The Effects of Different Matrices on Tomato Plant Growth for use in Future VOC Experiment

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Introduction

Tomatoes are known to produce volatile organic compounds (VOCs). VOCs are known greenhouse gases. VOCs emitted by tomatoes growing in greenhouses can be converted to electricity and CO_2, increasing growth and productivity. Tomatoes grown in greenhouses provide a model environment and organism for study as they are a sealed system, where VOCs can be removed by converting to CO_2. In order to detect VOCs a proof of concept study was performed using two different strains of tomatoes, Roma and Sweetie. Growth was analyzed using two different matrices of Whatman filter paper and Jiffy peat pellets. Tomatoes were germinated and grown in Schenk & Hildebrandt Basal Salt Mixture. Variables examined were length of shoots and length of roots.

Background

This concept was conceived after noticing that eucalyptus trees grown during deuteration experiments produced strong odors. Further research showed that many plants produced larger than average amounts of Biogenic Volatile Organic Compounds (BVOCs). Some of these BVOCs, such as 6-carbon alcohols, are combustible. This stimulates the thought that, if grown in a controlled environment such as a greenhouse, some plants could produce enough combustible BVOCs to enhance the carbon dioxide (CO^2) for reintroduction to those plants, as well as a host of other benefits.

Since tomatoes are grown in mass quantities in greenhouses to meet demand, using them as test products was relatively simple. The principle experiment was broken into two phases. Phase 1 was the actual growth of tomato plants from seed. The two breeds of tomato selected for testing were Roma and Sweetie due to their high demand for produce and their hardy disposition for growth in vast conditions. Some test seeds were planted on filter paper with only growth solution as would be used hydroponically, while others were planted in peat soil. Seeds were then studied under controlled environmental conditions similar to those in a greenhouse for growth rates.

During Phase 2 of the experiment, established tomato plants of both mentioned breeds will be studied for VOC production. In the test model, a pump pulls the air containing the BVOCs produced from the plants in the greenhouse through a tin oxide sensor that detects, and in essence burns, combustible BVOCs. The combustion process creates carbon dioxide that is then sent to the gas analyzer where the CO2 percentages are measured to then be recycled back to the greenhouse for uptake by the tomato plants.

The produced enhanced carbon dioxide aides the plants in producing larger and better tasting fruit. Furthermore, BVOC emissions into the atmosphere, water consumption, and greenhouse heating costs would be reduced, while the growing season and production is increased.

Methods

1. Dissolve Basal Salt Mixture into 1 L distilled water.
2. Label jars:
   - Roma with filter
   - Roma with peat
   - Sweetie with filter
   - Sweetie with peat
3. Place materials in jars:
   - Peat moss soil in 2 jars
   - 1 filter paper in 2 separate jars
4. Pour Basal Salt Mixture into jars.
   - Peat: Enough to moisten soil (~50 ML)
   - Filter: Enough to cover the filter paper
5. Use forceps to place 4 seeds (roma and sweetie) into appropriate jars. Space seeds equally apart and 1 inch from edge of jar.
6. Close jars with vented lids and place in location with indirect sunlight.
7. Monitor daily and collect observations. Record length of shoots and roots in data table (cm).
8. Calculate the average length of shoots and roots for each jar after 10 days.

Materials

- 5 32 Oz Mason Jars
- 2 Whatman Filter Papers 90 mm diameter
- Distilled water (1 L)
- Schenk and Hildebrandt Basal Salt Mixture
- Peat Moss Soil (2)
- Tomato Seeds - Roma (8 seeds)
- Tomato Seeds - Sweetie (8 seeds)
- 4 vented lids
- 1 closed lid
- Forceps

Results

Root and shoot growth were averaged from 7 participants' measurements over a 9 day period. All measurements and averages were recorded in millimeters.	Key	
	R	Root Growth
	S	Shoot Growth
	F	Whatman #1 Filter Paper
	P	Peat Pellet

Figure 1: Description of data collected, units and key.

Days	Roma R-F	Sweetie R-F	Roma R-P	Sweetie R-P	Roma S-F	Sweetie S-F	Roma S-P	Sweetie S-P
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0.75	0.07	0.19	0.19	0	0	0	0
4	4.74	1.75	4.06	0.94	1.91	2.00	1.63	1.38
5	14.43	6.89	N/A	N/A	7.62	5.46	13.93	12.91
6	19.50	13.10	N/A	N/A	19.38	12.97	27.69	21.58
7	31.70	23.62	N/A	N/A	31.01	23.17	40.39	34.18
8	38.06	30.54	N/A	N/A	53.04	33.94	53.53	48.06
9	50.12	36.70	N/A	N/A	64.48	39.79	59.48	54.66

Table 1: Data collected over 9 day period of the tomato varieties Roma and Sweetie; averages of lengths of roots and shoots in millimeters.

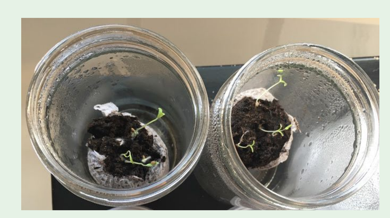
Figure 2: Peat Pellet Growth Week 1


Figure 3: Filter Paper Growth Week 1

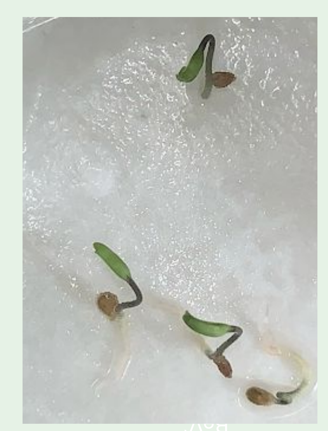
Figure 4: Filter Paper Germination

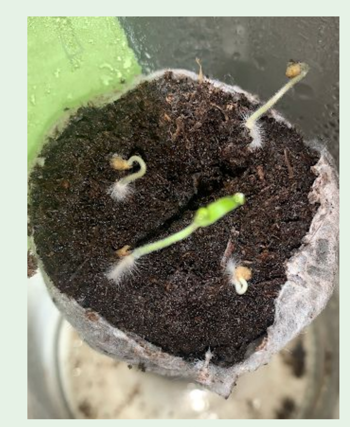
Figure 5: Peat Pellet Germination

Week 1

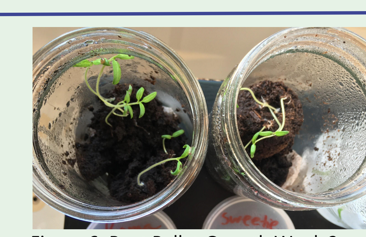
Figure 6: Peat Pellet Growth Week 2

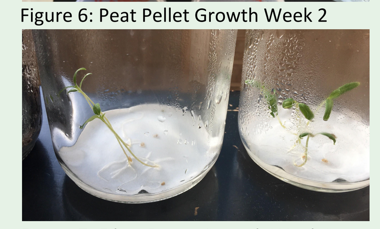
Figure 7: Filter Paper Growth Week 2


Figure 8: Filter Paper Growth


Figure 9: Peat Pellet Final Growth

Week 2

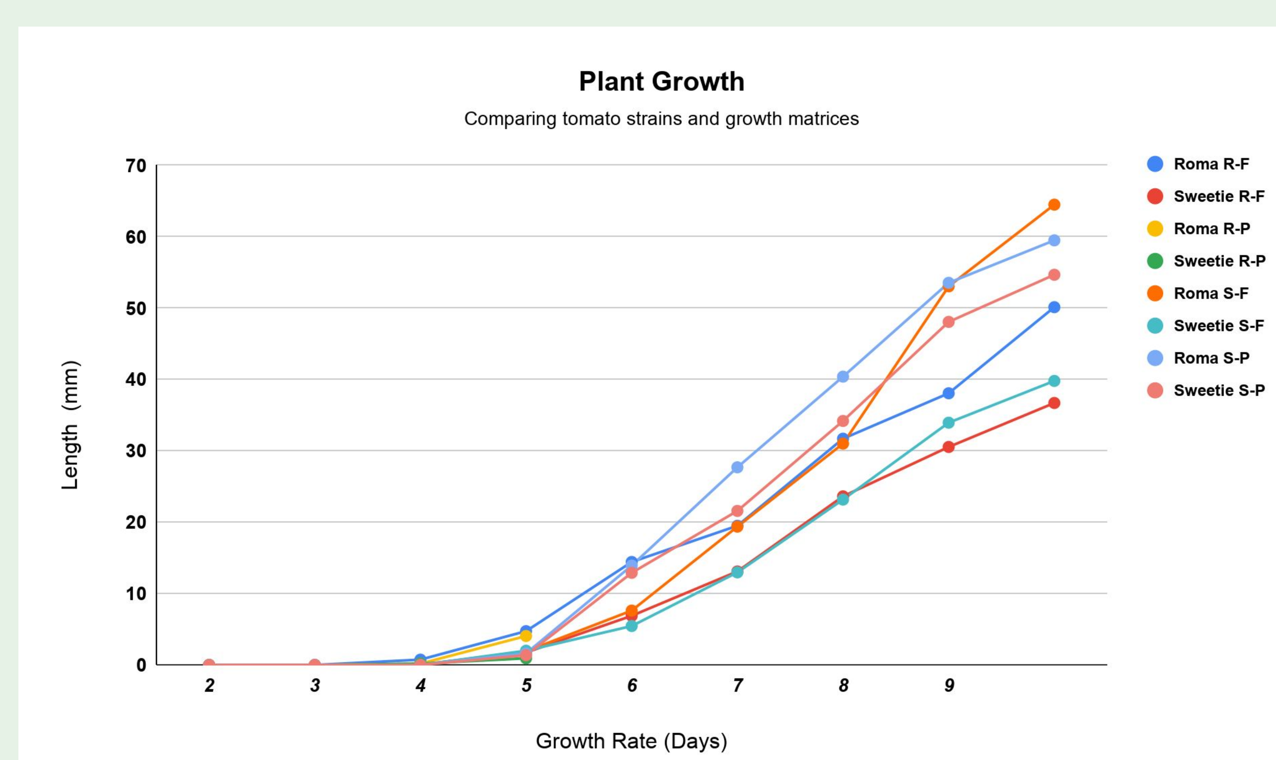

Figure 10: Graph of average root and shoot growth by day for the duration of the experiment in millimeters. R-F = Roots, Filter Paper; R-P = Roots, Peat Pellet; S-F = Shoots, Filter Paper; S-P = Shoots, Peat Pellet.

Conclusions

This experiment, as proposed, investigates the effects of different matrices on tomato plant growth for use in future experiments.

After 9 days of growth, the filter paper showed the greatest amount of root growth for both tomato species. The Roma had an average root growth rate of 0.926 mm/day and the Sweetie had an average root growth rate of 0.891 mm/day.

With respect to shoot growth, the peat pellets demonstrated the greatest growth with 0.905 mm/day for the Roma and 0.898 mm/day for the Sweetie. Determinate tomatoes, such as Roma, will reach a peak height within a certain timeframe and bear fruit all at once. Indeterminate tomatoes, such as Sweetie, will continue to grow and bear fruit throughout the growing season. Having this variety will give greenhouse growers more flexibility in establishing a set growing schedule.

Based on the data, the filter paper showed the greatest initial growth for the root systems, indicating that this could be a viable medium for starting tomato plants prior to moving to peat pods to encourage shoot growth.

The implications, provided by the results, can extend into further study of VOC emissions to extend growing seasons while generating a reduction in energy cost and consumption.

Future Research

- Collection of volatile organic compounds (VOCs) to burn and produce an electrical current and carbon dioxide production to increase greenhouse productivity
- Environmental impacts of VOCs on climate and carbon dioxide recycling
- Comparison of VOCs production for crop plants in greenhouses to produce electrical currents and carbon dioxide recycling for crop yield

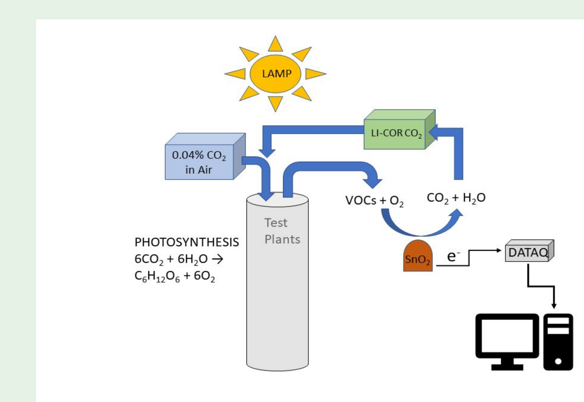

Figure 11: Tomato Power Concept: Combust BVOCs from tomatoes to CO2 to generate electricity then recycle CO2 for photosynthetic carbon fixation

Sources

Evans, B. (2020). Tomato Power Presentation (PowerPoint Presentation). ARC/ORNL Summer Institute.

Vivaldo, G., Masi, E., Taiti, C. *et al.* The network of plants volatile organic compounds. *Sci Rep* 7, 11050 https://www.nature.com/articles/s41598-017-10975-x#Abs1 (2017). https://doi.org/10.1038/s41598-017-10975-x

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