The Effects of Irrigating Tomato Seeds with Varying Levels of Aqueous Saline Solutions on Germination

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Abstract:

Wild tomatoes living in the Galápagos Islands have genetic adaptations helping them survive saline conditions, and domestic tomatoes are moderately sensitive to salt. This could indicate a tomato seed can germinate in saline conditions, and it's origin could help seeds withstand salinization better than other crops. Tomato seeds take 5-10 days to germinate. This experimental study tested whether a tomato seed could tolerate irrigation with an aqueous solution with extreme salinity levels and germinate in the 10 day window. The formula for parts per notation was used to calculate the amount of salt needed to make the solution a different level on the salinity status scale, excluding marginal. The salinity status scale measured how saline the water was. There are three pots for each salinity status level. Five seeds planted in a pot were watered with a 30 ml solution once a day for ten days. A syringe was used to make measurements. The time it took for each seed to germinate, each pot's germination rate, and how long it took for the first seed to germinate in each pot determined the success of a seed's germination. Tomato seeds irrigated with freshwater germinated, and two of three pots watered with brackish water germinated. Fresh pots 1-3 and brackish pots 2 and 3 had germination rates of 100%. All other pots had germination rates of 0%, concluding tomato seeds could not withstand saline conditions.

Key terms:

- **Salinization: salt concentration in an environmental medium, notably soil.**
- **Salination: describing something treated with salt.**
- **Germination: the sprouting of the seed; the beginning of growth from a seed into a seedling or young plant.**
- **Parts per notation (ppt): Formula for calculating salt needed to make water saline.**
- **Salinity status scale: 6 level scale ranking salinity of water.**

Introduction

Salinity is a significant issue that has a detrimental impact on crops and vegetation. Salinization of soil can have many causes. The causes range from climatic factors such as the natural accumulation of soluble salts retained in the Earth, including salt not being flushed out by water in Earth due to dry climate and low precipitation, and a high evaporation rate, to human-induced factors, such as the use of water in arid environments with heavy soils, irrigation water, and fertilization. Salinization is also directly related to soil irrigation with water consisting of high contents of soluble salts. In many plants, soil salinity can affect a plant's ability to reproduce, decrease its rate of growth, and can also affect a plant's ability to uptake nutrients. It can also affect germination, a necessary process that influences crop yield and quality.

Salinity refers to the concentrations of salt in water or soils. Salinization can be divided into two main categories (this does not exclude other categories but only includes the two main categories that most commonly cause salinization). Primary salinization, also known as natural salinity, is caused by natural occurring processes or is naturally occurring salinity, such as accumulating salt from rainfall over the period of thousands of years, weathering of rocks, or water that is naturally saline (i.e., salt lakes, salt pans, salt marshes, and salt flats). Secondary, or dryland, salinization is caused by human activities, such as irrigation (irrigating land excessively or with poor quality water), dryland (cleared vegetation and changes in land use), and seawater intrusion. Salination is the term used to describe something treated with salt. For example, the soil has been salinated by over-irrigating crops in soil salinization. When salinated water is used to irrigate the soil, this can have adverse effects. If the salt level in the soil water is too high, making the water too saline, it can lead to water flowing from the plant roots back into the soil. This results in dehydration of the plant, causing yield decline or even the death of the plant. This is because water moves into plant roots by the process of osmosis, which depends on the level of salts in the soil water and the water contained in the plant. Salt can disrupt the plant's osmosis by pulling water from the cells. When plants are watered with saltwater, the water is evaporated or is used by the plant. However, the salt is left behind. Continuous irrigation of soil with saline water can cause salt to accumulate in the soil, leading to soil salinization. This is also known as sodification.

Salinity is known to have adverse effects on soil, but it can also have detrimental effects on plants. Dryland salinity can lead to soil erosion. Soil erosion can decrease a crop's fertility, leading to a decline in crop yields. Soil salinity can significantly reduce crop yields and stop plant reproduction, lead to a plant's decline in growth, and interfere with nitrogen uptake. It can also decrease a plant's nutrient uptake.

Germination in plants is the sprouting of the seed and is the beginning of growth from a seed into a seedling or young plant. Germination occurs when the embryo inside a seed absorbs water, resumes growth, and the radicle emerges through the seed coat. When there is enough water, a seed fills with water in a process called imbibition. The water activates enzymes, which then start the process of germination. The embryo proceeds to swell, then lengthen. When the embryo lengthens, it breaks through the seed's covering layers. The root meristem, or plant tissue responsible for growth, is activated, and the radicle, or embryonic root, emerges through the seed coat. Cotyledons, or embryonic leaves, break out. The shoot meristem is activated, which leads to the leaves of the seed forming, allowing the plant to get energy from the Sun. Water is an essential factor in the germination of a seed; therefore, the quality used to irrigate crops is very important, especially in the early stages of plant growth, including germination. Saline water can cause inhibition of a seed's germination and delay a seed's germination. Saline water can cause drought for plants and interfere with osmosis. This study used saline water to explore whether salinity can negatively affect soil and seed germination. Therefore, tomato seeds were selected for further experimentation due to their unique origin.

A tomato seed takes approximately 5-10 days to germinate. In this experiment, the tomato seeds will be measured on their germination rate and ability to germinate within this time. If the seed has not germinated within this time frame, data will be marked as N/A for not available. Tomato plants are moderately tolerant to salt. Similar to many other plants, tomatoes will not grow as well if they are watered with saline water rather than freshwater. However, a difference sets tomatoes apart from other plants. The current domestic tomato originates in South America close to the Galápagos Islands, where environmental conditions are harsh and the coast is highly saline. Two wild tomatoes endemic to the Galápagos Islands, Solanum cheesmaniae and Solanum galapagense, have adapted to the saline conditions. Cherry tomato seeds, which are a mix of domestic tomato seeds and wild currant-type tomatoes, originating from the Galápagos Islands, have been shown in research studies to be tastier and richer in antioxidants when grown in diluted seawater, which is saline. I chose the domestic tomato because where the tomato originated from makes it unique compared to other plants. The purpose of the study was to answer the following research questions and test the associated hypotheses.

Research Question and Hypotheses

1. Will tomato seeds germinate within the 10 day window in saline soil salinated by water?
2. Will tomato seeds have better saline tolerance than other seeds since the current domestic tomato originates from environments with extremely saline conditions?

Hypotheses

1. If the tomato seeds are irrigated with an aqueous solution that is between saline and brine on the salinity status scale, then the tomato seed will take longer to germinate, and the germination rate will be lower than its counterparts irrigated with aqueous solutions between fresh and brackish on the salinity status scale.
2. Because the current domestic tomato originates from environments with extremely saline conditions, this will give tomatoes an advantage over other crops that will help the seed have better saline tolerance, and take less time to germinate.

Rationale

The purpose of this experiment is to see whether a tomato seed can tolerate and withstand irrigation with an aqueous solution that contains very high levels of salt. The results will determine whether the origin of the tomato will help since the wild tomatoes living in the Galápagos Islands have genetic adaptations that help them survive the harsh conditions. The tomato seeds that take the least time to germinate and have high germination rates can withstand the salinity level of the water given to them. If the tomatoes cannot withstand the salinity level of the water, then the tomato seed will take a long time to germinate or not germinate at all within the ten days and will have a low germination rate. Whichever pot germinates first shows that the seed could withstand the salty conditions because irrigating soil with saline water can also cause soil salinization, which is detrimental to germination.

I chose this experiment because salinization is a major problem affecting soils worldwide. Salinization is not a new issue, and saline soil can be traced as far back as Mesopotamia when early civilizations failed agriculturally because they could not grow crops due to the human-induced saline soil. Because of rising sea levels, salinization is becoming a growing problem today. Earth's soil today is becoming too saline for crops to grow, which will eventually affect our food supply. Germination is a vital process at the beginning of a plant's growth cycle, and salinity significantly impacts how well a seed can germinate. I was curious to see how the tomato seed's germination rate would be affected using saline water since water is a crucial factor in germination.

Variables

The manipulated variable in this experiment was the salinity percentage of the water used to irrigate the tomato seeds. Three pots with five tomato seeds in each were used to test five different levels on the salinity status scale for water salinity, with 15 seeds in total. The formula for parts per notation (ppt) was used to find the amount of salt in each level. The ppt formula was used to find how much solute was in a solution. This experiment used the ppt formula to find how much salt was needed to make a saltwater solution of a certain percentage on the salinity status scale.

The responding variable was how many days it takes for each seed to germinate in pots 1-3 in each level and the germination rate for each pot. The time taken for the seeds to germinate was measured within ten days. Any seeds that germinate after ten days, or fail to germinate at all, were marked as N/A (not available). If the seed germinates within a normal time range, then it could be assumed that the tomato seed could withstand the saline conditions. If the tomato seed failed to germinate within ten days, it could be assumed that the saline levels of the water were too high for the seeds to germinate.

The control was the pots 1-3 watered with fresh water on the salinity status scale because no salt was added in the 30 ml solution, and the seeds were irrigated using water that did not go through salination.

The constants in this experiment were the 30 ml of the solution because all of the seeds were watered with 30 ml. The number of seeds planted in each pot was constant. Pots 1-3 testing each level on the salinity status scale for a total number of 15 pots was a constant. Tap water was also a constant.

Materials

The materials used for this experiment include three Ferry-Morse tomato 20 non-GMO pellet seeds, three Ferry-Morse 7 pot seed starter kit single 3” pots, Ferry-Morse 25 pack plant labels, Miracle-Gro seed starting potting mix, two 5 ml syringe, Morton sea salt, and Fiskars Fiber Composite Soil Scoop.

Research Methods

Ferry-Morse 7 pot seed starter kit single 3" pots were used to categorize three pots into each salinity status scale level, excluding marginal, for a total of 15 pots. There were 21 pots total because each seed starter kit had seven pots; however, only 15 of these pots were used for the experiment. Fiskars Fiber Composite Soil Scoop was used to scoop soil to fill ¾ of 15 Ferry-Morse seed starter kit pots. After the soil was settled in the pot, five Ferry-Morse tomato non-GMO pellet seeds were planted in each pot. The seeds were planted ¼ deep in the soil. The seeds were covered with the soil, and the soil was patted to make a flat layer. Fifteen of Ferry-Morse 25 pack plant labels were used to label three seeds for each salinity status scale level. Pots were labeled from 1-3 and categorized in groups of three to keep track of each tomato pot's progress. The 5 ml syringe was used to water each seed with a solution. In this experiment, salinated water was used, excluding freshwater. For the solutions with salt, another 5 ml syringe was used to measure the amount of Morton sea salt needed for each level. The parts per notation (ppt) formula was used to find the amount of salt required to make aqueous solution saline. The tomato seeds were watered with 30 ml of water (fresh for three and saltwater for 12) once per day. For the 30 ml of fresh water on the salinity status scale, if the ppt was 0, then the amount of salt needed to add to fresh pots 1-3 was 0 ml, which was 0 mg. For 30 ml of water that was brackish on the salinity status scale, if the ppt was 1.5, then the amount of salt needed to add to brackish pots 1-3 was 0.07 ml, which was 89.6 mg. For 30 ml of saline water on the salinity status scale, if the ppt was 6.5, then the amount of salt needed to add to saline pots 1-3 was 0.3 ml, which was 384 mg. For 30 ml of highly saline water on the salinity status scale, if the ppt was 22.5, then the amount of salt needed to add to highly saline pots 1-3 was 1 ml, which was 280 mg. For 30 ml of brine water on the salinity status scale, if the ppt was 70, then the amount of salt needed to add to brine pots 1-3 was 3 ml, which was 3,840 mg. The amount of salt in ml was subtracted from 30 ml to get the amount of water needed to make the saltwater solution. The 30 ml of water did not remain constant in this experiment; however, the 30 ml amount of solution did remain constant. After each seed was watered, each pot was covered with a thin layer of soil. Pots were placed in 70-75 degrees Fahrenheit during the day and placed in 60 to 65 degrees Fahrenheit at night for the best growing conditions.

The formula for parts per notation (ppt) was used to calculate the amount of salt needed to add to the water to make the soil in each pot a different salinity level. The 30 ml solution was used once a day to water the seeds in each pot. A 5 ml syringe was used to measure the salt for each solution accurately. The tomato seeds should have taken 5-10 days to germinate. All tomato seeds were in the same environment with the same amount of soil and light given. The water used to water the soil in each pot was tap water. Each pot had 5 seeds. The success of the tomato seed's germination was calculated based on the time it took for the seeds in each pot to germinate and the germination rate of each pot. The germination rate was calculated by dividing the number of seeds germinated by the total number of seeds planted and multiplying the quotient by 100.

The results of this experiment were analyzed by counting how many days it took each pot of tomato seeds to germinate the first seed. The results were also analyzed by how many pots out of the three testings on the same level on the salinity status scale were able to germinate. The salinity status scale is a scale with six different levels of salinity. The order from least saline to most saline included fresh, marginal, brackish, saline, highly saline, and brine. For this experiment, marginal water was skipped because the water could be used to irrigate crops safely if certain precautions were taken. The results were also analyzed using the germination rate. Germination rate was the percentage of seeds that germinated out of the seeds planted in a pot.

Results

Table 1. Days for each seed to germinate in fresh pots

Type	Seed 1	Seed 2	Seed 3	Seed 4	Seed 5
Fresh pot 1	4 days	5 days	6 days	6 days	6 days
Fresh pot 2	5 days	5 days	5 days	6 days	9 days
Fresh pot 3	5 days	5 days	5 days	5 days	5 days

Table 2. Days for each seed to germinate in brackish pots

Type	Seed 1	Seed 2	Seed 3	Seed 4	Seed 5
Brackish pot 1	N/A	N/A	N/A	N/A	N/A
Brackish pot 2	6 days	8 days	9 days	9 days	9 days
Brackish pot 3	6 days	7 days	7 days	9 days	9 days

Table 3. Days for each seed to germinate in saline pots

Type	Seed 1	Seed 2	Seed 3	Seed 4	Seed 5
Saline pot 1	N/A	N/A	N/A	N/A	N/A
Saline pot 2	N/A	N/A	N/A	N/A	N/A
Saline pot 3	N/A	N/A	N/A	N/A	N/A

Table 4. Days for each seed to germinate in highly saline pots

Type	Seed 1	Seed 2	Seed 3	Seed 4	Seed 5
Highly saline pot 1	N/A	N/A	N/A	N/A	N/A
Highly saline pot 2	N/A	N/A	N/A	N/A	N/A
Highly saline pot 3	N/A	N/A	N/A	N/A	N/A

Table 5. Days for each seed to germinate in brine pots

Type	Seed 1	Seed 2	Seed 3	Seed 4	Seed 5
Brine pot 1	N/A	N/A	N/A	N/A	N/A
Brine pot 2	N/A	N/A	N/A	N/A	N/A
Brine pot 3	N/A	N/A	N/A	N/A	N/A

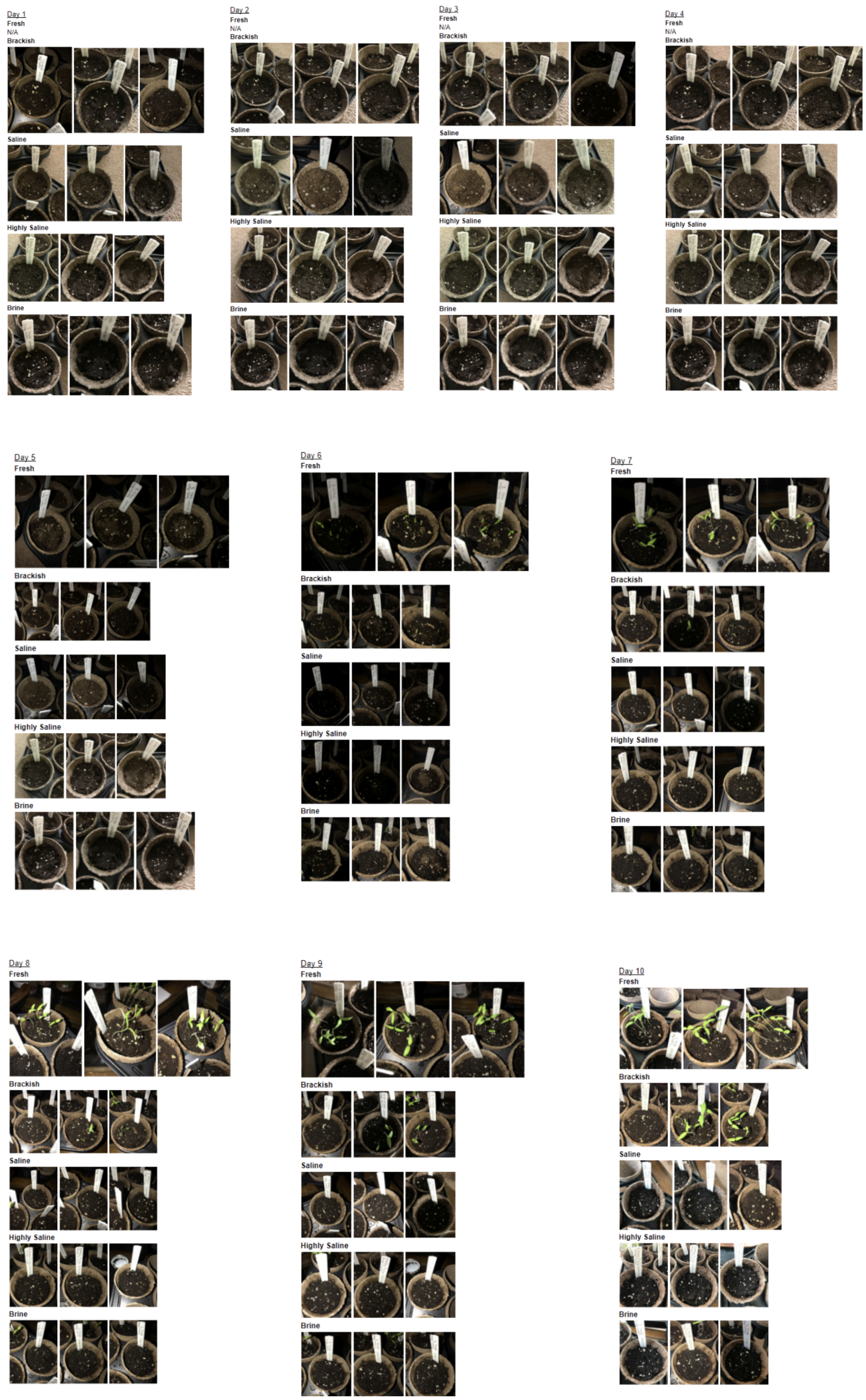

Figure 1. Images of pots throughout 10 day period.

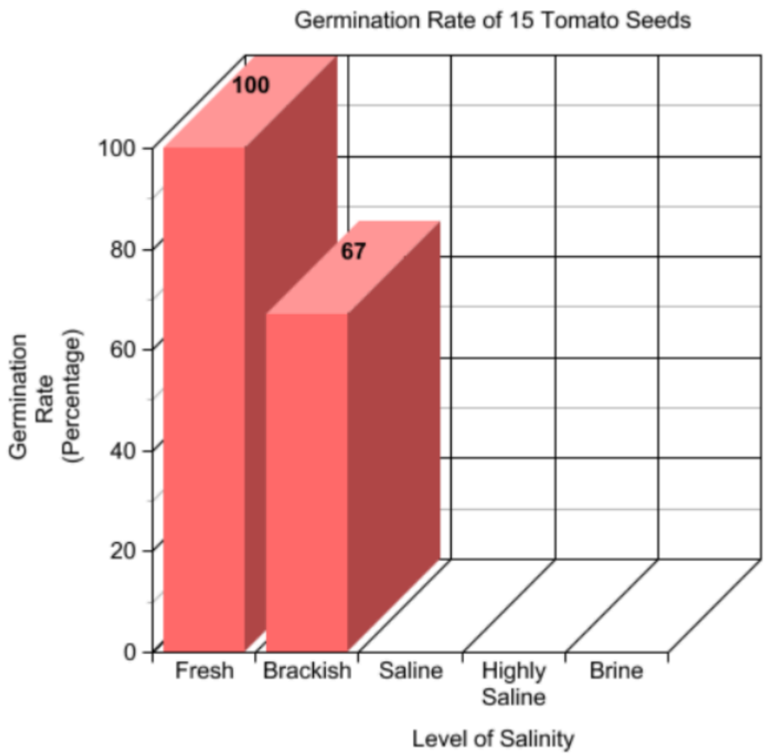

Figure 2. Germination rate of all tomato seeds in each category after 10 days.

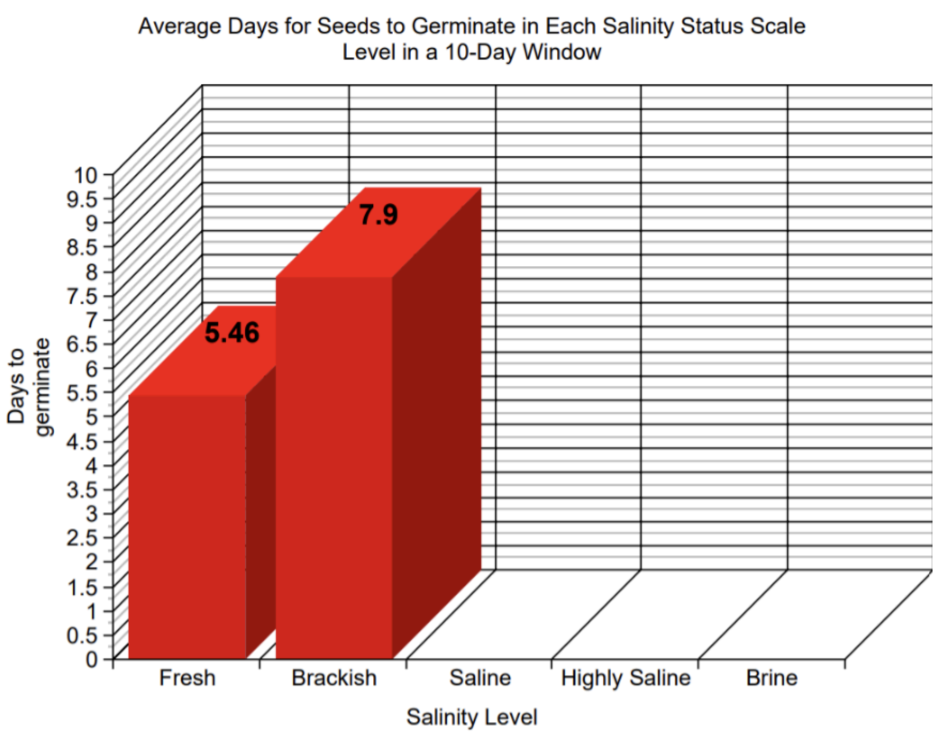

Figure 3. Average days for seeds to germinate in each category in a 10 day period.

Discussion and Conclusion

The data showed that the tomato seeds irrigated with water that was fresh on the salinity status scale were able to germinate, and two of three pots irrigated with brackish water on the salinity status scale were able to germinate. The other pots irrigated with saline, highly saline, and brine water could not germinate seeds within the 10 days. All fresh pots and brackish pots 2 and 3 had germination rates of 100%. All other pots had germination rates of 0%. The tomato seeds irrigated with water higher than brackish on the salinity status scale were unable to withstand the salty conditions and could not germinate.

Conclusion

The tomato seeds irrigated with saltwater between saline and brine on the salinity status scale did not germinate within the ten-day period. The tomato seeds irrigated with a solution between fresh and brackish on the salinity status scale were able to germinate, with the exception of brackish seed 1.

Pots watered with a 30 ml solution that is fresh on the salinity scale germinated in 6, 6, and 5 days. Fresh pots 1 and 2 germinated in 6 days, and fresh pot 3 germinated in 5 days. Brackish pots 2 and 3 germinated in 8 days, and brackish pot 1 could not germinate within the 10-day time frame. Pots watered with a 30 ml solution that is saline, highly saline, and brine on the salinity scale could not germinate within the 10-day time frame.

To conclude, my first hypothesis was correct because the seeds irrigated with water that was too salty were not able to germinate. The seeds were not able to germinate because of the hostile growing conditions. All pots irrigated with fresh and brackish water on the salinity status scale were able to germinate with the exception of brackish pot 1. The pots had a germination rate of 100% and were able to germinate five out of the five seeds planted. My second hypothesis was incorrect because the tomato seed was moderately tolerant to salt, and did not have an advantage over other seeds highly tolerant to salt. Therefore, more research is needed to figure out either how to resolve the issue of salinization on seed germination or change the seed genome to adapt and grow in saline conditions. Improvements to this experiment include using more accurate measuring devices for the salt concentrations, and doing this in a controlled lab setting. Use of an electrical conductivity meter could also be incorporated into an improved version of this experiment. Possible errors in this experiment include that the tomatoes were grown in winter. Although they were kept in temperatures suited for growing indoors, growing the seeds in the summer or spring would have been more advantageous.

This experiment helps us understand the severity of salinization, especially in brackish waters present in sea water. This experiment shows a glimpse of the potential impacts of rising sea levels on agriculture, and how we need to genetically modify tomatoes and other crops that are domesticated for consumption to have greater salinization tolerance, perhaps taking genes from Galapagos tomatoes with high salinity tolerance.

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