Exploring Unconventional Growing Methods to Promote Healthy Plant Growth in Common Household Plants: Tagetes patula L. and Lepidium sativum

Andrew Nguyen, Ryan Nguyen, Teacher Mrs. Williams

Fountain Valley High School, Fountain Valley, California

#### **Abstract**

#### Since its advent during the Green Revolution, chemical fertilizers have been increasingly used for household gardening and commercial agriculture worldwide. Such fertilizers have detrimental impacts to the environment, contributing to nutrient runoff and aquatic dead zones. At the same time, water consumption for agricultural needs has skyrocketed. Alternative growing methods are urgently needed to reduce the impacts of plant cultivation.

#### This experiment focuses on finding more sustainable growing methods that reduce chemical fertilizer or water usage that can be used at the household level for garden plants. Researchers hypothesized that the alternative growing methods would better encourage healthy plant growth as compared to a control. Several marigold and garden cress plants were observed over a 13 week period.

#### Metrics for healthy plant growth were height at first bloom, measuring each plant from base to tallest point, growing time, counted from day of sprout until the end of the experiment, and survival rate, calculated by dividing the amount of surviving plants over the amount of plants that sprouted.

#### The results indicated that the treatments had a statistically insignificant effect on marigold height and growth time, but the DWC (deep water culture) treatment for garden cress plants significantly increased the height and first bloom and decreased the growing time compared to the control group. For survival rate, the treatments had little effect on the garden cress, but the eggshell grounds, wick system, and DWC system groups outperformed the control group for marigolds.

#### **Introduction**

Approximately 12,000 years ago, humanity developed agriculture, ending their formerly nomadic and hunter-gatherer lifestyle. Multiple factors led to this. The end of the last Ice Age set up favorable conditions for crops to grow. As a result of this, humanity began to harvest these plants, slowly transitioning to depend more on and expand their fields. Permanent settlements developed around these agricultural sites, and civilizations prospered (1).

As agriculture has evolved, more complex techniques developed. For instance, slash-and-burn agriculture, the practice of burning areas of fertile land and allowing the ashes to resupply nutrients to the ground, has sustained crop yields for millennia (2). Later, improved techniques and tools developed that boosted productivity. For instance, crop rotation was used to improve the longevity and nutrient content of fields, and the seed drill reduced the amount of waste caused by avian predation on exposed seeds (3).

Most recently, the Green Revolution introduced modern technology into commercial and domestic agriculture, featuring chemical fertilizers and pesticides. Such chemical products have repercussions on the environment, namely increased phosphorous and nitrate concentrations from runoff (4). Excess nutrients enter bodies of water to create large algae blooms that can clog waterways and create “dead-zones,” where aquatic species cannot thrive, due to the oxygen-consuming decomposition of dead algae (5). Furthermore, pesticide runoff poisons fish and the humans of consume them (5).

At the same time, global water usage has skyrocketed for agricultural purposes (6). Approximately one-third of the world does not have access to clean drinking water (7).

Alternative growing methods that reduce chemical fertilizer use and water consumption are desperately required to reduce the environmental impacts of agriculture and plant cultivation. The researchers hypothesized that the application of alternative growing methods on common garden plants (Dwarf French Marigolds and Garden Cress) would better improve plant health, as determined by plant height at first bloom, plant survival rate, and growth time, in comparison to the control counterparts.

Plants require nutrients including nitrogen, phosphorus, potassium, calcium, and magnesium (8). Such nutrients can be found in a common household. Human urine was used as an organic fertilizer for its high nitrogen content from its chief component, urea, and accessibility (9). Eggshells were another organic fertilizer used due to its calcium content via calcium carbonate. Wood ash, produced from slash-and-burn agriculture, contains partially water-soluble calcium, potassium, and magnesium (2).

A study conducted by Blok, Jackson, et al. demonstrates higher growth yields from substrate-based growing, such as hydroponics, compared to soil-based growing from superior transport rates of water, nutrients, and oxygen (6). Hydroponics involves growing plants in a non-soil substrate with a nutrient reservoir. Water from the nutrient solution is recirculated and reused amongst plants, thereby reducing its consumption. Two common hydroponic systems were selected for this project: wick and deep water culture (DWC). Wick systems use a wick to deliver the nutrient solution to the substrate while DWC systems partially submerge plant roots directly into the nutrient solution.

 This experiment demonstrates certain alternative growing methods have specific effects on plant growth in terms of plant height at first bloom, plant survival rates, and plant growth time.

#### **Results**

 The marigolds and garden cress were tested in the same manner. Germinated seeds were planted in soil or substrate, depending on the treatment. Group 1 (Control) seeds were grown conventionally in soil, Group 2 (Urea Solution) seeds were watered with a urine-based urea solution weekly, Group 3 (Burnt Foliage) seeds were given wood ashes weekly, Group 4 (Eggshell Grounds) were given finely-ground shards of eggshells, Group 5 (Wick System) seeds were grown in a wick-style hydroponic system, and Group 6 (DWC System) seeds were grown in a deep water culture hydroponic system. Researchers monitored plant growth over a 13 week period.

 All plants were placed in the same general location and received the same amount of sun. The in-ground treatments were all watered at the same time enough to moisten the top of the soil and leaves. Additionally, the soil used for all in-ground treatments was taken from the same location.

 First, the average plant height at first bloom was examined. For the marigolds, there was variation in average plant height, but there was no statistical significance between the 6 treatments (p=0.058) (**Figures 1, 2**). For the garden cress, there was variation in average plant height at first bloom as well. Plant height was significantly higher in Group 6 while lowest in Group 2 (p-value < 0.05, one-way ANOVA) (**Figures 1, 2**). A post hoc Tukey-Kramer test with treated garden cress compared to the control revealed statistical significance only for the DWC treatment.

 The effects of each treatment on the survival of each plant was also assessed. At the end of the 13-week experiment, the proportion of surviving plants was calculated by diving the amount of plants continuing to grow by the amount of plants that sprouted. The control group for marigolds had the lowest proportion of surviving plants, 0.4 (2 plants), while the eggshell grounds, wick system, and DWC System groups had the highest proportion of surviving plants, 1 (6 plants) (**Figures 1, 3**). For garden cress, every treatment group had roughly equal proportion of surviving plants. The Urea Solution, Burnt Foliage, and Wick System groups had a survival rate of 0.83 (5 plants) while the control, eggshell grounds, and DWC System groups had a rate of 1 (6 plants) (**Figures 1, 3**).

 The average growth time, the amount of days the average plant took to bloom from sprouting, for each treatment was also assessed. For the marigolds, there was no statistical significance between the average growth times for all 6 treatments (p=0.077) (**Figures 1, 4**). For the garden cress, average growth time was significantly lower in Group 6 as to the other treatments (p-value < 0.05, one-way ANOVA) (**Figures 1, 4**). Follow-up post hoc Tukey-Kramer tests between the controls and other treatments revealed no statistical significance.

 Additionally, marigolds in Groups 2, 3, and 4 developed a purple color in their lower leaves (**Figure 5**).

#### **Discussion**

Select growing methods have shown to encourage healthy plant growth by yielding taller plants at first bloom, increasing survival rates, and decreasing growth times. The initial hypothesis was correct in some respects.

This study reveals that growing garden cress with a deep water culture hydroponics system increased garden cress height at first bloom at a statically significant level compared to a control. However, the selected growing methods applied to marigolds did not cause plant heights at first bloom to be statistically significant. Therefore, the nutrients supplied by the in-ground treatments and the method of hydroponics did not have a noticeable effect on plant height for marigolds. As a result, it is not conclusive whether or not the selected methods have a significant effect on plant height at first bloom for marigolds. More data with other plant varieties is necessary to determine the efficacy of these methods or if these methods merely have a neutral effect on certain species. On the other hand, for the garden cress, the DWC treatment had the highest average height at first bloom, indicating its success in encouraging healthy plant growth. Taller plants, as compared to short plants, would indicate the presence of critical nutrients and minerals required for healthy plant growth.

The experiment also indicated that plant growth time was affected for only garden cress, though there was no statistical significance between the control and the other treatments. Longer growth times would indicate slower growth from a lack of nutrients, which is consistent with the findings. The lowest average growth time for garden cress came from the DWC treatment while the higher average growth times came from the in-ground treatments and control, which had fewer supplied nutrients. Shorter growth times would indicate heathy plant growth due to the presence of necessary nutrients. For marigolds, there was no meaningful difference between average growth times for all the treatments, demonstrating a difference in treatment efficacy based on plant types.

The study additionally demonstrates the impact each treatment has on the survival rate of both types of plants. While the survival rate for garden cress plants are roughly similar, the rates for marigolds vary. Group 1 marigolds (the Control group) had the lowest survival rate while Groups 4, 5, and 6 (the Eggshell Grounds, Wick System, and DWC System groups) had the highest survival rates. A higher survival rate indicate healthy plant growth as the soil contains the necessary nutrients. For the marigolds, a lower survival rate for the control group is obvious, as no nutrient-bearing treatment was applied. However, the higher survival rates for the Eggshell Grounds, Wick System, and DWC System treatments demonstrate their contribution to healthy plant growth since all were successful in sustaining every marigold that sprouted. For the cress, similar survival rates, where up to one plant died for each treatment, reveals a limited impact each treatment had in sustaining the garden cress plants.

Notably, across all the plant health metrics (height, survival rate, and time to bloom), DWC System groups consistently outperform or are equal to other growing methods. This may point to the DWC System’s overall high capability of providing nutrients to its plants. A similar case may be made for the Eggshell Grounds and Wick System groups for marigolds. However, in the case of the Burnt Foliage groups, this does not apply. In both marigolds and the garden cress, the proportion of surviving plants remains the same value of approximately 0.8 with a similar rate of decline (dying off around the 40 day mark). This suggests the burnt foliage may not be a very effective method. Similarly, Urea Solution groups across both plants had a similar survival rate; however, there is a greater disparity between when they started to die off.

The development of a purple color in the leaves of marigolds in Groups 2, 3, and 4 indicate a phosphorus deficiency in the soil (10). As none of the treatments applied to the in-ground plants supplied phosphorus, this is not surprising. Further research may consider other unconventional growing methods to supplement the lack of phosphorus.

This study demonstrates simple, more environmentally-conscious growing methods that can be applied to household gardens, using common objects often overlooked in the house to reduce chemical fertilizer usage and water-efficient hydroponic systems to reduce water consumption.

There are multiple limitations within this study. First, only up to 6 plants for each treatment were tracked over the 13-week period. Additionally, only two types of plants were taken into consideration for this experiment. Future studies should include a greater variety of garden plants and more individual plants for each treatment. A greater sample size of marigolds and garden cress may have led to statistically significant results for average plant height at first bloom and average growth time, respectively. Second, this study was conducted for only 13 weeks. Further research may track these plants over months or years across different annual seasons and multiple growing seasons to evaluate the long-term effects of each treatment on the plants. Third, this experiment only considered height at first bloom, survival rate, and growing time as metrics for plant health. Additional studies may consider more indicators of plant health such as weight and root condition. Moreover, plant height may be biased due to natural variations in height due to changing leaf positions. Fourth, researchers only tracked height until the plant first bloomed. Changes in overall plant may have occurred after data collection stopped and been missed. Lastly, it is unknown if these treatments would be practical on the wide-scale commercial agricultural level.

#### **Materials and Methods**

# Germination and Planting

 To germinate the marigold and garden cress seeds, seeds were placed between moistened paper towels in an airtight plastic bag for 1-2 days, until the seeds were hydrated, at room temperature (70°F). Once roots or sprouts began emerging, the seeds were transferred into the soil or growing medium at a depth of 0.25 inches (6 mm). Two marigold seeds were planted in a dirt pot while six garden cress seeds were planted in a dirt pot. One marigold seed was planted in a 1:1 ratio of vermiculite and perlite for the Wick System treatment and in perlite alone for the DWC treatment. One garden cress seed was planted in a 1:1 ratio of vermiculite and perlite for the Wick System treatment and in perlite for the DWC treatment.

# Plant Maintenance

 Plants grown in dirt were watered daily. Each watering session moistened the top of the soil. The plants were watered between two and six times daily, depending on the time of year and weather conditions. Watering was sufficient to keep plants from wilting. The marigolds and garden cress pots and hydroponic systems were placed in an area with full sun. Any plants that died and all weeds were removed upon detection.

# In-Ground Treatment Preparation & Application

 To create the urea solution, a sample of urine and tap water were combined into a 1:1 ratio. The solution was applied directly to the soil, enough to saturate the surface. To create the burnt foliage, dried lawn clippings and woodchips were burnt. About one teaspoon of ashes were spread on the surface of the soil. To create the eggshell grounds, several eggshells were washed then ground into fine shards using a mortar and pestle. About 1 teaspoon of grounds were spread on the surface of the soil.

# Hydroponic Construction

 To create the Wick System hydroponics, a plastic juice bottle was rinsed and cleaned before being cut along its neck. The top of the bottle was inverted to serve as a pot. The bottom of the bottle was filled with the nutrient solution (detailed below). The wicks were created from recycled socks cut and plugged tightly into the bottle opening. Each wick clearly extended into the nutrient solution. The growing medium was a 1:1 mixture of perlite and vermiculite filling the pot to approximately 80% capacity (**Figure 6**).

 To create the DWC System hydroponics, 6 oz. yogurt containers were recycled into a nest pots. Four slits longitudinally were cut in each container and four openings were made at the bottom corners (**Figure 7**). Twelve holes the size of a nest pot were cut into a block of Styrofoam large enough to fit into the top of the container. Each fashioned nest pot was filled with perlite to about 75% capacity. The block was made to float on top of the nutrient solution. At the bottom of the container, two air stones were attached on each side. Both air stones were attached to an air pump by plastic tubing and connectors (**Figure 8**).

# Hydroponic Maintenance

 All hydroponically grown plants were given a nutrient solution composed of water and plant food. The wick system plants were grown in a solution composed of 0.25 cup of water and 0.5 tsp of plant food. The DWC system plants were grown in a solution composed of 5 gallons of water and 7 tsp of plant food. Each week, the nutrient solutions were drained and replaced. Any occurrences of algae were removed with a 3% hydrogen peroxide solution and thorough rinse with water.

# Data Collection

 Each day, the height of every plant was measured, from base of stem to the highest point of the plant (bud, flower, or leaf) using a length of string and ruler. The height at first bloom (when a bud opened into a flower) was used for statistical analysis.

 The plants were allowed to grow in the Southern California climate during the months of May to August for up to 13 weeks. Once a plant bloomed, researchers stopped tracking its plant height and observed only qualitative changes.

#### **References**

1. History.com Editors. “Neolithic Revolution.” *History.com*, A&E Television Networks, 12 Jan. 2018, [www.history.com/topics/pre-history/neolithic-revolution](http://www.history.com/topics/pre-history/neolithic-revolution).
2. “(PDF) Slash-and-Burn Agriculture, Effects Of.” *ResearchGate*, [www.researchgate.net/publication/288177807\_Slash-and-Burn\_Agriculture\_Effects\_of](http://www.researchgate.net/publication/288177807_Slash-and-Burn_Agriculture_Effects_of).
3. The Editors of Encyclopaedia Britannica. “Agricultural Revolution.” *Encyclopædia Britannica*, Encyclopædia Britannica, Inc., 4 Dec. 2015, [www.britannica.com/topic/agricultural-revolution](http://www.britannica.com/topic/agricultural-revolution).
4. Eghball, B., et al. “LONG–TERM MANURE AND FERTILIZER APPLICATION EFFECTS ON PHOSPHORUS AND NITROGEN IN RUNOFF.” *Transactions of the ASAE*, American Society of Agricultural and Biological Engineers, 1 Jan. 1970, elibrary.asabe.org/abstract.asp?aid=8850.
5. “How Fertilizers Harm Earth More Than Help Your Lawn.” *Scientific American*, Scientific American, 20 July 2009, [www.scientificamerican.com/article/how-fertilizers-harm-earth/](http://www.scientificamerican.com/article/how-fertilizers-harm-earth/).
6. Blok, Chris, et al. “Maximum Plant Uptakes for Water, Nutrients, and Oxygen Are Not Always Met by Irrigation Rate and Distribution in Water-Based Cultivation Systems.” *Frontiers*, Frontiers, 29 Mar. 2017, [www.frontiersin.org/articles/10.3389/fpls.2017.00562/full](http://www.frontiersin.org/articles/10.3389/fpls.2017.00562/full).
7. Boano, Fulvio, et al. *A Review of Nature-Based Solutions for Greywater Treatment: Applications, Hydraulic Design, and Environmental Benefits*. 15 Nov. 2019, [www.sciencedirect.com/science/article/pii/S0048969719347229](http://www.sciencedirect.com/science/article/pii/S0048969719347229).
8. White, P J, and P H Brown. “Plant Nutrition for Sustainable Development and Global Health.” *Annals of Botany*, Oxford University Press, June 2010, www.ncbi.nlm.nih.gov/pmc/articles/PMC2887071/.
9. Marieb, Elaine Nicpon, and Katja Hoehn. *Human Anatomy & Physiology*. Benjamin Cummings, 2010.
10. Additional information Acknowledgments. The author acknowledges support of the Washington Tree Fruit Research Commission and the Winter Pear Control Committee of the Northwest Pear Bureau. “Phosphorus Deficiency Symptoms in Leaves of Apple and Pear Trees as Influenced by Available Soil Phosphorus.” *Taylor & Francis*, [www.tandfonline.com/doi/full/10.1081/CSS-120002757](http://www.tandfonline.com/doi/full/10.1081/CSS-120002757).

#### **Acknowledgements**

 We would like to thank our parents for providing us with the funds to perform this research project as well as Andrew’s family members for assisting with the draining and cleaning of the hydroponics systems each week.

#### **Data Figures**

1. **Mean plant heights at first bloom and growth time with standard error and survival rate for marigolds and garden cress**.
2. **Average height at first bloom for marigolds** (left) **and garden cress** (right). Height was recorded when the plant first bloomed. Error bars represent the standard error. The Eggshell Ground group has the highest average plant height at first bloom for marigolds (26.76 cm). The DWC System group has the highest average plant height at first bloom for garden cress (25.5 cm).
3. **Survival rate for marigolds** (top) **and garden cress** (bottom). The proportion of surviving plants was calculated by dividing the amount of plants remaining at the end of the experiment over the amount of plants that sprouted. The survival rates out from the marigolds is highest for the Eggshell Grounds, Wick System, and DWC System treatments (1) and lowest for the Control group (0.4). The survival rates for the garden cress are highest for the control group and Eggshell Grounds and DWC system treatments (all plants surviving) while the remaining treatments had one plant die.
4. **Average growth time for marigolds** (left) **and garden cress** (right). Growth time was recorded when the plant first sprouted until it bloomed. Plants that died during the experiment were not included. Error bars represent the standard error. The lowest average growth time for marigolds came from the Wick System group (49.33 days). The lowest average growth time for garden cress came from the DWC System group (26.67 days).
5. **Picture of the marigold plants with lower leaves acquiring a purple color**. Certain marigold plants in the Urea Solution, Burnt Foliage, and Eggshell Grounds groups developed purple leaves.
6. **Wick system set-up**. No plants are in the system for photographic purposes.
7. **Nest pot construction for DWC system**. No plants are in the system for photographic purposes.
8. **DWC system set-up**. No plants are in the system for photographic purposes.