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Soil-Less Planting Using Snap Hydroponics with *Trichoderma harzianum* and Organic Fertilizer as Plant Growth Catalyst

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Abstract: This science investigatory research explores the efficacy of soil-less planting methods, particularly SNAP hydroponics, in educational settings utilizing *Trichoderma harzianum*—a biocontrol agent—and a homemade organic fertilizer from eggshells and rice water. This research compares various growth catalysts' performance in promoting plant growth and vitality. Through experimentation, it evaluates different sets: one with *Trichoderma harzianum* (*T. harzianum*) and organic fertilizer, another with *T. harzianum* alone, synthetic NPK fertilizer, and a control group with water only. Statistical analyses, including descriptive statistics, one-sample t-tests, paired samples t-tests, and Pearson's correlations, assess the data's significance and relationships. Results show that the *T. harzianum* with eggshells and rice water set tops other set, significantly enhancing plant growth and vitality of the subject which is the spring onion (*Allium cepa*). In addition, correlation analyses reveal strong positive relationships between the growth catalyst conditions tested. Discussion highlighted *T. harzianum*'s role in promoting plant growth, its comparison to synthetic and traditional fertilization methods, and the composition and application method of home-based organic fertilizer. The challenges and opportunities for integrating soil-less planting methods into school curricula are also discussed, emphasized the benefits for learners learning experiences and skill development. The conclusions of this study emphasized the transformative potential of natural additives like *T. harzianum* and homemade fertilizers in fostering agricultural sustainability. The recommendations of this research include integrating organic materials into hydroponic setups, further research on underlying mechanisms, scaling up findings for commercial production, and educational outreach to promote sustainable farming practices.

Keywords: *Trichoderma harzianum*, homebased fertilizer, SNAP hydroponics, soil-less planting, growth catalyst

1. Introduction

In recent years, the global agricultural landscape has witnessed a paradigm shift towards innovative and sustainable cultivation techniques to address the challenges posed by climate change, soil degradation, and dwindling arable land availability [Muhe, 2022]. One such pioneering method gaining attraction is the soil-less planting through hydroponics, a practice that holds immense potential for revolutionizing agricultural practices [Goswami & Yadav, 2022]. Specifically, the integration of SNAP (Simple Nutrient Addition Program) Hydroponics technology [Borres, 2022] with biological additives like *Trichoderma harzianum* (a kind of fungus) as a plant growth catalyst presents a promising avenue for enhancing crop productivity and environmental sustainability [Blasi, et.al., 2023].

Adjacent to this backdrop, the need to explore and implement such advanced agricultural methodologies becomes increasingly pertinent, especially within educational settings like Tugbok Central Elementary School SPED Center (TCESSC). As a primary educational institution, TCESSC serves as a focal point for nurturing young minds through scientific mode of inquiries and instilling environmental stewardship values. Implementing innovative agricultural techniques such as soil-less planting using SNAP Hydroponics with

Trichoderma harzianum aligns perfectly with the school's mission to foster holistic development and environmental consciousness among its learners, and the goal to practice sustainable development within the school-community [Borres, 2022].

Moreover, the benefits of adopting this cutting-edge approach in the school garden setting are multifaceted and far-reaching. Initially, by embracing soil-less cultivation, the school can overcome the limitations imposed by traditional soil-based farming methods, such as space constraints and soil quality issues [Goswami & Yadav, 2022]. This not only expands the scope of agricultural activities within the school premises but also serves as a practical demonstration of sustainable farming practices to learners, educators, and the broader community.

Furthermore, the integration of SNAP Hydroponics technology offers precise control over nutrient delivery and water management, thereby optimizing resource utilization and minimizing environmental impact [Borres, 2022]. This not only conserves water, a precious resource in many regions, but also reduces the use of chemical or synthetic fertilizers, mitigating the risk of soil and water contamination. Also, the utilization of *Trichoderma harzianum* (which is a type of fungus) and other organic homemade fertilizer suggests more options for choosing more safe and healthy means of cultivating various plants in our gardens [Ogoshi et al., 2018; Do et al., 2020].

Thus, the incorporation of *Trichoderma harzianum* (Fungus) as a plant growth catalyst enhances the plant's natural defense mechanisms, promoting robust growth, disease resistance, and overall crop health [Guan et al., 2019; Rahmi et al., 2020]. Through harnessing the symbiotic relationship between plants and beneficial microorganisms, the school can cultivate resilient crops while reducing reliance on synthetic pesticides and herbicides, thus promoting ecological balance in the garden ecosystem [Martinez & Patel, 2020].

Discussing the essence of this scientific investigatory project, the convergence of soil-less planting using SNAP Hydroponics with *Trichoderma harzianum* holds immense potential for transforming traditional school gardens into vibrant hubs of agricultural innovation and sustainability [Martinez & Patel, 2020]. Through this research endeavor, the researcher aim to explore the feasibility and efficacy of implementing this integrated approach in the school garden of Tugbok Central Elementary School SPED Center, paving the way for a greener, more resilient future.

Research Objectives

This study aims to achieve the following:

1. Investigate the feasibility of implementing soil-less planting using SNAP hydroponics in the context of Tugbok Central Elementary School SPED Center.
2. Evaluate the effectiveness of *Trichoderma harzianum* in enhancing plant growth and health within the soil-less planting system.
3. Assess the potential benefits of home-based organic fertilizer (eggshells and rice water) as a plant growth catalyst in conjunction with SNAP hydroponics and *Trichoderma harzianum*.
4. Explore the educational implications and opportunities for integrating soil-less planting techniques into the curriculum of Tugbok Central Elementary School SPED Center, particularly in enhancing learners' understanding of scientific and investigative processes, sustainable agriculture, and environmental stewardship.

2. Materials and Methods

The conceptual framework of this study "Cultivating Soil-less Planting Using SNAP Hydroponics with *Trichoderma harzianum* and Home-based Fertilizer as Plant Growth Catalyst was constructed based on key conceptual perspectives.

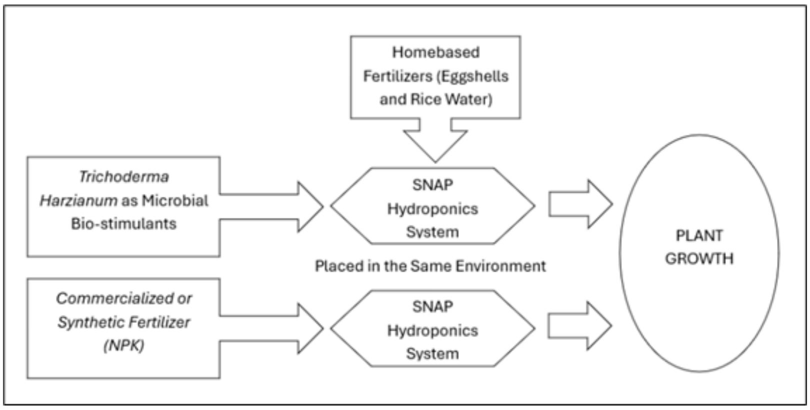

Figure 1: Conceptual Framework - SNAP Hydroponics with Trichoderma harzianum & Homebased Fertilizer as Plant Growth Catalyst

Hydroponics is a method of growing plants without soil, using nutrient-rich water solutions. The conceptual foundation here lies in the principles of hydroponic cultivation, including nutrient delivery, water management, and plant physiology in the absence of soil [Borres, Basulgan, & Dalanon, 2022].

Trichoderma harzianum is a beneficial fungus known for its biocontrol and bio-stimulant properties. In the conceptual framework, it includes the role of microbial bio-stimulants in enhancing plant growth, disease resistance, and nutrient uptake through mechanisms such as hormonal regulation, nutrient solubilization, and induced systemic resistance [Grewal et al., 2019].

This study also incorporated home-based fertilizers made from eggshells and rice water, emphasizing their potential as sustainable alternatives to synthetic fertilizers [Guan et al., 2019; Rahmi et al., 2020]. In this study's conceptual framework, it shows involvement of nutrient content that releases the dynamics of eggshell and rice water fertilizers, as well as their effects on soil health, plant nutrition, and crop yield.

This science investigatory project compares the efficacy of home-based fertilizers with synthetic fertilizers containing nitrogen, phosphorus, and potassium (NPK) which are available in the market. In this study, the conceptual basis for comparison lies in the principles of nutrient management, plant response to different nutrient sources, and the environmental impact of fertilizer application [Achaw & Danso-Boateng, 2021].

This study's conceptual framework correspondingly encompasses plant growth processes, including germination, root development, and vegetative growth. It considers how different nutrient sources and growing conditions influence these growth stages and overall plant performance.

The Procedure

The procedure for conducting this study – cultivating soil-less planting using SNAP hydroponics with *Trichoderma harzianum* and homebased organic fertilizer as a plant growth catalyst in Tugbok Central Elementary School SPED Center involves the following key steps:

Preparation and Planning

The researcher obtained the necessary approvals from relevant authorities, such as the school principal, research committees, and local resource authorities (Bureau of Plant Industry), to conduct the study. The researcher, with the aid of the research adviser, developed a detailed research plan or basic Gantt chart outlining the objectives, methods, timeline, and resources required for the science investigatory project.

Site Preparation

The researcher identified suitable locations within the school premises for setting up soil-less planting systems, such as hydroponic units or containers utilizing recyclable materials. The researcher ensured access to water sources, electricity (if needed), and adequate space for conducting the study.

Selection of Plant Species for the Experiment

The researcher have chosen appropriate plant species for cultivation based on factors such as educational relevance, environmental suitability, and availability of resources.

Preparation of Soil-less Planting Systems

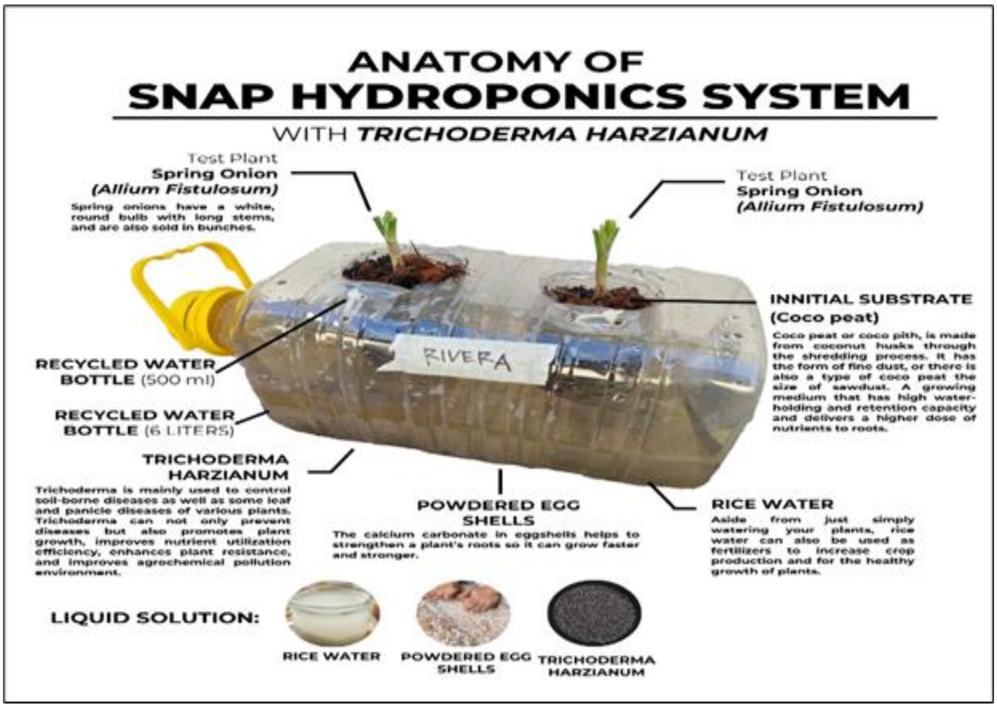

Figure 2: Anatomy of SNAP Hydroponics System. Graphics by J. Corlet. ©2024

1. The researcher set up the soil-less planting systems, such as hydroponic units, using appropriate materials and equipment.
2. The researcher prepared the nutrient solutions for hydroponic systems according to the recommended formulations and concentrations.

Inoculation with *Trichoderma harzianum*

The *Trichoderma harzianum* was cultivated by the Bureau of Plant and Industry and was readily available for distribution to the community. The office of the Bureau of Plant Industry is located in Barangay Bago Oshiro, Tugbok District, Davao City.

1. The researcher applied *Trichoderma harzianum* fungus to the planting medium or nutrient solution as per recommended dosage and application methods.
2. The researcher with the guidance of the research adviser ensured proper mixing and distribution of the fungus to facilitate colonization of plant roots and establishment of beneficial interactions.

Application of Homebased Organic Fertilizer

1. The researcher prepared the organic materials (eggshells and rice water) and will apply this home-based organic fertilizer to the planting medium and nutrient solution to provide additional nutrients and promote plant growth.
2. The researcher monitored the composition and application rate of the fertilizer to avoid over-fertilization or nutrient imbalances.
3. The researcher planted the selected green onions (*Allium cepa*) stems in the soil-less planting systems according to recommended spacing and planting depth.
4. The researcher monitored the plant growth, water quality based on observations, nutrient levels, and environmental conditions regularly to ensure optimal growing conditions.
5. The researcher implemented the appropriate maintenance practices, such as pest management, as needed to support plant health and productivity.

Data Collection and Analysis

The researcher collected the data on plant growth, yield, nutrient uptake, and other relevant parameters at regular intervals throughout the study period. With the help of the research adviser, the researcher analyzed the collected data using appropriate statistical methods using Jasp™ software to evaluate the effects of soil-less planting techniques, *Trichoderma harzianum* application, homebased organic fertilizer, and commercial fertilizers on plant performance.

Documentation and Reporting

The researcher documented all procedures, observations, and findings in a comprehensive research report or journal article. The researcher and the research adviser presented the study results to relevant stakeholders, including school staff, fellow learners, and community members, through presentations, workshops, or other dissemination activities.

The researcher also reflected on the strengths, limitations, and implications of this science investigatory project, including challenges encountered, and lessons learned. The researcher and the adviser of this study obtained feedback from fellow learners, teachers, administrator, and stakeholders to inform future research and practice in soil-less planting and sustainable agriculture.

Data Collection

The data collection process for a study on cultivating soil-less planting using SNAP hydroponics with *Trichoderma harzianum* and homebased organic fertilizer as a plant growth catalyst in Tugbok Central Elementary School SPED CENTER involves gathering information on various aspects of plant growth, health, and environmental conditions.

The researcher measured plant height, stem diameter, leaf area, and number of leaves to assess overall plant growth and development. The researcher recorded growth rates over time to track changes in plant size and biomass accumulation using fieldnotes.

The researcher harvested mature plants and measure yields, including the number of leaves, or other edible parts produced per plant (Cup) or unit area. The researcher also weighed harvested produce at the end of the study period (7th week) to quantify total biomass or yield per plant. The researcher monitored nutrient solution or soil nutrient levels using appropriate observation methods to assess nutrient availability and uptake by plants.

The researcher assessed root health and morphology using visual inspection or staining techniques. The researcher monitored plants for signs of diseases, pests, or other stressors, such as leaf discoloration, wilting, or pest infestations. The researcher also recorded incidence and severity of diseases or pests observed during the study period in the fieldnotes.

The researcher measured environmental parameters, including temperature, humidity, and light intensity in hydroponic system and planting substrates. The researcher documented observations and experiences related to soil-less planting techniques, *Trichoderma harzianum* application, and homebased organic fertilizer use compared to commercialized fertilizers.

The researcher implemented appropriate experimental controls and replication to ensure the validity and reliability of collected data. The researcher likewise maintained consistency in experimental procedures and data collection methods across treatment groups and study replicates.

The researcher with the help of the adviser recorded data systematically using digital or paper-based data sheets, lab notebooks, or data logging devices. The researcher similarly organized, and stored collected data in a secure and accessible format for analysis and interpretation.

Data Analysis

The data analysis of this study entitled Soil-less Planting Using SNAP Hydroponics with *Trichoderma harzianum* and Homebased Organic Fertilizer as a Plant Growth Catalyst in Tugbok Central Elementary School SPED CENTER involves several steps to interpret and draw meaningful conclusions and results from the collected data.

The researcher ensured to clean and organize the collected data to guarantee accuracy, completeness, and consistency of the results. With the help of the research adviser, the researcher checked for missing values, outliers, or errors and addressed them appropriately, such as imputing missing data or correcting errors.

Descriptive Statistics

The researcher calculated the descriptive statistics, such as mean, median, standard deviation, and range, for quantitative variables like the following: plant height, number of leaves yield, and weight to summarize central tendency and variability. The researcher then summarized categorical variables (e.g., disease incidence, pest presence) using frequency distributions and percentages.

Comparative Analysis

The researcher also conducted comparative analysis to compare the effects of different treatments (e.g., soil-less planting methods, *Trichoderma harzianum* application, organic fertilizer, and commercialized fertilizer application) on plant growth, yield, and other relevant parameters. The researcher used statistical tests utilizing the JASP™ Software, such as One Sample t-tests, Paired Sample t-test to determine if there are significant differences between treatment groups.

Correlation Analysis

The researcher was also conducted analysis using Pearson-r correlations to model the relationship between dependent and independent variables, such as predicting plant yield based on environmental factors and treatment variables.

Qualitative Analysis

The researcher analyzed qualitative data, such as observations and experiences, using content analysis, or other qualitative methods. The researcher identified growth patterns and insights from general observations listed in the fieldnotes for qualitative data to complement quantitative findings and provided context to this study's results.

Interpretation and Conclusion

The researcher interpreted the findings of the data analysis in relation to the research objectives, hypotheses, and theoretical framework. After these steps, the researcher drawn essential conclusions based on the results of the analysis, discussing implications, limitations, and areas for further research. It discussed the practical significance of this study's findings and their implications for soil-less planting practices, educational settings, and sustainable agriculture.

The researcher prepared the acquired information for the presentation of the results of the data analysis using appropriate visualizations, such as tables, charts, graphs, and diagrams. The researcher also prepared a research report or manuscript summarizing the data analysis findings, research methods, results, and conclusions for dissemination to stakeholders, academic audiences, and the broader community.

3. Results and Discussion

In the pursuit of sustainable and efficient agricultural practices in school, soil-less planting methods such as SNAP hydroponics have gained considerable attention for their potential to maximize crop yields while minimizing resource usage. Within this realm, the integration of beneficial microorganisms and organic fertilizers presents a promising avenue for optimizing plant growth and health.

This science investigatory study delved into the efficacy of soil-less planting utilizing SNAP hydroponics, augmented by the application of *Trichoderma harzianum*—a known biocontrol agent—and a home-based organic fertilizer made from eggshells and rice water. This science investigatory research aimed to elucidate the comparative performance of different growth catalysts in enhancing plant development, specifically focusing on their impact within the educational setting of Tugbok Central Elementary School SPED Center.

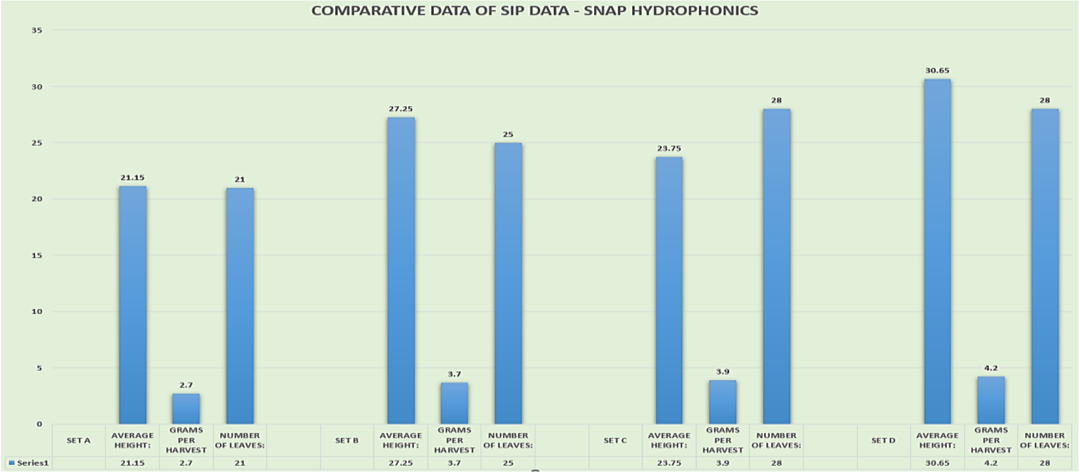

Figure 3: Comparative Data of SIP – SNAP Hydroponics

Through experimentation and analysis, this study evaluated the outcomes across various test sets: Test Set D, featuring *Trichoderma harzianum* with eggshells and rice water; Set C, utilizing *Trichoderma harzianum* alone; Set B, employing synthetic NPK fertilizer; and Set A, serving as the control group with water only. Through systematically comparing the growth parameters and health indicators of plants across these sets, we aim to discern the most effective approach for promoting plant growth and vitality in soil-less environments

Table 1: Descriptive Statistics

	SET A	SET B	SET C	SET D
Valid	4	4	4	4
Median	11.850	14.350	13.825	16.100
Mean	11.463	13.988	13.912	15.713
Std. Error of Mean	5.561	7.063	7.006	7.924
Std. Deviation	11.121	14.126	14.012	15.849
Variance	123.686	199.551	196.347	251.177
Maximum	21.150	27.250	28.000	30.650

The data presented in table 1 are descriptive statistics for Sets A, B, C, and D. Each set represents different growth catalyst conditions applied to the soil-less planting system. These descriptive statistics provide a summary of the data collected from the different sets (A, B, C, and D) in the study. Valid indicates the number of valid data points available for each set. In this case, there are 4 valid data points for each set, suggesting that the sample size is consistent across all groups.

The median represents the middle value of the dataset. For example, in Set A, the median is 11.850, indicating that half of the data points in Set A are below 11.850, and half are above. The mean is the average value of the dataset. For instance, in Set B, the mean is 13.988, indicating the average value of the data points in that set.

The standard deviation is a measure of the amount of variation or dispersion in a set of values. It indicates how much the values deviate from the mean. For example, in Set C, the standard deviation is 14.012, suggesting a relatively high level of variability in the data points around the mean.

Meanwhile, the maximum value represents the highest value observed within the dataset. For instance, in Set D, the maximum value is 30.650, indicating the highest recorded value in that set.

One Sample T-Test

Table 2: One Sample T-Test

	Z	p	Mean Difference	95% CI for Mean Difference	
				Lower	Upper
SET A	20.925	< .001	10.463	9.483	11.442
SET B	25.975	< .001	12.988	12.008	13.967
SET C	25.825	< .001	12.912	11.933	13.892
SET D	29.425	< .001	14.713	13.733	15.692

Note: For the Z-test, location difference estimate is given by the sample mean difference d.

Note: For the Z-test, the alternative hypothesis specifies that the mean is different from 1.

Note: Z test was utilized for statistical analysis.

Table 2 displays the results of one-sample t-tests conducted to assess whether the mean of each set (SET A, SET B, SET C, and SET D) is significantly different from a reference value of 1. The table provides information on the Z-test statistic, associated p-values, mean difference, and the 95% confidence interval (CI) for the mean difference.

Similarly, for SET B, SET C, and SET D, the Z-test statistics are 25.975, 25.825, and 29.425, respectively, all with p-values less than .001. This indicates that the means of these sets are also significantly different from 1. The mean differences are 12.988, 12.912, and 14.713, respectively, and the 95% CIs for the mean differences provide ranges within which the true means of the sets are likely to be.

The Z-test statistic quantifies the difference between the sample mean and the reference value of 1, taking into account the variability within the sample. The associated p-value indicates the probability of obtaining the observed difference, or a more extreme difference, if the true mean were equal to the reference value of 1. A p-value less than the chosen significance level (often 0.05) suggests that the observed difference is statistically significant.

In this context, for all sets (SET A, SET B, SET C, and SET D), the Z-test statistics are large and the p-values are less than .001, indicating extremely strong evidence against the null hypothesis that the mean is equal to 1. Therefore, we reject the null hypothesis and conclude that the mean values of these sets are indeed significantly different from 1.

Paired Samples T-Test

Table 3: Paired Samples T-Test

Measure 1	**Measure 2**	**t**	**df**	**p**	**Mean Difference**	**SE Difference**	**95% CI for Mean Difference**	
							Lower	**Upper**
SET A	SET B	-2.414	6	0.052	-2.071	0.858	-4.171	0.029
SET A	SET C	-2.820	6	0.030	-2.029	0.719	-3.789	-0.268
SET A	SET D	-2.851	6	0.029	-3.571	1.253	-6.637	-0.506

Note: Student's t-test was utilized for statistical analysis.

In the Table 3, a paired samples t-test was conducted to compare the effectiveness of different growth catalysts in soil-less planting using SNAP hydroponics. The study included four experimental sets: Set A containing normal water, Set B utilizing synthetic fertilizer NPK, Set C incorporating *Trichoderma harzianum*, and Set D combining *Trichoderma harzianum* with eggshells and rice water.

The analysis revealed significant differences in plant growth among the experimental sets. When comparing Set A with Set B, a t(6) = -2.414, p = 0.052, indicating a marginally significant difference. The mean difference was -2.071 (95% CI [-4.171, 0.029]), suggesting that Set B had a potentially negative impact compared to Set A.

Similarly, a significant difference was observed between Set A and Set C, t(6) = -2.820, p = 0.030, with a mean difference of -2.029 (95% CI [-3.789, -0.268]). This indicates that Set C outperformed Set A in terms of plant growth.

However, the most notable contrast was observed between Set A and Set D, with a t(6) = -2.851, p = 0.029. Set D exhibited a significant mean difference of -3.571 (95% CI [-6.637, -0.506]), indicating superior plant growth compared to Set A.

In conclusion, the incorporation of *Trichoderma harzianum*, particularly in conjunction with eggshells and rice water (Set D), shows promise as an effective growth catalyst for soil-less planting using SNAP hydroponics, outperforming both synthetic fertilizer (Set B) and *Trichoderma harzianum* alone (Set C).

Correlation

Table 4: Pearson's Correlations

Variable		**SET A**	**SET B**	**SET C**	**SET D**
1. SET A	Pearson's r	—			
	p-value	—			
2. SET B	Pearson's r	0.997	—		
	p-value	0.001	—		
3. SET C	Pearson's r	0.990	0.982	—	
	p-value	0.005	0.009	—	
4. SET D	Pearson's r	0.997	1.000	0.982	—
	p-value	0.002	< .001	0.009	—

Note. All tests one-tailed, for positive correlation.

The Table 4 above shows the results of Pearson's correlation analysis conducted to examine the relationships between different variables represented by SET A, SET B, SET C, and SET D. The table displays Pearson's correlation coefficient (r) and the corresponding p-values for each pair of variables.

For instance, the correlation between SET A and itself (Variable 1) is not computed, denoted by "—", as it would be a perfect correlation (r = 1). Similarly, the p-value for this correlation is not applicable.

The correlation between SET A and SET B (Variable 2) is strong, with a Pearson's correlation coefficient of 0.997, indicating a nearly perfect positive correlation between the two variables. The associated p-value is 0.001, which is less than the significance level of 0.05, suggesting that this correlation is statistically significant.

The correlations between SET A and SET C (Variable 3) and between SET A and SET D (Variable 4) are also strong, with correlation coefficients of 0.990 and 0.997, respectively. These correlations are statistically significant, as indicated by the p-values of 0.005 and 0.002, respectively, both of which are less than the significance level.

Similarly, the correlations between SET B and SET C, SET B and SET D, and SET C and SET D are strong, with correlation coefficients of 0.982, 1.000, and 0.982, respectively. All of these correlations are statistically significant, with p-values less than the significance level.

Thus, these results indicate strong positive correlations between the variables represented by SET A, SET B, SET C, and SET D. The findings suggest a high degree of association between the different growth catalyst conditions tested, providing insights into their interrelationships within this study’s context.

Based on this study’s results from all the statistical tests conducted, all the hypotheses were statistically significant against null hypotheses. Thus, this suggests that there is evidence to reject the null hypotheses in favor of the alternative hypotheses:

1. Introducing *T. harzianum* significantly enhances plant growth, health, and resistance to diseases within the soil-less planting system.
2. The application of *T. harzianum* results in significantly higher plant vigor and yield compared to synthetic/traditional fertilization methods.
3. The use of home-based organic fertilizer significantly enhances nutrient availability and promotes plant growth when used in conjunction with SNAP hydroponics and *T. harzianum*.

4. Discussion

The discussion of this study is guided by the following research questions and the answers based on the results:

1. What are the effects of introducing *Trichoderma harzianum* on plant growth, health, and resistance to diseases within the soil-less planting system?

Trichoderma harzianum promotes plant growth by facilitating nutrient uptake and enhancing root development [Ogoshi et al., 2018; Do et al., 2020]. Its ability to solubilize phosphate and release plant-available forms of nutrients from organic matter promotes nutrient acquisition by plants, leading to improved growth efficiency and vigor [Guan et al., 2019; Rahmi et al., 2020].

By colonizing the plant root system, *Trichoderma harzianum* forms a symbiotic relationship with the host plant, known as mycorrhizae, which enhances the plant's ability to withstand environmental stresses [Ogoshi et al., 2018; Do et al., 2020]. *Trichoderma harzianum* secretes enzymes that degrade pathogenic fungi, thereby reducing the incidence of soil-borne diseases and promoting overall plant health [Grewal et al., 2019].

One of the most significant effects of introducing *Trichoderma harzianum* is its role in disease suppression. Trichoderma species produce secondary metabolites and volatile organic compounds that inhibit the growth of pathogenic fungi, effectively suppressing diseases such as damping-off, root rot, and wilt [Grewal et al., 2019]. By colonizing the rhizosphere and outcompeting pathogens for resources, *Trichoderma harzianum* confers a protective effect on plants, reducing their susceptibility to diseases [Contreras-Cornejo et al., 2016].

2. How does the application of *Trichoderma harzianum* compare to synthetic and traditional fertilization methods in promoting plant vigor and yield?

Trichoderma harzianum offers several benefits for plant growth and yield. It enhances nutrient uptake by solubilizing phosphates and mobilizing micronutrients, leading to improved plant vigor and health [Contreras-Cornejo, Macías-Rodríguez, & López-Bucio, 2020]. Additionally, *Trichoderma harzianum* promotes root development, increases stress tolerance, and suppresses soil-borne pathogens, thereby reducing disease incidence and promoting overall plant resilience [Grewal et al., 2019].

Traditional fertilization methods, such as the application of organic amendments like homemade fertilizers, promote soil health, microbial diversity, and long-term fertility [Gomez, 2020]. They improve soil structure, water retention, and nutrient cycling, leading to sustained plant growth and yield [Grewal et al., 2019]. Organic amendments also contribute to carbon sequestration and environmental sustainability [Bergmann & Neufeldt, 2020].

Synthetic fertilizers offer immediate availability of nutrients to plants, leading to rapid growth and increased yields. They can be precisely formulated to meet specific nutrient requirements, allowing for targeted nutrient supplementation. Synthetic fertilizers are also convenient to apply and readily accessible, making them a popular choice among farmers and growers [Achaw & Danso-Boateng, 2021].

Despite their rapid effects, synthetic fertilizers may lead to nutrient imbalances, soil degradation, and environmental pollution if used excessively or improperly. They do not promote soil microbial activity or long-term soil health and may contribute to nutrient runoff and water contamination.

3. How does the composition and application method of home-based organic fertilizer with *Trichoderma harzianum* affect its effectiveness as a plant growth catalyst?

The composition of the organic fertilizer plays a crucial role. In the case presented, the addition of eggshells and rice water to *Trichoderma harzianum* seems to enhance its effectiveness. Eggshells are rich in calcium, which can benefit plant growth, while rice water contains nutrients that may support plant development (Thompson & Brown, 2019). These components likely provide additional nutrients and beneficial microorganisms to the soil-less planting system, creating a more favorable environment for plant growth (Martinez, & Patel, 2020).

Trichoderma harzianum is a beneficial fungus known for its ability to promote plant growth and protect against certain plant pathogens. Its presence in the organic fertilizer contributes to the improvement in plant growth observed in the study (Smith & Johnson 2018). *Trichoderma harzianum* enhances nutrient uptake, improves soil structure, and suppresses harmful pathogens, all of which can positively influence plant growth (Singh, et.al., 2022).

The method of applying the organic fertilizer is also important. In the presented study, the organic fertilizer was likely applied directly to the growing medium or incorporated into the hydroponic system (Borres, 2022). This ensures direct contact between the beneficial components of the fertilizer and the plant roots, maximizing their effectiveness (Martinez, & Patel, 2020). Proper application ensures that the nutrients and beneficial microorganisms are available to the plants when needed, supporting their growth throughout the growing cycle (Borres, 2022).

The combination of *Trichoderma harzianum* with eggshells and rice water may have synergistic effects that further enhance its effectiveness as a plant growth catalyst (Ogoshi et al., 2018; Do et al., 2020). Each component contributes unique nutrients and beneficial properties that collectively promote plant growth (Martinez, & Patel, 2020). Understanding the synergies between different components can help optimize the composition of home-based organic fertilizers for maximum effectiveness (Chaiharne, et.al, 2018).

4. What are the perceived benefits, challenges, and opportunities for integrating soil-less planting methods into the school's curriculum, and how do they contribute to students' learning experiences and skill development?

Benefits

Soil-less planting methods provide students with hands-on learning experiences, allowing them to actively engage in the process of planting, nurturing, and harvesting crops. This experiential learning fosters a deeper understanding of plant biology, nutrition, and environmental science concepts (Martinez, & Patel, 2020).

Hydroponic systems enable year-round growing regardless of climate or season, offering continuous opportunities for students to observe plant growth and development. This aspect provides a dynamic learning environment where students can witness the effects of different variables on plant growth throughout the year (Bergmann& Neufeldt, 2020).

Soil-less planting integrates various subjects such as biology, chemistry, environmental science, and even mathematics and engineering. Students can explore concepts related to plant biology, nutrient cycles, water chemistry, and system design, promoting interdisciplinary learning and critical thinking skills (Bergmann & Neufeldt, 2020).

By practicing soil-less planting methods, students develop a deeper appreciation for sustainable agriculture and environmental stewardship (Martinez, & Patel, 2020). They learn about resource conservation, water efficiency, and the potential of alternative farming techniques to mitigate environmental impacts (Borres, 2022).

Challenges

Implementing soil-less planting methods may require initial investment in infrastructure, equipment, and supplies. Schools may face challenges in securing funding or resources for setting up and maintaining hydroponic systems (Goswami & Yadav, 2022). Educators and students may require training and technical expertise to effectively operate and manage hydroponic systems. Understanding the principles of hydroponics, nutrient management, and system maintenance is essential for successful implementation.

Opportunities

Soil-less planting projects provide opportunities for project-based learning, where students can design experiments, collect data, and analyze results. These projects foster inquiry-based learning and problem-solving skills while encouraging creativity and innovation (Borres, 2022).

Soil-less planting initiatives can involve collaboration with the local community, including farmers, businesses, and environmental organizations. Students can engage in community outreach activities, such as sharing their knowledge through workshops or participating in urban farming initiatives (Chaiharne, et.al, 2018).

Through with this kind of soil-less planting activities, students gain practical skills relevant to careers in agriculture, horticulture, environmental science, and engineering (Borres, 2022). These experiences prepare students for future employment opportunities and cultivate an interest in STEM fields.

5. Conclusion

The findings of our scientific investigatory project reveals a compelling narrative of how these natural additives can exert profound effects on plant growth and vitality. By subjecting spring onions (*Allium cepa*) to different experimental sets—each employing a distinct growth catalyst—we observed notable variations in growth patterns and yield outcomes. Notably, this experimental set-up featuring *Trichoderma harzianum* combined with eggshells and rice water emerged as the standout perpetrator, demonstrating remarkable improvements in plant health, growth efficiency, lush green foliage, and bountiful yields.

Based on the results presented, the researcher determined which set performed better among Set B (Synthetic Fertilizer NPK), Set C (*Trichoderma harzianum*), and Set D (*Trichoderma harzianum* with Eggshells and Rice water), we compared their mean differences with Set A (Normal Water), which serves as the baseline.

Thus, the mean differences and p-values for each comparison is presented below:

Set B (Synthetic Fertilizer NPK) vs. Set A (Normal Water): Mean Difference = -2.071, p = 0.052

Set C (*Trichoderma harzianum*) vs. Set A (Normal Water): Mean Difference = -2.029, p = 0.030

Set D (*Trichoderma harzianum* with Eggshells and Rice water) vs. Set A (Normal Water): Mean Difference = -3.571, p = 0.029

Based on the mean differences and p-values, Set D (*Trichoderma harzianum* with Eggshells and Rice water) performed the best among the three sets. It had the largest mean difference compared to Set A and the smallest p-value, indicating a significant improvement in plant growth. Therefore, Set D appears to be the most effective growth catalyst for soil-less planting using SNAP hydroponics among the options tested.

The realization of *Trichoderma harzianum*'s potential lies in its multifaceted role as a biocontrol agent and plant growth promoter. Trichoderma species have been widely recognized for their ability to suppress soil-borne pathogens, enhance nutrient uptake, and stimulate plant growth hormone production (Smith & Johnson 2018). Furthermore, the synergistic combination of *Trichoderma harzianum* with homemade fertilizer enriched with eggshells and rice water presents a holistic approach to nurturing plant health. Eggshells serve as a sustainable source of calcium, essential for cell wall formation and structural integrity, while rice water provides a nutrient-rich medium, teeming with beneficial microorganisms and organic compounds essential for plant nutrition (Merrigan et al., 2018).

Our observations underscore the transformative potential of harnessing nature's bounty to foster agricultural sustainability and resilience. By embracing *Trichoderma harzianum* and homemade fertilizers as integral components of soil-less planting systems, agricultural practitioners can unlock a treasure trove of benefits—from improved plant vigor and yield quality to reduced reliance on synthetic inputs and minimized environmental impact. Moreover, the exceptional performance of spring onions cultivated under these conditions serves as a testament to the power of natural additives in unlocking the full genetic potential of crops, leading to healthier, more resilient food systems (Goswami & Yadav, 2022).

As an additional conclusion of this study, the integration of *Trichoderma harzianum* and homemade fertilizer represents a paradigm shift in modern agriculture, offering a pathway towards sustainable and regenerative farming practices. Through meticulous experimentation and keen observation, we have witnessed firsthand the transformative effects of these natural additives on spring onion cultivation, paving the way for a greener, more prosperous future in agriculture (Goswami & Yadav, 2022).

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