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DEPARTMENT OF PLANT SCIENCE

Water Temperature Effects on the Emergence of Tomato Seedlings

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ABSTRACT

Tomatoes are a staple in food dishes around the world (OECD, 2017). They are very popular and can usually be found in home gardens. These plants are either started from seed in the garden or started in a greenhouse to be sold in a garden center. In order to get a relatively large plant that individuals seek for their gardens, plants need to be started before the spring season. The only way for this to happen is to grow them in a greenhouse or ship them in from an outside source. When growing in a greenhouse each week of growing can be a huge difference for a plant. I wanted to test if there was a way to speed up the process of emergence in a greenhouse using different water temperatures and other physical factors. There were two trials completed each over the course of 14 days. The water temperatures were hot at about 182°F, cold at about 38°F, and room temperature at about 68°F. Each temperature of water had four different treatments- no factors, cling wrap on the pots, the pots on a heat mat, and a combination of the cling wrap and the heat mat. The results indicate that the best treatments for emergence are room temperature water with no factors and room temperature water with a heating mat.

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Introduction

Tomatoes, *Solanum lycopersicum*, are very highly consumed around the world and belong to the nightshade family, *Solanaceae* (OECD, 2017). Tomatoes are a perennial herbaceous plant but are usually grown as annuals (OECD, 2017). The growth habit varies from indeterminate to determinate and plants can reach up to 3 meters tall (OECD, 2017). Leaves are alternately arranged and the stems and leaves are covered in trichomes that give the plant its signature smell (OECD, 2017). Worldwide, tomato production in 2014 was about 171 million tons grown across 5 million hectares (OECD, 2017). Not only can tomatoes be grown in fields and gardens, they can also be grown in greenhouses (OECD, 2017). The fruit comes in a variety of colors, shapes, and sizes and are a staple in gardens due to their high value in vitamins and minerals, ease of growing, flavor, and versatility in food dishes (OECD, 2017). Individuals can start plants from seeds in their gardens, but usually plants are purchased from a garden center and transplanted into the garden (OECD, 2017). These plants that are sold at garden centers are usually started in a greenhouse to ensure good size and quality in time for the start of the spring season (OECD, 2017).

When producing plants in a greenhouse, starting plants a week or two earlier can make the plants ready for market faster. This allows the sales of plants earlier, which can be the difference between being the first to bring plants to market and getting prime prices, or being late to market and getting poor prices for the product because everyone already has the plants they need. I wanted to therefore see if there could possibly be a way to help increase the speed of emergence of tomato seeds in a greenhouse that might not be too costly to greenhouse owners if

proven effective. Therefore, I tested if different temperatures of water in combination with or without cling wrap and a heating mat would benefit or inhibit their emergence. The different treatments I tested were three different water temperatures room temperature water, hot water, and cold water. Water temperature was evaluated alone or with cling wrap, with a heat mat, or with cling wrap and a heat mat. My hypothesis is that room temperature water with the heat mat and cling wrap will produce the best results.

The Experiment

For this research experiment, there were a lot of supplies to gather before starting. This included the potting soil, plug flats, heat mat, cling wrap, coffee pot/machine, soil thermometer, tomato seeds, air temperature/humidity monitor, popsicle sticks, and the water sources. I cut up 11- 12x6 flats to get 30 plug cells for each treatment in the two trials. The cells were filled with soil and watered to field capacity before planting. I then poked a hole with a popsicle stick a quarter of an inch deep in each plug and planted one seed per plug. The cultivar used was 'Mountain Fresh Plus' from a seed distributer with a 90% germination rate. The containers were placed in their sections either on or off the heating mat. The heat mat that was used was set at a temperature of 72°F. They were labeled with a popsicle stick indicating their treatment type and were then watered to field capacity with their designated temperatures. The cling wrap was then placed on the corresponding plug cells (view Figure 1 for layout of experiment). Once I returned to water again, the soil temperatures were taken from one plug in each treatment with a soil thermometer. The plug cells were then watered with their corresponding temperatures to field capacity and the soil temperatures were taken after the water finished draining out with the soil thermometer. Ten minutes passed after the watering and the soil temperatures were taken again. Cling wrap was removed before watering and replaced after all the soil temperatures were taken. The plug cells were also removed from the heat mat to water to ensure the water temperatures did not run and affect the other treatments as well as affect the heat mat. Plug cells were then replaced to the heat mat once all temperatures were taken. This process was continued every time the plug cells were watered every other day. Once the plants emerged from the potting media and opened their cotyledons, they were counted and recorded. To prevent extraneous variables, the plug containers from the flats were cut into the same sizes to create a 6x5 block, filled with the

same potting soil, placed on the same greenhouse bench, and only one heat mat was used. There were also two identical trials completed, both 14 days long, to compare the results.

Figure 1: Layout of the experiment on the greenhouse bench.

During the experiment, I recorded the dates, water temperatures, soil temperatures before watering, after watering, and 10 minutes after watering, when and how many seedlings emerged, air temperature, and humidity. During the experiment a few issues did occur. Due to severe weather issues from snow there were two times where the time between watering was 3 days.

During the first day of trial 1, one of the greenhouse heaters broke causing the greenhouse temperature to drop to 58°F but was eventually fixed that day bringing the temperature back up. There also were a couple days in a row during the second trial where the temperatures were higher than normal outside of the greenhouse.

The Differing Factors

Soil Temperature

For tomatoes to germinate, the minimum soil temperature must be 50°F, the maximum soil temperature can be 95°F, the optimum soil temperature should be 85°F, and the optimum soil temperature range should be 70-95°F (DuPont and Stivers, 2021). In field soil, a seed needs the soil moisture to be 50-75 percent field capacity in order to initiate germination, so with watering to field capacity the amount of water will not be an issue affecting germination rate (DuPont and Stivers, 2021). By providing also the correct amount of oxygen, temperatures, and light the seeds will germinate the best (DuPont and Stivers, 2021). If one of these factors is off the seeds can germinate slowly or unevenly (DuPont and Stivers, 2021).

Cling Wrap

The cling wrap is wrapped over the containers to trap in humidity. By trapping in humidity it provides better growing conditions for the seeds. For this experiment I wanted to see what would happen if I continued to let the cling wrap on after they emerged. It is recommended that the cling wrap be removed after emergence to allow air and light to reach the plants, and to remove the intense humidity that seedlings may not like (Floret Flowers, 2017). Refer to Figure 2 to see how the cling wrap affected the seedlings growth.

Figure 2: Plant Comparison- Cling wrap used on the bottom group of plants, but not on the top group of plants.

Heat Mat

By using a heat mat, optimal germination soil temperature is able to be reached at all times of the day (DuPont and Stivers, 2021). This is because the heat mat can be set at a specific temperature according to seed requirements (DuPont and Stivers, 2021). If the other germination requirements are met, germination and emergence will be quicker.

Water Temperatures- Help/Inhibit

Having a cold water temperature treatment that is below the minimum soil temperature of 50°F can cause the seeds to go into dormancy and not grow (DuPont and Stivers, 2021). Due to using a cold water treatment there may be a delay in germination compared to the room temperature water. When using room temperature water you would be very close to the lower end of the optimum range at 70°F and should help the seeds germinate (DuPont and Stivers, 2021). This water should not inhibit the seeds in any way. Hot water, can be used to perform a hot water seed treatment (Utah State University Extension, 2020). This is done by placing seeds in a water bath for 10 minutes at 100°F, then placing in a second water bath ranging from 118-125°F for 20-60 minutes depending on the crop (Utah State University Extension, 2020). Then they would be placed in cold water for 5 minutes to stop the heating (Utah State University Extension, 2020). If the water is too hot however, it can end up sterilizing the soil (McCall, 1981). Complete sterilization requires temperatures of 212°F, and partial sterilization requires temperatures of 140-160°F (McCall, 1981).

Results

Water Temperatures

The water treatments were applied every day as close as possible to get the best results. Water was filled in 2-liter bottles and let to sit to room temperature overnight for the room temperature water treatments. For the cold water treatments, numerous identical insulated travel mugs with ice cubes in the water were used to get the water to temperature. The cold water sat to get to temperature for about half an hour before use. The hot water treatments received water that was run through a coffee pot, which regulated to one temperature every use. The coffee pot was plugged into an outlet and run in the greenhouse to ensure uniform temperature. The plants were watered to field capacity to ensure they were all watered the same amount. The average water temperatures are shown in Table 1 for trial one and Table 2 for trial two.

Date	**Water Temperature Treatment**		
	Room Temperature (°F)	Cold Temperature (°F)	Hot Temperature (°F)
25-Feb	66	38	182
28-Feb	68	38	182
2-Mar	68	40	182
4-Mar	68	38	182
6-Mar	68	42	182
9-Mar	68	40	182
AVERAGES	**68**	**39**	**182**

Table 1: Water temperatures for trial 1

Date	Water Temperature Treatment		
	Room Temperature (°F)	Cold Temperature (°F)	Hot Temperature (°F)
12-Mar	68	38	182
14-Mar	68	37	182
16-Mar	68	36	182
18-Mar	68	38	182
20-Mar	68	36	182
22-Mar	68	36	182
24-Mar	68	36	182
AVERAGES	**68**	**37**	**182**

Table 2: Water temperatures for trial 2

Soil Temperatures

The potting soil temperatures were measured before watering, after watering, and 10 minutes after watering for every treatment. I measured before watering to see what the soil temperatures were before the effect of the water and to see how the heat mats were affecting the soil. I measured after watering to see the immediate difference the water would cause. I then measured temperature 10 minutes after watering to see how long the affect from the water was lasting. If you view Table 3, you will be able to see the average differences between the three measurements collected from each measurement for trial 1. These measurements for trial 2 are shown in Table 4. Due to a spike in outdoor temperatures during trial 2, the data would be skewed from averaging the numbers so the differences were averaged instead to get a better idea

of the overall temperature change. The highest temperature the hot water caused was about 140°F. The room temperature water reached a high of about 68°F. The cold water caused the lowest temperature of about 50°F. There was little change in soil temperatures for the room temperature water in both trials. The hot water made a large difference in temperature, and the temperature change remained after the 10 minutes.

Treatment	Average temp. change after adding water treatment (°F)	Average temp. change from before watering to 10 minutes after watering (°F)	Average temp. change from after watering to 10 minutes after watering (°F)
A1: RT	-1.6	-0.8	0.8
A2: RT- CW	-2.4	-1.2	1.2
A3: RT- HM	-2.8	-2	0.8
A4: RT- CW+HM	-2.4	-1.2	1.2
B1: CT	-14.8	-11.6	3.2
B2: CT- CW	-14	-8.8	5.2
B3: CT- HM	-22	-16.8	5.2
B4: CT- CW+HM	-18.8	-13.2	5.6
C1: HT	50.8	40.4	-10.4
C2: HT- CW	48	38	-10
C3: HT- HM	49.4	36	-13.4
C4: HT- CW+HM	44.8	34.4	-10.4

Table 3: Change in soil temperatures before and after applying water treatments from trial 1

Key: RT- Room Temperature Water, CT- Cold Temperature Water, HT- Hot Temperature Water, CW- Cling Wrap, HM- Heat Mat

Treatment	Average temp. change after adding water treatment (°F)	Average temp. change from before watering to 10 minutes after watering (°F)	Average temp. change from after watering to 10 minutes after watering (°F)
A1: RT	-4.2	-3.3	0.8
A2: RT- CW	-4.7	-3.7	1.0
A3: RT- HM	-2.8	-2.2	0.7
A4: RT- CW+HM	-7.3	-5.7	1.7
B1: CT	-18.7	-13.7	5.0
B2: CT- CW	-17.0	-11.8	5.2
B3: CT- HM	-19.0	-14.3	4.7
B4: CT- CW+HM	-18.7	-14.3	4.3
C1: HT	53.0	43.3	-9.7
C2: HT- CW	49.3	34.0	-15.3
C3: HT- HM	61.2	47.7	-13.5
C4: HT- CW+HM	51.7	37.7	-14.0

Table 4: Change in soil temperatures before and after applying water treatments from trial 2

Key: RT- Room Temperature Water, CT- Cold Temperature Water, HT- Hot Temperature Water, CW- Cling Wrap, HM- Heat Mat

Humidity and Greenhouse Temperatures

In order to see how the greenhouse environment was affecting the plants that were growing, a monitoring device was used that determined the air humidity and temperature. This helped to see if there might be an explanation for any spikes in soil temperatures before watering

or if it might have affected the emergence of the plants. If you view Figure 1, the air humidity and temperatures can be seen for trial 1 and Figure 2 shows the air humidity and temperatures for trial 2. Looking at the second trial you can see there was a large increase in air temperatures compared to the first trial which may explain the huge spike that was seen in emergence for trial 2. During the first trial, the temperatures were relatively similar. Humidity varied over both trials.

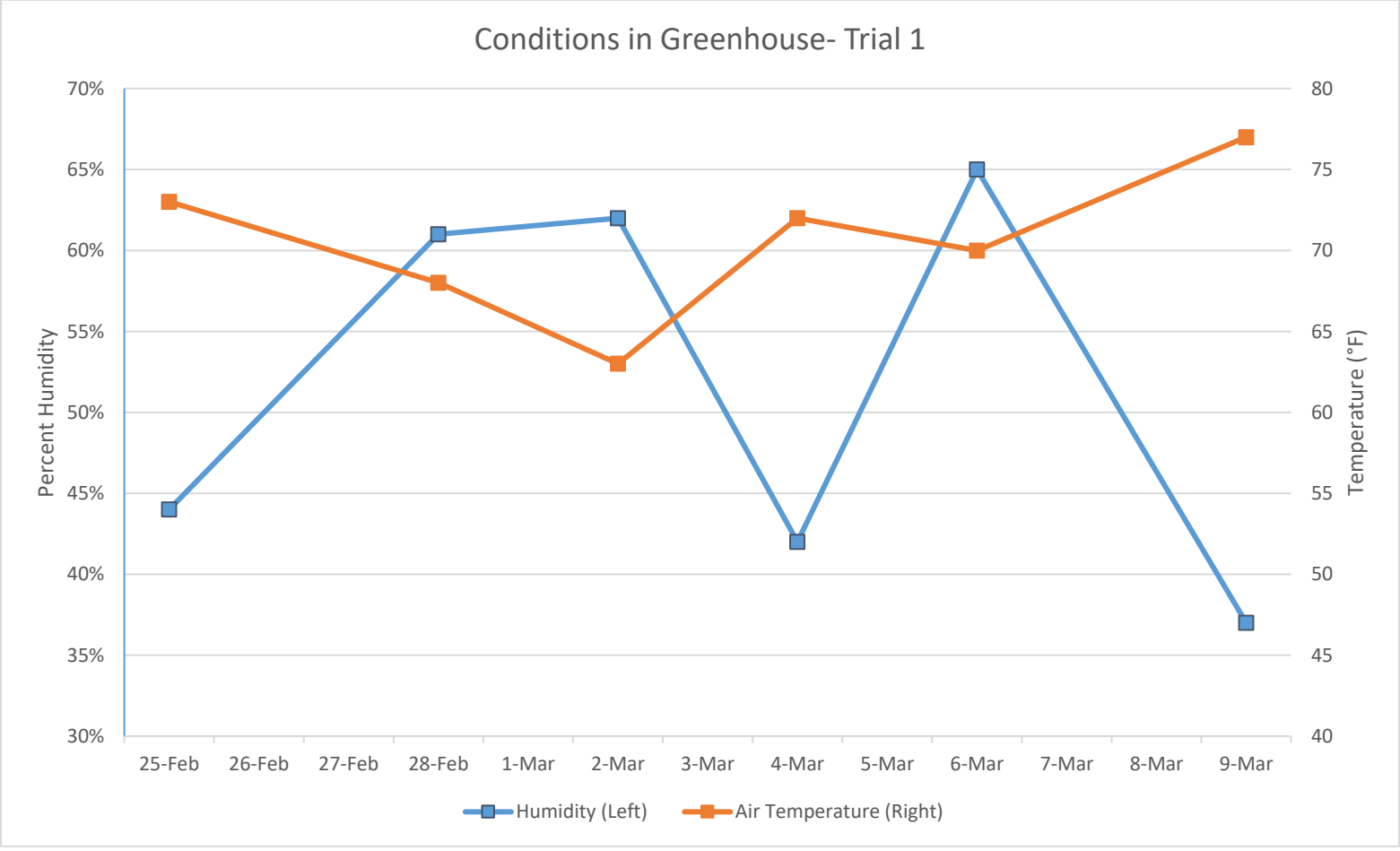

Figure 3: The greenhouse conditions from trial 1: air temperature (°F) and humidity (%)

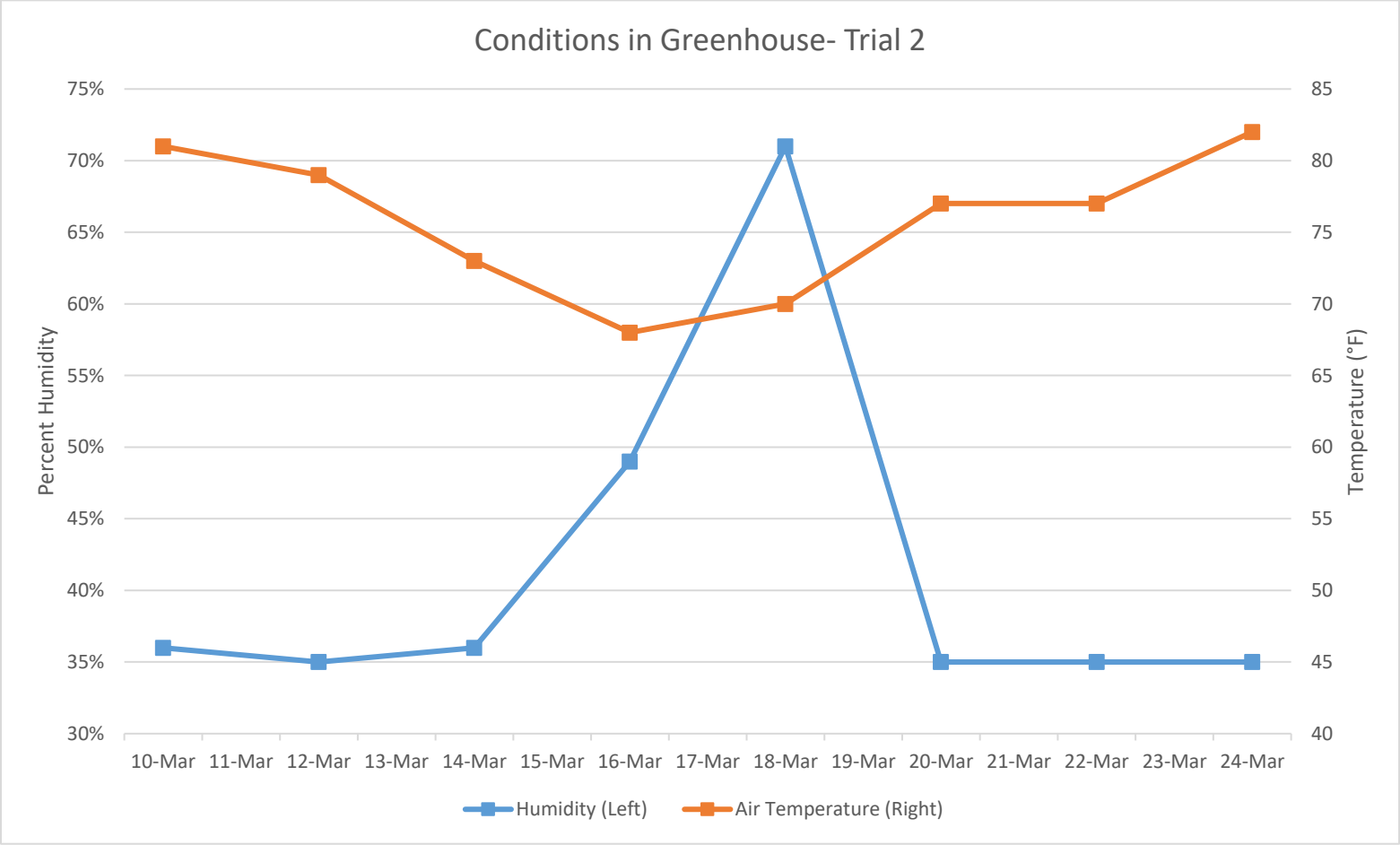

Figure 4: The greenhouse conditions from trial 2: air temperature (°F) and humidity (%)

Emergence

The results of emergence varied between the two trials. I believe that the spike in outside temperature during the second trial contributed to the increase of emergence across treatments in the second trial causing the differences between the two trials. For the number of plants emerged per treatment for trial 1 view Figure 3, for trial 2 view Figure 4. At the first signs of life during trial 1, the cling wrap and heat mat with room temperature water showed the biggest spike in plants that emerged followed by the cold temperature water with the cling wrap and heat mat. By

the end of the 14 days however, the biggest amounts of plants that emerged were in the room temperature water treatments with no factors, the room temperature water with the heat mat, and the cold temperature water with the heat mat. During trial 2, the plants all emerged relatively similarly across all of the treatments. By the end the biggest amount of plants were in the room temperature water with no factors, the room temperature water with the heat mat, and the cold temperature water with no factors. During both trials though, the worst treatments for emergence were the room temperature and cold temperature water with just cling wrap. The hot water treatments for both trials had no emergence, due to the temperatures being too high.

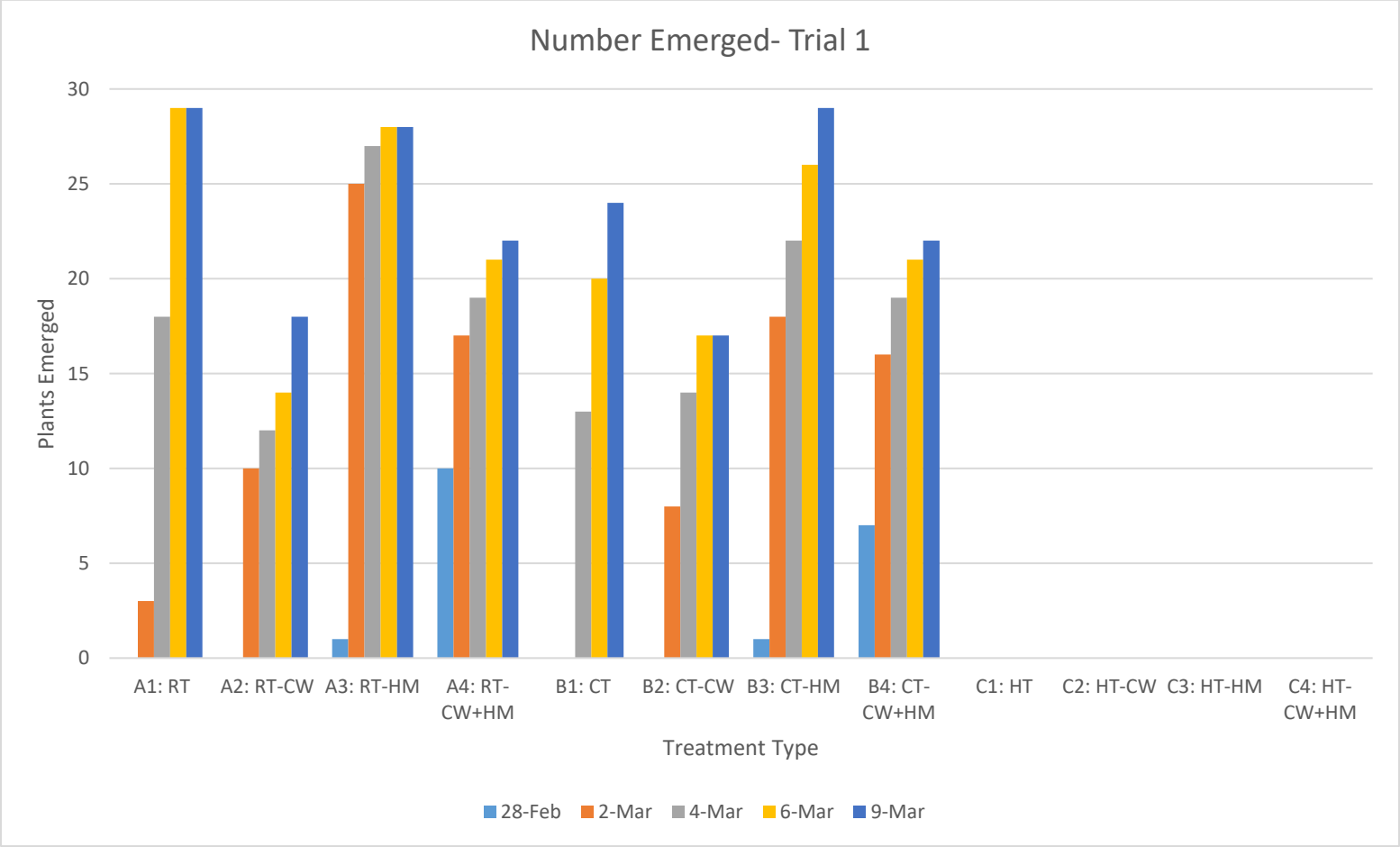

Figure 5: The number of tomato seedlings that emerged from trial 1: cotyledons must be expanded to count

Key: RT- Room Temperature Water, CT- Cold Temperature Water, HT- Hot Temperature Water, CW- Cling Wrap, HM- Heat Mat

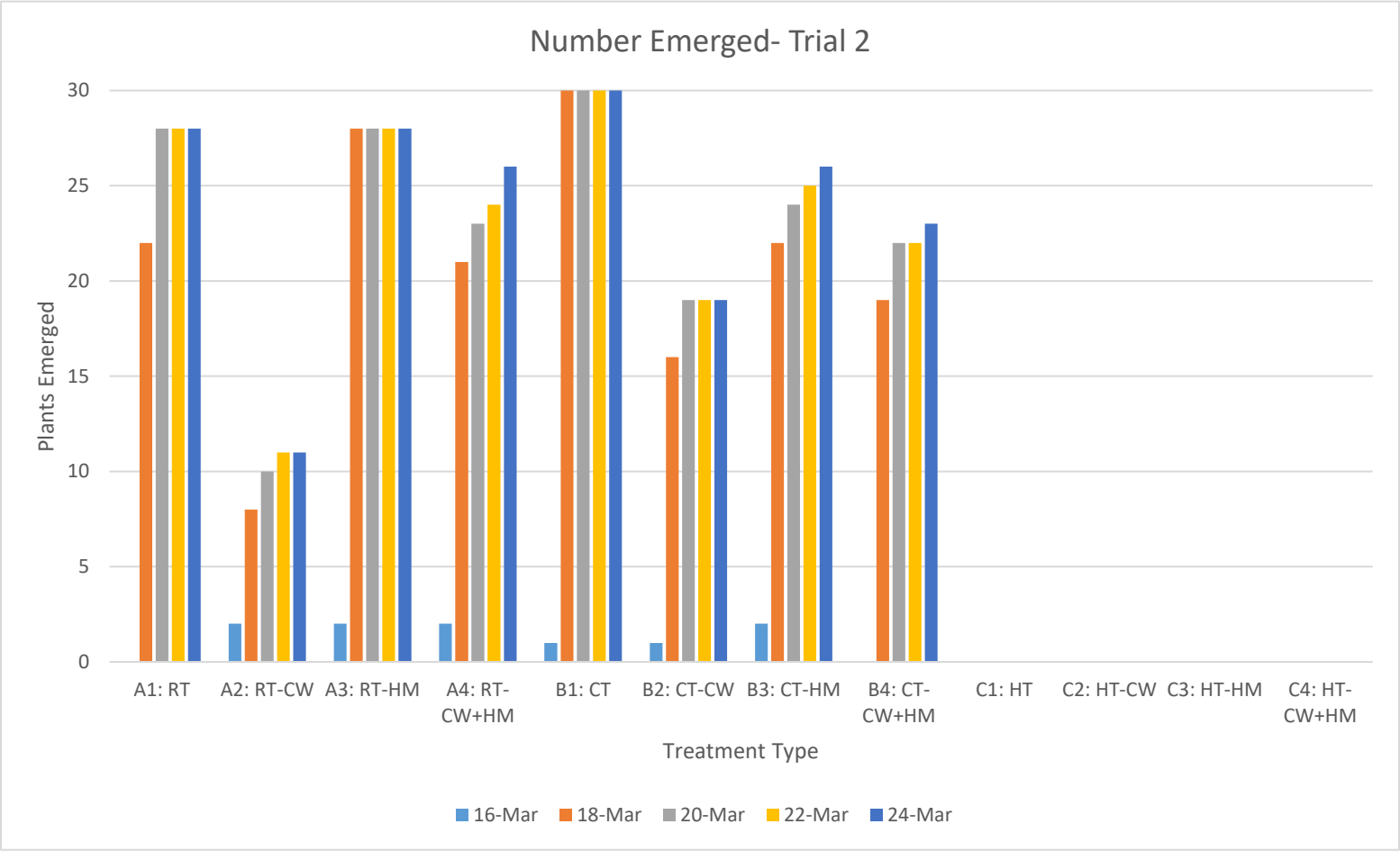

Figure 6: The number of tomato seedlings that emerged from trial 2: cotyledons must be expanded to count

Key: RT- Room Temperature Water, CT- Cold Temperature Water, HT- Hot Temperature Water, CW- Cling Wrap, HM- Heat Mat

Conclusion

Overall, more trials would have to be completed to determine if these treatments would be effective for increasing emergence rates in seedlings. The hot water treatment however would not be effective to promote seedling emergence. The temperatures during the experiment were hot enough to partially sterilize the soil and are the probable cause why none of the seedlings emerged in all of the hot water treatments (McCall, 1981). Results from emergence for both trials show the heat mats help emergence compared to those that only received cling wrap or no outside factors. This can be explained due to the optimum soil temperature range for tomatoes being between 70-95°F (DuPont and Stivers, 2021) and the heat mat temperature being a constant 72°F. Since the treatments that were on the heat mat were receiving soil temperatures within the optimum range, they were able to emerge quicker and more uniformly. The cling wrap treatments did not do as well when not combined with the heat mat, but if it would be removed once emergence occurs in a future trial it might have better results. The changes in temperature were the most extreme for the cold and hot water which may have caused the decrease in and lack of emergence in the treatments. The purpose of this experiment was to determine which treatment(s) resulted in a greater emergence rate, so possibly having trials completed when the outside weather is colder could have greater results with treatments using the heat mat. Based on this experiment, using a heat mat and room temperature water would have the best chance at giving the best emergence; it would just have to be determined if it would be financially viable to implement in a greenhouse setting.

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