Evaluating the Effects Chemical Complexity on the Early Growth of Crassula Ovata Cuttings

Snehansh Bachala
Rouse High School, Leander Texas, 78641.

Summary

Urban environments often lack greenery despite past research suggesting that green spaces are strongly linked to an improved mental state. Among the most resilient of plants is the Jade Plant (Crassula ovata). Despite their resilience, little research has been conducted testing their interaction with unconventional household liquids. The purpose of this study is to investigate the effects of six common household liquids such as plain water, sparkling water, black coffee, milk coffee, tea, and coffee grounds on the growth of Jade Plant cuttings over a period of four weeks. The study employed an experimental design in which eighteen Jade Plant cuttings are exposed to standardized conditions, with fluid type being the only independent variable. It was determined that plain water produced the highest growth, followed by tea and coffee grounds, with milk coffee and black coffee having significant inhibitory effects on plant growth while sparkling water was determined to have no effects on plant growth. These findings support the hypothesis that chemically simple irrigation solutions are optimal for plant growth, with plant growth having a negative correlation with solutions that contain acids, caffeine, and even organic compounds, contributing to the understanding of plant environment interactions.

Literature Review

Urban environments are increasingly dominated by concrete structures and brutalist design, with fewer plants and less visible greenery. At the same time, research consistently links access to green spaces with better mental health and well being (Barton, n.d.). Succulents are well suited to address this problem because they can tolerate poor soils, irregular watering, and harsh microclimates, which means that they can survive in apartments, offices, and dense urban streetscapes whereas other plants that aren't as resistant. However, while there is growing interest in using unconventional inputs such as carbonated water, coffee, tea, or coffee-based composts to influence plant growth, there is little research on how everyday household fluids affect the growth of tough ornamental plants in controlled conditions. In particular, no studies were found that evaluate how household fluid solutions and chemically complex compounds influence the short-term growth of succulent cuttings. This gap leads to the guiding research question: To what extent are jade cuttings growth affected by varying chemical compounds at room temperature in a four-week period, in comparison to plain water? The hypothesis being that plain water will produce the greatest net growth and that sparkling water will produce the least.

Recognized Patterns:

Across the literature, a first clear pattern is that relatively small changes in the chemical composition of a liquid can produce large differences in biological response. In a field study on tomatoes, Novero et al. compared drip irrigation with plain water and carbonated water and reported that carbonated water under plastic mulch increased yield by approximately 10 to 16 percent (Novero et al., 1991). This effect did not result from additional moisture since irrigation volumes were comparable. Instead, carbonated water produced brief spikes in canopy CO and, more importantly, elevated soil CO and lowered soil pH for several days, which likely improved nutrient availability and uptake (Novero et al., 1991). Kaur et al. observed a similar sensitivity in beverage formulation; by systematically increasing the proportion of brewed black tea extract in a tea and fruit energy drink, they showed that caffeine, total phenolics, and antioxidant activity rose in a dose-dependent manner, whereas apple concentrate mainly modified sweetness, acidity, and soluble solids (Kaur et al., 2021). In other words, the authors specifically highlighted that higher tea extract resulted in greater caffeine and phenolic content which means that relatively small changes in the recipe significantly shift the drinks flavor profile (Kaur et al., 2021). Taken together, these studies imply that household fluids like sparkling water, black coffee, milk coffee, and tea are unlikely to act as neutral water sources.

A second pattern is that the quality and environmental context of caffeinated and tea-based substances strongly influence their effects in both plants and humans. Ye et al. demonstrate that tea plants regulate caffeine through complex crosstalk between jasmonate (JA) and gibberellin (GA) pathways (Ye et al., 2025). DELLA proteins actually improve resistance against fungal infection, while knockdown of these proteins produces lower caffeine and weaker defense (Ye et al., 2025). This paper poses caffeine as a flexible defense metabolite shaped by signaling networks rather than a fixed trait. Jhou et al. link the chemical quality to the environment by growing Camellia formosensis under three different natural light intensities in a several Taiwanese forest sites in which they found that higher light quantity increased bud yield and elevated certain catechins while deeper shade increased EC and sometimes reduced caffeine (Jhou et al., 2025). Their effects depend on how they are grown, processed, brewed, and combined with other components. When applied to the present research problem, this can mean that brewed black coffee, unsweetened milk coffee, and tea prepared at home may differ in caffeine, polyphenol, and fat content in ways that alter both biological plant responses and microbial activity in the soil around jade cuttings.

A third recurring pattern is that the coffee-based inputs and compost teas can support plant growth and promote disease resistance at certain doses and recipes but they can also become harmful when overapplied or even when the microbial populations are not controlled. Ciesielczuk et al. prepared experimental fertilizers from blood meal, spent coffee grounds, and biomass ash, then tested them on early seed germination and root growth of cress, wheat, cucumber, and mustard (Ciesielczuk et al., 2017). They found that at low to moderate doses, germination was acceptable and some species like cucumber even had longer roots, meaning it can be helpful. But, it is important to keep in mind that at higher doses, particularly in mixes with elevated salinity or pH, root growth was inhibited and sensitive species like cress were strongly affected

(Ciesielczuk et al., 2017). The authors emphasize that coffee-based fertilizers can shift from beneficial to toxic depending on concentration and composition as well as its suitability to each plant. Dionne et al. investigated non aerated compost teas made from different manures and organic materials and applied them to tomato seeds and seedlings exposed to pathogens (Dionne et al., 2012). All teas strongly slowed fungal growth and reduced seedling mortality, but they didn't reduce damage from Rhizoctonia which is a thin fungi form (Dionne et al., 2012). When most of the teas were sterilized, a lot of the protective effects disappeared which meant that the live microbial communities were vital to suppress disease (Dionne et al., 2012). The authors also noticed that tea recipes, compost sources, and brewing conditions can substantially change outcomes.

Overall, existing studies lead to an overarching insight. It is that fluid chemistry matters since caffeinated and tea-based substances function within complex quality and environmental contexts and it is important to keep in mind that coffee-based soil inputs are highly dose and microbe dependent. However, there remains a clear gap regarding the controlled application of everyday household fluids to succulent cuttings, particularly jade plants, over a short growth period. A study that waters jade cuttings with plain water, sparkling water, black coffee, unsweetened milk coffee, tea brews, and coffee grounds in solution directly builds on these patterns and addresses an unanswered question that is relevant to low-cost strategies for increasing resilient greenery in urban environments to combat ecosystem deprivation.

Research Design & Methodology

Design:

The aim of this project is to examine the effect of different domestic fluids for the early growth of Jade cuttings. The inquiry that this project intends to answer is if domestic household fluids, and domestic wastes, engender any difference to the growth of succulents when put to the test in a home environment. Succulents are widely used in urban greening projects due to their environmental resilience and ease of growth for promoting environmental greenery in harsh urban areas that lean towards brutalist architectures, thereby harming mental health of the people in that area.

There is one experimental design that has been complemented by the utilization of repeated trials and standardized procedures to improve the reliability of results. All the variables in the environment, such as the type of soil, size of the pot, temperature and fluid type, light, and irrigation interval, are standardized. This proportional watering method was used to ensure consistency across treatments while minimizing overwatering risk, which is particularly critical for succulent species with the only factor that has been allowed to be variable in this experiment is the fluid type that the cutting receives.

Subjects:

The subjects for the experiment consisted of eighteen cuttings of the jade plant (Crassula ovata). The jade plant was chosen as the model species because it is known to root well from cuttings, withstand the drought phase, and be a commonly studied type of succulent for studying the early growth of succulents as well as its resilience and accessibility. The cuttings will come from a single plant to limit natural genetic and developmental variability with each sample as a data point.

Growth was measured as the net biomass increase from the beginning of the completion of the four week term. The measurement of the increase in mass was used because growth in jade cuttings is sometimes slight, and measuring growth in terms of height or leaf expansion might be difficult and indeterminate in a short period of four weeks.

Research Procedures:

Based on the prepared materials, a pack of approximately half a cup of succulent soil was measured and put in each plastic cup to maintain equality in the amount of soil in the eighteen cups. The weight of each jade cutting was measured before the plant to determine the initial weight with one cutting placed in the center of each cup. All the cups rested along the windowsills in relatively close proximity to provide an equal amount of light. Using a thermometer, the temperature of each fluid was verified to be at 74F before watering each cup. Each cup was given a fluid amounting to 12.5 ± 2.5 percent of the soil's weight when dried. This proportion was maintained to avoid the risks associated with overwatering, especially in succulents. The soil was allowed to dry completely each time after the watering process and this absence of moisture in the soil column was determined by checking the exterior walls of the cup to make sure there was no moisture present.

Each of the cuttings taken out at the end of week four was removed, cleaned delicately to remove any clinging soil, and weighed with the same scale. The net growth value was then calculated by subtracting the initial weight from the final weight. For each fluid category, the three growth values (A, B, and C) were averaged. The averages were then ranked in order from highest to lowest to find the values with the highest and lowest growth rates in each fluid category. If a cutting died in the test, it was assigned a growth value of zero to represent its results.

Justification of Methodology:

To ensure rigor and generalizability of the results, future studies should ensure that plant growth is assessed more rigorously by using statistical models to compare mean differences between conditions. One-way ANOVA can be used to compare means between conditions to check if the null hypothesis, are $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6$, is true with the alternate hypothesis being that at least one μ plant growth differs to a non negligible biomass difference. In addition to that, Tukey's HSD can be used for post-hoc pairwise comparison.

Limitations

Like any scientific experiment involving plant growth, some constraints are bound to occur. The changing temperatures with the seasons, especially the cold winter air, may inhibit growth of the cuttings regardless of treatment groups. Divergences in the biology of the individual cuttings, despite coming from the same source, are bound to occur.

Another hazard associated with milk and organic residue treatment methods is mold growth since it can be damaging to root development and growth because mold development has the potential to be transferred from one pot to another in the case of close placement of the cups containing the growth medium. The measure taken to prevent this from happening is by keeping the cups 3 inches apart and frequent check-ups. Even with those precautions, the potential for interference by microorganisms still exists. The test period is only four weeks, and the results are thus limited to the initial growth pattern and cannot extend to the entire life process in terms of plant health and maturity.

Ethical Considerations

The project does not involve human subjects and does not include any endangered species and all the materials used will be commonly known household materials. Any waste liquids, especially those that tend to mold easily, will be properly disposed of. Since the jade plants are hardy and unobtrusive, the risks associated with the project are low. There are no issues associated with anonymity and human subjects safety and consent. Moreover, results may lack detail due to the food scale used in this experiment's lack of ability to display more than one decimal point when measuring in grams.

Delimitations

There are a number of boundaries that will be clearly defined within this project. Only those related to jade cuttings will be considered, while other succulent species and full-grown jade plants will be omitted. The conditions will also be confined to a particular indoors setting in order to provide a standardized effect due to light and temperatures. The number of household fluids to be employed is also limited to six examples for this study.

Results

The results obtained from the experiment show very distinct differentiation in the results obtained from all the six treatments of fluids, and it is evident that all the plant cuttings watered with plain water showed the highest levels of growth. The plant cuttings watered with plain water showed a total increase in growth of 7.5 grams across all three trials. The levels of growth obtained from all the plant cuttings were also very consistent, and they showed levels of 2.5, 2.3, and 2.7 grams. The second-highest levels of growth were obtained from plant cuttings watered with tea, and they showed a total increase in growth of 5.3 grams. Although this is a very low level of growth compared to the levels obtained from plant cuttings watered with plain water, all the plant cuttings showed very consistent levels of growth across all three trials, and they showed levels of 1.8, 1.6, and 1.9 grams. The plant cuttings watered with coffee grounds showed moderate levels of growth, and they showed a total increase in growth of 3.5 grams. They have a very low level of growth compared to plant cuttings watered with tea and plant cuttings watered with plain water with all plant cuttings showing some levels of growth, and they showed levels of 1.2, 1.0, and 1.3 grams.

On the other hand, the results obtained for the milk coffee indicated that it caused limited growth with the total amount of growth being only 1.2 grams. Even though the results obtained indicated that there was an increase in the mass of the cuttings, the amount of growth was limited in nature. This shows that some form of constraint was in place, despite the fact that growth was evident. The results obtained for the black coffee indicated that it caused negligible growth with a total amount of growth of only about 0.2 grams. Out of the three replicates, two of them did not show any form of growth, while the third one showed a small amount of growth in the mass of the cutting. This indicates that some form of inhibition was in place, as the results were negative in nature. The worst form of results was obtained for the sparkling water, as no form of growth was evident in all the replicates. The raw data in the table can be seen in **Figure 1**.

Results	Water (74°)	Black coffee (74°)	Milk coffee (74°)	Ardor Sparkling Water (74°)	Tea Leaf (74°)	Coffee Ground (74°)
Growth for Cup A (grams)	2.5	0	0.5	0	1.8	1.2
Growth for Cup B (grams)	2.3	0.2	0.3	0	1.6	1
Growth for Cup C (grams)	2.7	0	0.4	0	1.9	1.3
Total Growth per Cup	7.5	0.2	1.2	0	5.3	3.5
Order (Greatest --> Least) Growth	1	5	4	6	2	3

Figure 1

The results obtained from the experiment indicate that there is a gradient of efficacy in place, as the results show that the efficacy of the growth decreases as the treatments move further away from the chemical simplicity of the water. It is crucial to note that all the treatments with a higher acidity level and chemical complexity stunted growth.

Discussion

When comparing the data with each independent variable, it becomes evident to the extent of growth of each chemical compound stimulated in Figure 2.

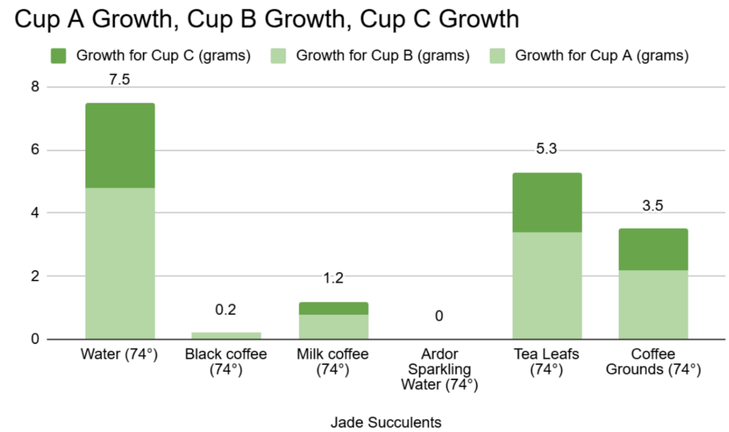

Figure 2

Findings and Analysis:

First, a one way analysis of variance (ANOVA) was conducted to determine whether there were statistically significant differences in mean growth among the six fluid treatments. ANOVA is the right method to analyze this data because the experiment has one independent variable (the type of fluid), multiple groups (6 different liquid growth stimulants), and one dependent variable (plant growth measured in grams of net biomass). In order to conduct the experiment, the variables - MSB, MSW, SSB, SSW, and F - statistic need to be defined.

1. MSB = average variation **between** groups
2. MSW = average variation between **within** groups
3. SSB = variation between the mean growth of each fluid group and the overall mean growth
4. SSW = variation between each fluid group to depict the random variation among plants receiving the same treatment
5. F = the ratio of variation between groups to variations within groups

The F statistic was calculated in the ANOVA method as shown in **Figure 3**.

The F-statistic is defined as:

$$F = \frac{\mathrm{MSB}}{\mathrm{MSW}}$$

where:

$$\mathrm{MSB} = \frac{SSB}{k-1}$$

$$\mathrm{MSW} = \frac{SSW}{N-k}$$

The sum of squares between groups (SSB) is calculated as:

$$SSB = \sum n_i \left(\bar{x}_i - \bar{x}_{\text{overall}}\right)^2$$

The sum of squares within groups (SSW) is calculated as:

$$SSW = \sum\sum \left(x_{ij} - \bar{x}_i\right)^2$$

$$F = \frac{\mathrm{MSB}}{\mathrm{MSW}} = 166.75$$

A one-way ANOVA revealed a statistically significant effect of fluid type on plant growth, $F(5,12) = 166.75$, $p < 0.001$.

Figure 3

This result suggests that at least one treatment group mean differs to a non-negligible amount from the others. Observationally, the water treatment produced the highest mean growth while black coffee and sparkling water produced the lowest growth. Tea and coffee grounds showed moderate growth while milk coffee resulted in limited growth, supporting the conclusion that fluid composition has a significant impact on the early growth of jade plant cuttings.

Although the ANOVA confirms statistically significant differences among groups, the small sample size limits the statistical credibility of the data analysis so larger sample sizes are needed to confirm the applicability of these findings. Additionally, uncontrolled variables such as minor differences in cutting health or micro-environmental variation may have contributed to observed differences.

Based on the ANOVA analysis, we reject the null hypothesis, meaning that there is convincing statistical evidence to prove that the alternate hypothesis is right. This analysis can further be specified to provide substantial support for the original hypothesis that the plain water would produce the highest rate of growth for the jade cuttings. The most relevant studies to this particular study were the ones that supported the viability of the concept of chemical neutrality. The water, which had none of the chemicals like caffeine, sugars, acids, and other gases, provided the growing environment for the jade cuttings to thrive in, suggesting that the absence of chemical stressors support early plant development. Instead of improving growth, the addition of complex chemicals stunted the growth of the cuttings by introducing instability in the root systems of the plant. The failure of sparkle to increase growth is contrary to Novero et al.'s (1991) findings where carbonated water promoted tomato growth by 10-16%. The reason for this contrast in results is because while their experiment was performed on mature tomato plants with fully developed root system, this study used jade cuttings without roots. Root formation is particularly sensitive to external conditions. Therefore, the addition of CO and reduced pH levels in sparkle would have altered the optimal conditions for rooting. Since there was zero growth in all replicates, the lack of effect is directly attributed to the treatment itself. The negative effect of both black coffee and milk coffee is consistent with Ciesielczuk et al. (2017)'s findings that plant growth can be impeded by coffee based treatments due to imbalance in chemical composition and pH. As seen from the results, the fluids created conditions that were detrimental to early root development. On one hand, the strong performance of tea is consistent with Kaur et al.'s (2021) finding about tea's bioactivity and presence of phenolics and antioxidants. But since the effect was inferior to that produced by water, it shows that these components were unnecessary for early growth and possibly induced chemical stress. Overall, these results provide additional evidence for the literature showing that minor changes in the chemical composition of a solution lead to significant biological responses (Novero et al., 1991; Ciesielczuk et al., 2017). Furthermore, it shows once again that the effect of various substances, including caffeine and other chemicals, depends strongly on the context. In the context of the present study, the fact that the jade plant is considered to be one of the most adaptable plants in the world has also demonstrated the idea that, even in the most resistant species of plants, the growth of the plants in the early stages is highly dependent on the environmental conditions.

Implications

The implications of this study are quite widespread and can be considered in various ways. The primary implication is the applicability of this study to general plant care methods in harsh conditions that can be implemented in urban conditions to combat greenery nullification which has been proven to psychologically contribute to an exacerbated metal state. While it is clear that this study is representative of one of the more significant queries in terms of plant care in general, it is also representative of plant-environment relations in general. Regarding sustainability, it is also worth noting that this study offers an in depth understanding of one of the more emerging trends in plant care. Such a trend is the utilization of household waste liquids in plant care. While it is in line with the general sustainability agenda, it is worth noting that it does not necessarily contribute to a more favorable plant growth and development. In fact, it can even lead to stunted growth and/or stagnation of growth and development in plants, as is the case of sparkling water and black coffee. Based on the findings of this study, it is evident that unconventional approaches to the care of plants, like the use of liquids from household waste, may not only be ineffective for the survival and growth of plants but can also be detrimental to the survival of the plants.

Future Directions

One of the first and most important areas for further study with regard to this study is growth dynamics. While the four-week period of this study is within the early stages of development for the plant, it is also important to note that this is a period of time that is mainly for the development of the root structure and for the development of the plant's biomass. By extending this period of time for further study, there is the opportunity to further understand inhibiting factors in the development of the plant and to determine whether or not these factors are present in the development process of the plant in the future or whether or not they have diminished and possibly even reversed in their role in the development process of the plant.

Further research can be conducted in the area of soil microbiology and its relation to the development of plants. The effect of coffee and milk, for instance, may have varying effects on the composition of the soil and the microbiology present in the solution. Further research in the area may be conducted to have a better understanding of the effect of the composition of the solution on the development of the plants and the possible effect of the soil microbiology on the development of the plants.

Another area of expansion of the research is further increasing the scope of the research to cover more plant species. Although the research on the Crassula ovata has increased its chances of yielding better results due to the hardiness of the plant, the chances are still present that the plants may react differently to the research. For instance, the effect of the solution on succulents compared to plants that are not succulents, or the effect of the solution on plants that are resistant to drought compared to plants that require constant water level maintenance for them to develop, may give an idea of the universality of the research. Although the parameter of mass is easy to measure for the development of the plants, it may not give an all-around view of the development of the plants. Another line of study that may yield interesting results is to study the dynamics of soil chemistry. While it has already been established that the level of fluids in the soil has some effect on the plants, what exactly happens to these levels after each treatment still needs to be established. This line of study may yield some results on what exactly happens when different fluids are used.

An additional form of expansion would be to tailor this study to be used to study the effects of environmental variability. This can be done by introducing different levels of light, temperature, and humidity. While the study was done in a controlled environment within the indoor setting, introducing this level of variability may be useful to further tailor this experiment to establish its reliability.

Lastly, there is room for this line of study to be used as part of a broader study on the concept of sustainable urban systems. This can be done by studying the effect of using grey water, compost liquid, and other alternative media for the plants. This may be useful in developing more efficient urban gardening techniques. While this may be useful, this study has shown that these alternative media have a detrimental effect on the plants if not properly evaluated to ensure that they do not hinder plant growth.

Conclusion

The purpose of this study was to explore the seemingly simplistic but under-explored topic of what effect common household fluids have on the growth of plant cuttings. The results demonstrate that water is the most effective fluid for plant growth, indicated by the highest level of net biomass growth. On the other hand, fluids like caffeine, acid, and carbonation, have all demonstrated the reduction/inhibition of plant growth, meaning that any deviation in the chemically neutral environment will have important consequences. In the case of the jade plant cuttings, this does not mean that the plant cuttings are not sensitive.

On a broader scale, the study contributes to the further understanding of the relationship between plants and the environment, demonstrating the way in which micro-scale differences in the fluids' compositions can produce macro-scale differences in the results. The study further demonstrates the understanding that the context in which the plants are exposed to the particular agent or substance can produce differences in the results, with the differences being both positive and negative in their effects, and the development stage playing an important role in the overall result.

The study has given clear and definitive guidelines in the care of plants and has shown the advantages of simplicity and consistency rather than having to experiment using unconventional materials. The study has important implications for the success rate of plant propagation in urban greening programs, household gardeners, and educational programs. This study ultimately proves that plant growth can strongly be influenced by the composition of the watering solution and has in the process demonstrated further understandings of the way in which plants are sensitive to the environment and the conditions that are necessary for the development of life in the very early stages. These findings also open the door for further research on plant environment interactions.

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