seed's capability of germinating. High salinity in a seed's environment can lead to a low osmotic potential, which may eventually result in little to no water uptake. Mycorrhiza fungi are a specific type of fungi that establish a mutualistic association between plant roots and fungi. This relationship often permits plants to uptake nutrients and water more readily. Mycorrhizal fungi help plants build a tolerance to stressful conditions like salinity, heat, and extreme temperatures. This experiment was conducted under four different treatments: 0.5M salt concentration with wild root organic mighty mycorrhizae, 0.2M salt concentration with mycorrhizae, no salt concentration but mycorrhizae added, and a control group (no salt concentration and no mycorrhizae), with all treatments containing an equal amount of soil (miracle grow potting mix soil) and corn seeds. These four separate treatments were placed in a growth chamber set to 12 hours of light at 26°C (to represent daytime) and 12 hours of darkness at 23°C (to represent nighttime). The measurements were taken over the course of three weeks. A major finding was that the presence of salinity significantly inhibited the growth of corn plants. In addition, the presence of mycorrhizae allowed for relatively faster and healthier growth of the plants. These revealed that salinity has a negative effect on plant growth. However, if mycorrhizae are present, this negative effect is mitigated as the plant develops a remarkable tolerance against salinity. Furthermore, the results indicate that the plant grown with mycorrhizae will more readily uptake more nutrients and water, overall producing a healthier plant.

Keywords: Salinity; Mycorrhizal; Corn Growth

Introduction

Salinity reduces plant reproduction and growth, hinders nitrogen uptake, and interferes with a seed's ability to germinate [6]. A saline soil is generally defined as one in which the electrical conductivity (EC) of the saturation extract (EC_e) in the root zone exceeds 4 dS m^{-1} (approximately 40 mM NaCl) at 25 °C and has an exchangeable sodium of 15% [11]. Therefore, high salinity in a seed's surroundings leads to a low osmotic potential, which then leads to little to no water uptake [7]. Modern agriculture is facing twin challenge of ensuring global food security and executing it in a sustainable manner. However, the rapidly expanding salinity stress in cultivable areas poses a major peril to crop yield. Among various biotechnological techniques being used to reduce the negative effects of salinity, the use of arbuscular mycorrhizal fungi (AMF) is considered to be an efficient approach for bio-amelioration of salinity stress [4]. Mycorrhizal fungi are a type of fungus that allows plants to uptake sufficient nutrients and water from the soil, overall causing the plant to grow faster and healthier [1]. It helps regulate and increase chlorophyll content, and the efficiency of water under environmental stresses [1]. There are three main types of mycorrhizal fungi: arbuscular mycorrhizal fungi (AMF), ectomycorrhizal (EM) fungi, and endomycorrhizal fungi. Endomycorrhiza penetrates deep into the plant, whereas ectomycorrhiza does not penetrate deep into the plant [5]. AMF are microorganisms in the soil that form a symbiosis with the majority of plants; the spores in the soil become germinated, which then infect the root and form arbuscular structures in the cells [10]. Many researchers believe when AMF is present in plants it builds tolerance in the plants against stressful conditions like salinity, heat, drought, and extreme temperatures [2]. However, high levels of salinity can reduce the efficiency and symbiotic capability of AMF, as opposed to plants that have no salinity at all [3]. When saline is present in the soil of a plant, it can lead to a reduction in the uptake of calcium, potassium, and phosphorus, but mycorrhiza helps control this reduction and enhances the productivity of plant production [9].

Increases in salt pollution may subsequently increase the salinity in soil and other ecosystems. This experiment aims to test the effect of varying salinity levels on the efficiency of Mycorrhizal association and corn growth. The measurements of the corn height, stem width, and canopy spread depend on the varying salinity levels and the presence of mycorrhizae. It was hypothesized that the treatment that had the highest amount of saline with mycorrhizae present, will show the least amount of growth, and the treatment that has no saline present with mycorrhizae will show the most amount of growth. The purpose of this experiment was to see if typical salt pollution caused by improper waste disposal had a positive or negative effect on the efficiency of mycorrhizae and corn growth. This experiment can be utilized by scientists and agriculturists to narrow down the environment plants are being planted in, to see if the environment has an effect on the plant's growth.

Materials and Methods

Materials

The materials utilized throughout the duration of the experiment were 18.5" inch plastic plant trays, 2.30-2.40-liter planting pots, Soil (miracle grow potting mix soil), Mycorrhizae (wildroot organic mighty mycorrhizae), Adaptis growth chamber cmp6050 (Conviron), Iodized Salt, Corn seeds (Carolina Biological Supply Company), Distilled water (Walmart), and a Meter ruler.

Methods

Four plant pots containing soil (miracle grow potting mix soil) were put in four different plastic trays. The miracle-grow potting mixes contain a blend of sphagnum peat moss, aged bark fines, perlite, plant food, and a wetting agent. The experimental design is a randomized complete block design. In each plant pot, an equal amount of soil was added, and a total of two corn seeds of the same variety were added to each separate plant pot. The four different trays were split into four different treatments and were labeled treatment one, treatment two, treatment three, and treatment four. Treatment one contained 0.5M salt with mycorrhizae, treatment two contained 0.2M salt with mycorrhizae, treatment three had no salt concentration, but it had mycorrhizae, and treatment four was the control group, in which, it contained no salt concentration and no mycorrhizae. A total of 500 mg of mycorrhizae (in powdery form) was added to the soil in treatment 1, treatment 2, and treatment 3. To make different salt concentrations for the experiment, one molar salt concentration was first made by dissolving 58.5 grams of salt in one liter of water, Serial dilutions were made from the 1M salt solution into 0.5M and 0.2M concentrations which were used for the different treatments. 500 ml of the 0.5M salt solution was added to the plastic tray of treatment one, 500 ml of the 0.2M salt solution was added to the plastic tray of treatment two, and an equal amount of distilled water was added to treatments three and four.

The four different treatments were placed in a growth chamber, set to 12 hours of light at 26°C (to represent daytime) and 12 hours of darkness at 23°C (to represent nighttime). The reported daytime and nighttime ranges for optimum yield of corn plant are 25°C - 35°C and 16.7°C - 23.3°C, respectively [12]. The measurements of each plant under the different treatments were taken every three to four days, for the span of three weeks. The measurements included the number of seeds germinated, plant height (cm), stem width, and canopy spread. Plant height was measured using a meter rule standing beside each corn plant from the surface above soil level to the apex of the plant. Stem width was calculated by wrapping a thread around the stem at 1 cm above the soil surface. A mark is made on the thread after wrapping it around the stem. The tip of the thread is then placed at 0 cm on the meter rule and stretched out to the marked point on the thread. Canopy spread was measured by placing meter rule at the end of spread of the two apical leaves from left to right. The mean values of all the measurements were calculated.

Results

This experiment analyzes the effects of different salinity on mycorrhizal association and corn height (cm). The two-factor analysis of variance (ANOVA) for treatment and time effects on plant height conducted (Table 1). The treatments had highly significant effects on corn plants height ($P < 0.001$). Twenty-two days after planting (DAP), treatment three (no salt concentration with mycorrhizae), reached its peak height, averaging over 42 cm, whereas treatment two (0.2M salt with mycorrhizae), reached its peak height 15 DAP, with an average of 19.1 cm (Figure 1).

With respect to stem width, treatments and the interactions between treatment and time also had a highly significant ($P < 0.001$) effect (Table 2).

8 DAP, treatment four (control group: no salt concentration and no mycorrhizae), reached its peak stem width, with an average of 1.875 cm, as opposed to treatment three (no salt concentration with mycorrhizae), which reached its peak stem width 12 DAP, with an average of 4 cm (Figure 2).

Furthermore, there was a highly significant treatment effect on the canopy spread of corn plants as revealed by ANOVA (Table 3).

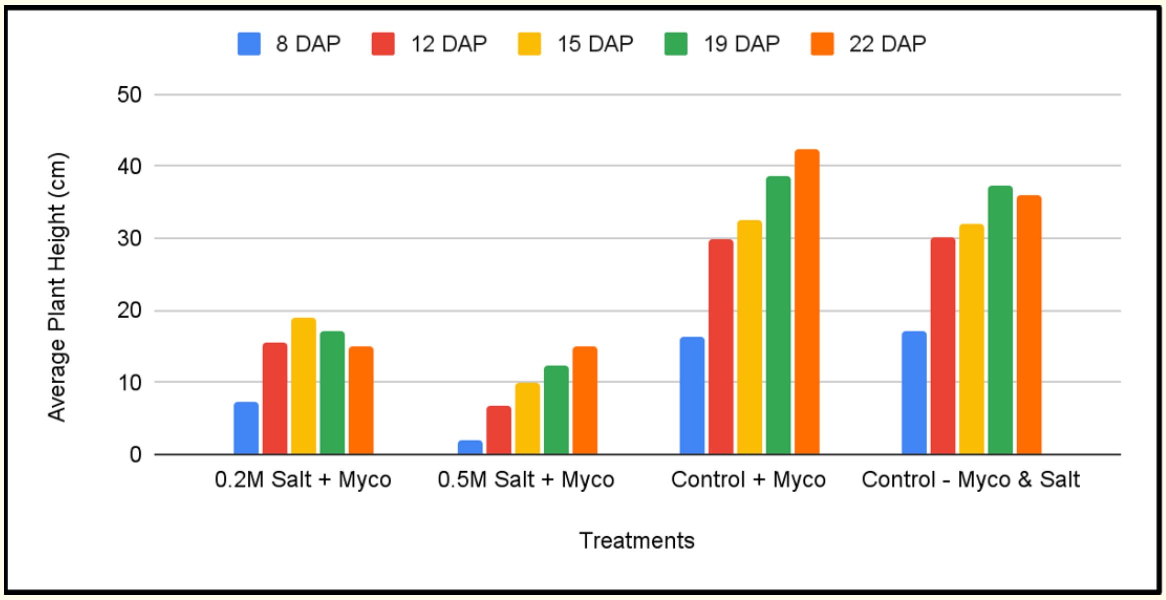

Figure 1: Bar graph of the average plant height (cm) of corn over the course of three weeks based on the different salt treatments.

Source of Variation	SS	df	MS	F	P-value	F crit
Treatment	8041.141	3	2680.380	87.829	< 0.001	2.758
Time (DAP)	2943.516	4	735.879	24.113	< 0.001	2.525
Interaction	518.066	12	43.172	1.415	0.185	1.917
Within	1831.085	60	30.518			
Total	13333.808	79				

Table 1: Two-Factor Analysis of Variance (ANOVA) For Treatment and Time Effects on Plant Height.

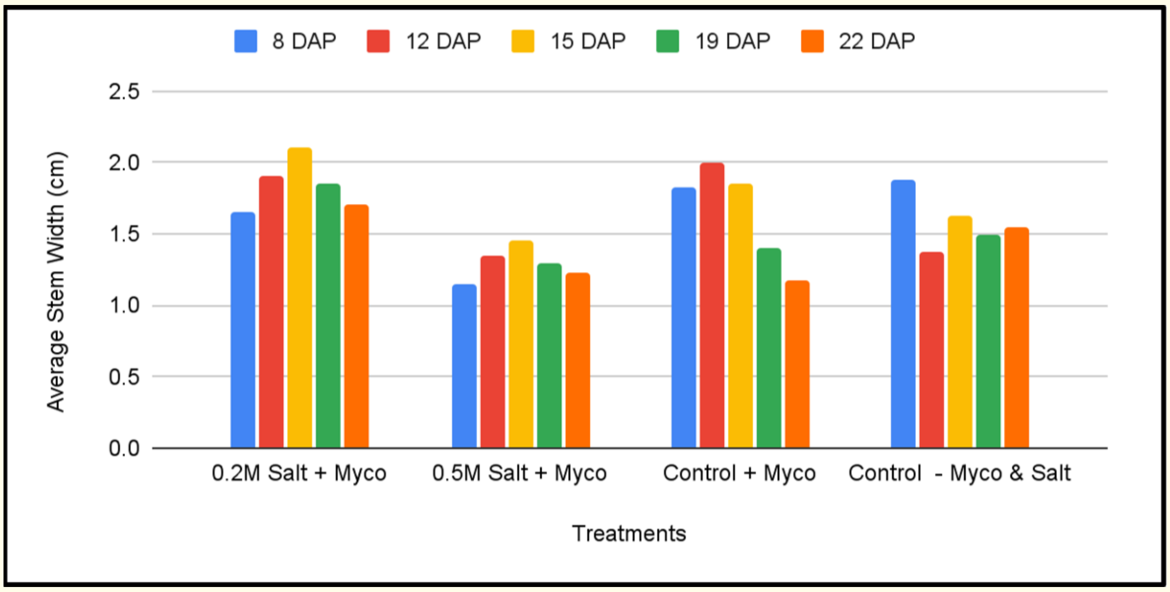

Figure 2: Bar graph of the average stem width of corn over the course of three weeks based on the different salt treatments.

Source of Variation	SS	df	MS	F	P-value	F crit
Treatment	4.629	3	1.543	27.132	< 0.001	2.758
Time (DAP)	1.247	4	0.312	5.480	0.001	2.525
Interaction	3.676	12	0.306	5.386	< 0.001	1.917
Within	3.413	60	0.057			
Total	12.965	79				

Table 2: Two-Factor Analysis of Variance (ANOVA) For Treatment and Time Effects on Stem Width.

Source of Variation	SS	df	MS	F	P-value	F crit
Treatment	1999.464	3	666.488	60.825	< 0.001	2.758
Time (DAP)	1176.275	4	294.069	26.837	< 0.001	2.525
Interaction	354.669	12	29.556	2.697	0.006	1.917
Within	657.445	60	10.957			
Total	4187.852	79				

Table 3: Two-Factor Analysis of Variance (ANOVA) For Treatment and Time Effects on Canopy Spread.

22 DAP, treatment one (0.5M salt with mycorrhizae), reached its peak canopy spread, with an average of 6.375 cm, and treatment three (no salt concentration but with mycorrhizae), reached its peak canopy also spread 22 DAP, but with an average of 23.25 cm (Figure 3).

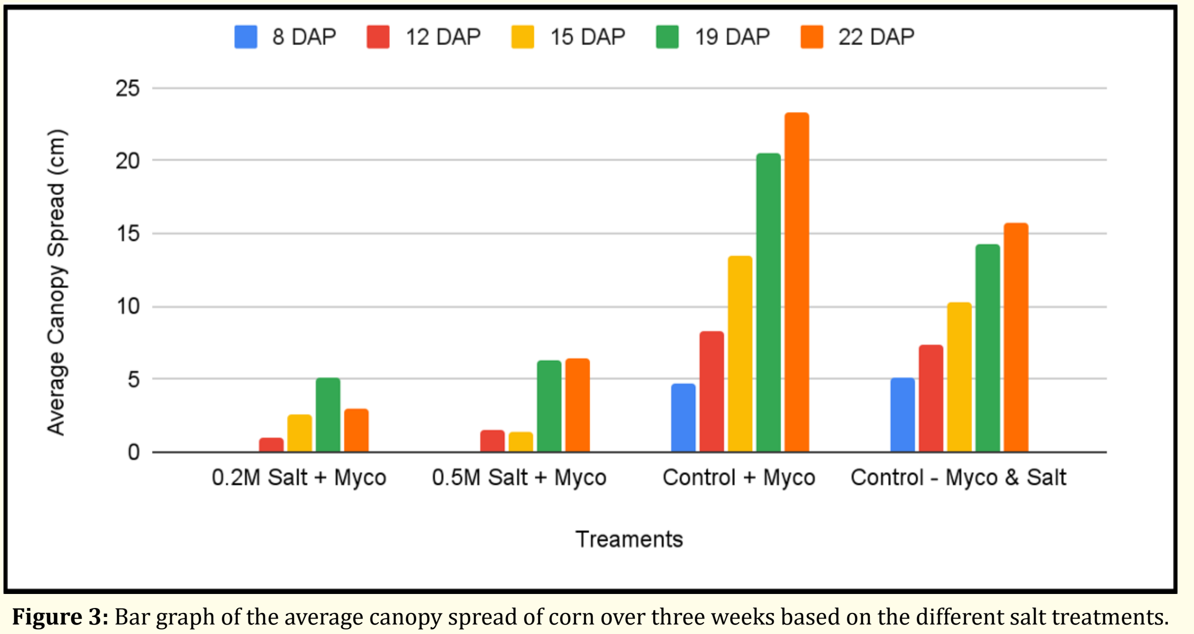

Figure 3: Bar graph of the average canopy spread of corn over three weeks based on the different salt treatments.

At the end of the third week, treatment one (0.5M salt with mycorrhizae), had a mean height of 9.19 cm, mean stem width of 1.3 cm, and a mean canopy spread of 3.12 cm. Treatment two (0.2M salt with mycorrhizae), had a mean height of 14.88 cm, mean stem width of 1.84 cm, and a mean canopy spread of 2.35 cm. Treatment three (no salt concentration with mycorrhizae), had a mean height of 32 cm, mean stem width of 2.05 cm, and a mean canopy spread of 14.05. Treatment four (control group: no salt concentration and no mycorrhizae), had a mean height of 30.5 cm, mean stem width of 1.585 cm, and a mean canopy spread of 10.55 cm. (Table 4).

The treatment that had the highest mean height (32 cm) was treatment three (no salt concentration but with mycorrhizae), and the treatment with the lowest mean height (9.19 cm) was treatment one (0.5M salt with mycorrhizae) (Figure 4). Two corn plant stands were found wilting 2 weeks after planting (WAP) in two different pots under treatment 1 (0.5M salt with mycorrhizae).

	Treatment one (0.5M salt with mycorrhizae)	Treatment two (0.2M salt with mycorrhizae)	Treatment three (no salt concentration but with mycorrhizae)	Treatment four (control group: no salt concentration and no mycorrhizae)
Mean Plant Height (cm)	9.19	14.88	32	30.5
Mean Stem Width (cm)	1.3	1.84	2.05	1.585
Mean Canopy Spread (cm)	3.12	2.35	14.05	10.55

Table 4: Comparative mean values of growth parameters 22 days after planting under exposure to different saline conditions and mycorrhizae.

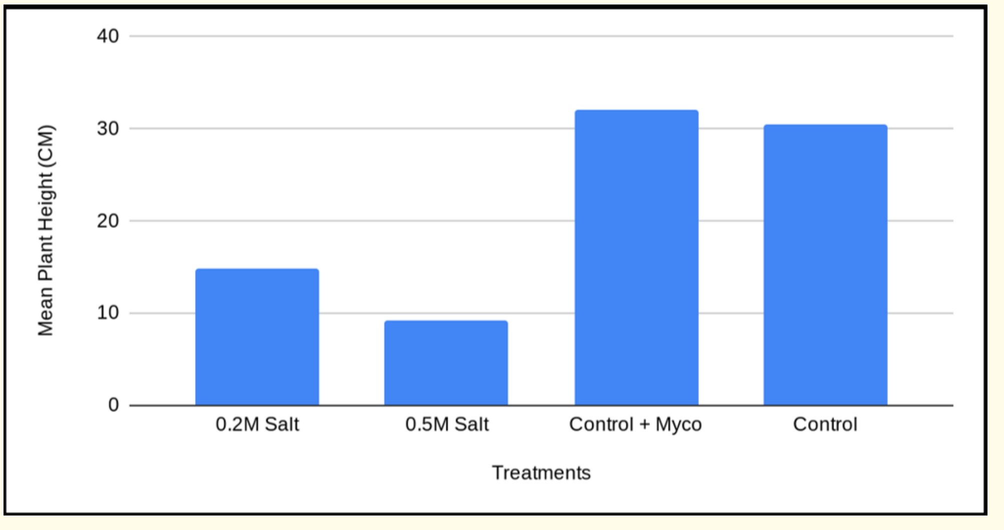

Figure 4: The mean height at the end of the three weeks of the different treatments exposed to different salinity levels.

At the end of the three weeks, a microscopic cross section of the corn roots in treatment three was taken to show the positive effect of mycorrhizae on the structure of the corn roots (Plate 1).

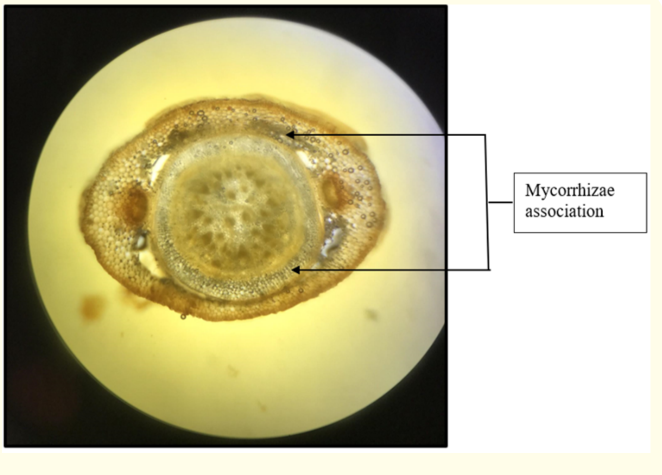

Plate 1: Microscopic cross sections of corn roots under treatment 3 (mycorrhizae added, but no salt). The moldy green coloration is the mycorrhizae association within the vascular and cortical tissues of the plant roots.

At the end of the three weeks, another microscopic cross section of the corn roots in treatment one was taken, to show the negative effect salinity has on corn root structure, and the efficiency on mycorrhizae (Plate 2).

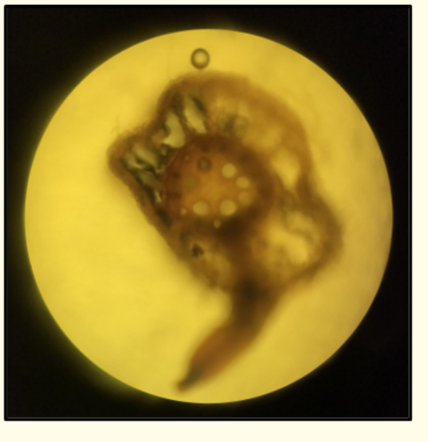

Plate 2: Microscopic cross sections of corn roots under treatment 1 (mycorrhizae added plus 0.5M salt concentration). No mycorrhizae association was observed.

Discussion

This experiment was designed in a randomized complete block design, which is a design used for agricultural experiments, whereby the experimental units are grouped into blocks, based on known or suspected variation [6]. Treatment one: 0.5M salt with mycorrhizae had an average height of 9.19 cm, at the end of the three weeks. Treatment two: 0.2M salt with mycorrhizae had an average height of 14.88 cm, at the end of the three weeks. Treatment three: no salt concentration with mycorrhizae had an average height of 32 cm, at the end of the three weeks. Treatment four: control group (no salt concentration and no mycorrhizae) had an average of 30.5 cm, at the end of the three weeks.

The data collected from this experiment indicate that salinity has a negative effect on corn growth, stem width, and canopy spread. Treatment three showed the most growth out of all the treatments, which was expected considering that it had mycorrhizae and no salinity present, to hinder the corn's height, stem width, and canopy spread. (Plate 1).

Treatment one showed the least growth out of all the treatments, this is because it had the highest amount of salinity out of all the treatments, which affected the efficiency of the mycorrhizae on the corn's overall growth. However, if the mycorrhizae were not present in this treatment, the results would be significantly lower than what was collected (Plate 2). This assertion was made because corn plants under treatment 2 (with lower salt concentration and same amount of mycorrhizae) showed higher growth rate. This implies the effect of higher salt concentration on mycorrhizae activities.

As for the results of treatment three, since treatment three had no salt present, the mycorrhiza was not able to work at its full efficiency; treatment one had the most salt present out of all the treatments, which caused the mycorrhizae not to work effectively on the growth of corn. The results do agree with the research and support the hypothesis that the treatment that had the highest amount of salt with mycorrhizae present, will show the least amount of growth, and the treatment that has no salt present with mycorrhizae will show the most amount of growth because the treatment that no salt present with mycorrhizae grew the most than the treatment that had the highest amount of salinity present with mycorrhizae [3].

To improve this experiment, a control group that only had salt present, should be added. This can also be done at different salt concentrations. Adding this different control group to the experiment would have provided a comparison to the treatments that had salt present with mycorrhizae, to show that the presence of mycorrhizae still caused the corn plants to grow, even if there was salt present, as opposed to if the plant had only salt with no mycorrhizae present. The growth chamber was set properly for 12 hours of light (to represent daytime) and 12 hours of darkness (to represent nighttime), and the right temperature of 26°C for the day and 23°C for the night for the duration of the experiment. A possible source of error could have been that the duration of light and darkness, as well as the set temperature, may not be the optimum condition for corn growth. Therefore, more literature should be reviewed on optimum growth conditions for corn. The experiment could overall be improved in the future by making another control group to have a better comparison, and including more samples, to make the experiment more reliable and accurate. Different corn varieties or genotypes can also be subjected to different salt concentrations with and without mycorrhizae application.

Conclusion

The hypothesis that the treatment that had the highest amount of salinity with mycorrhizae present will show the least amount of growth, and the treatment that has no salt present with mycorrhizae will show the most amount of growth, was supported, according to the data that were collected. The hypothesis was supported because treatment three: no salt concentration with mycorrhizae had the highest amount of growth, and treatment one: 0.5M salt with mycorrhizae had the lowest amount of growth. This experiment was completed by making four different treatments: 0.5M salt concentration with mycorrhizae, 0.2M salt concentration with mycorrhizae, no salt concentration but mycorrhizae added, and a control group (no salt concentration and no mycorrhizae), that all had an equal amount of soil and same variety of corn seeds. These four different treatments were placed in a growth chamber set to 12 hours of light at 26°C (to represent daytime) and 12 hours of darkness at 23°C (to represent nighttime). The measurements were taken over the course of three weeks. The measurements were plant height, stem width, and canopy spread. The experiment resulted in the following results: treatment one (0.5M salt with mycorrhizae), had a mean height of 9.19 cm, mean stem width of 1.3 cm, and a mean canopy spread of 3.12 cm. Treatment two (0.2M salt with mycorrhizae), had a mean height of 14.88 cm, mean stem width of 1.84 cm, and a mean canopy spread of 2.35 cm. Treatment three (no salt concentration with mycorrhizae), had a mean height of 32 cm, mean stem width of 2.05 cm, and a mean canopy spread of 14.05. Treatment four (control group: no salt concentration and no mycorrhizae), had a mean height of 30.5 cm, mean stem width of 1.585 cm, and a mean canopy spread of 10.55 cm. (Table 1). This is because salinity affects the efficiency of mycorrhizae, so any plants that have salt present will not grow significantly, as opposed to plants with no salt present. This study has shown that mycorrhizal fungi serve as a natural mechanism to mitigate the negative effects of salinity on plants, making them a potential tool for sustainable agriculture in saline environments. Further understanding of the interactions between mycorrhizal fungi and salinity at various degree can help researchers and farmers develop strategies to improve crop productivity in saline soils while reducing the need for chemical inputs. Therefore, future study will expose same variety of corn to various concentrations of salt in soil water treated with AMF to elucidate at what extent of salt concentration will the symbiotic relationship of the fungi not enhance plant tolerance and growth. Also, same variety of corn will be exposed to high salt concentration without any mycorrhizal fungi application.

Acknowledgments

The first author says a big thank you to the Department of Biology (Allen University) for providing her with the needed materials and a sufficient lab environment. She would also like to thank Dr. Degenhardt (Ridge View High School) for their assistance throughout the construction of this research paper. This research was supported by the Department of Biology, Allen University, and the Department of Research, Biomedical Sciences Magnet, Ridge View High School.

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