Fermented Rice Water as a Sustainable Nutrient Alternative: Effects on Growth and Chlorophyll Content of Hydroponic Basil (*Ocimum basilicum*)

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Abstract

Hydroponics is a method of growing plants without soil by using water and nutrients instead. It is helpful in areas with limited space and water. However, commercial hydroponic nutrient solutions can be expensive. This study investigated whether fermented rice water (FRW), a household by-product, could be used as a low-cost and sustainable alternative nutrient solution for growing basil (*Ocimum basilicum*) in a hydroponic system. The experiment used six treatments: plain water, commercial nutrient solution, and four concentrations of fermented rice water (5%, 10%, 15%, and 20%). Each treatment had three replicates, with three seeds per replicate, for a total of 54 basil seeds. Coconut coir was used as the growing medium. All plants were kept under the same light, temperature, and water conditions. Germination was observed daily for 14 days, while plant height, number of true leaves, and chlorophyll content were measured on Days 7, 14, and 21. Chlorophyll content was measured using a portable chlorophyll meter (SPAD meter). Results showed that basil plants treated with 10% fermented rice water had high germination rates, taller plant height, more leaves, and higher chlorophyll content compared to other treatments. The 10% FRW treatment performed similarly to the commercial nutrient solution, while plants grown with plain water showed the lowest growth and chlorophyll levels. These findings suggest that fermented rice water, especially at a 10% concentration, can be an effective, eco-friendly, and affordable nutrient option for hydroponic basil production.

Background Research

With growing concerns about food security, there is an increasing need for sustainable and low-cost methods of food production. Hydroponics is a soilless farming technique that allows plants to grow efficiently in small spaces while using less water than traditional soil farming. Because of these advantages, hydroponics is becoming popular in schools and small-scale gardening. However, commercial hydroponic nutrient solutions can be expensive and may not always be available to students or small growers. Fermented rice water (FRW), a common household by-product, contains nutrients and beneficial microorganisms that may help plants grow. This study explores the potential of fermented rice water as an alternative nutrient solution for growing basil in a hydroponic system, with the goal of promoting sustainability, affordability, and environmental awareness (Taiz et al., 2018; Shoji & Hirano, 2020).

Basil (*Ocimum basilicum*) is a fast-growing herb commonly used for cooking and traditional medicine. It is well suited for hydroponic systems because it has a shallow root system and grows quickly. Plant growth and productivity are closely related to chlorophyll content, which is important for photosynthesis, the process plants use to make food. Previous studies have shown that the type and amount of nutrients available to plants can greatly affect chlorophyll production and overall plant health (Lichtenthaler & Wellburn, 1983). In recent years, organic nutrient sources have gained attention as environmentally friendly alternatives to chemical fertilizers, especially in sustainable farming systems.

Principles of Hydroponics

Hydroponics is based on the principle that plants do not need soil to grow, but instead require water, nutrients, light, and oxygen. In hydroponic systems, nutrients are dissolved in water and absorbed directly by plant roots, allowing plants to grow more efficiently. Coconut coir is often used as a growing medium because it provides support for the roots while retaining moisture and allowing proper air circulation. Using organic nutrient solutions, such as fermented rice water, may help improve sustainability while still supporting healthy plant growth.

Current Research and Innovations

Recent research has focused on finding alternative and organic nutrient solutions for hydroponic systems. Scientists aim to improve nutrient efficiency while reducing environmental impact and production costs. Advances in small-scale and portable hydroponic systems have also made hydroponics more accessible for classroom experiments and home gardening. These innovations support the exploration of simple and eco-friendly nutrient sources like fermented rice water.

Main Problem

This study aims to determine the effects of fermented rice water on the germination, growth, and chlorophyll content of basil plants grown in a hydroponic system.

Research Goals

1. To determine the effect of fermented rice water on the germination of basil seeds grown hydroponically.
2. To evaluate the effect of fermented rice water on the overall growth of basil plants by measuring plant height and number of true leaves.
3. To determine whether fermented rice water affects the chlorophyll content of basil leaves compared to other nutrient treatments.

Problem Questions

1. How does fermented rice water affect the germination of basil seeds?
2. How does fermented rice water influence the overall growth of basil plants grown hydroponically?
3. Is there a significant difference in chlorophyll content among basil plants grown under different nutrient treatments?

Hypotheses

Null Hypothesis (H_0)

Fermented rice water does not affect the germination, growth, or chlorophyll content of hydroponic basil plants.

Alternative Hypothesis (H_1)

Fermented rice water affects the germination, growth, and chlorophyll content of hydroponic basil plants.

Variables

Independent Variable

The type of water or nutrient solution used, including:

- Plain water
- Commercial nutrient solution
- Fermented rice water (FRW)

Dependent Variables

- Germination rate of basil seeds
- Overall growth of basil plants (plant height and number of leaves)
- Chlorophyll content of basil leaves

Controlled Variables (Constants)

- Type of plant used (basil)
- Number of seeds planted
- Growing medium (coconut coir)
- Hydroponic setup
- Light exposure, temperature, and water volume
- Duration of the experiment

Methodology/ Procedures

A. Germination Rate of Basil Seeds

Experimental Design and Setup

The study employed a completely randomized experimental design consisting of six treatments, each with three replicates, resulting in a total of 18 hydroponic setups. Each replicate contained three basil (*Ocimum basilicum*) seeds, for a total of 54 seeds used in the experiment. Coconut coir was used as the growing medium and placed in net cups within a hydroponic system. All setups were maintained under uniform environmental conditions, including the same light exposure, ambient temperature, and water availability, to minimize external variability.

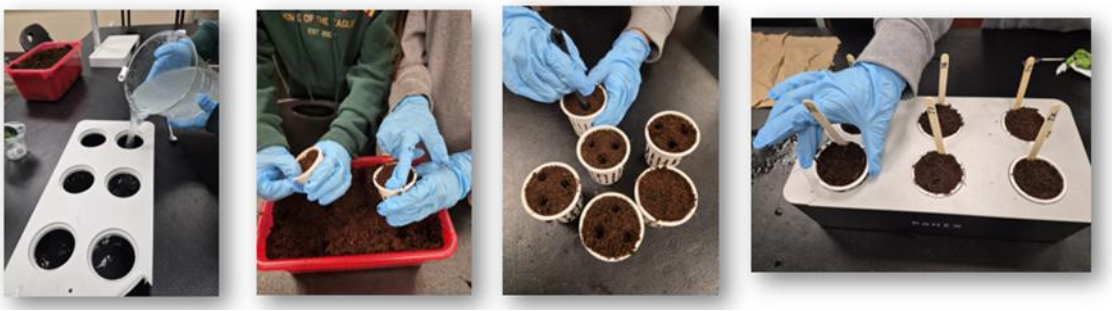


Fig. 1. Step-by-Step Hydroponic Setup and Seed Planting Procedure.

1. This figure shows the preparation of the hydroponic system and planting of basil seeds prior to germination monitoring.
2. The hydroponic unit was prepared and placed on a stable surface.
3. The assigned nutrient solution was poured into the reservoir according to treatment.
4. Coconut coir was moistened and placed into each net cup as the growing medium.
5. Three basil (*Ocimum basilicum*) seeds were planted per cup and lightly covered with coir.
6. Cups were arranged in the hydroponic system according to treatment labels (T1–T6).
7. All setups were maintained under uniform light, temperature, and water conditions.

Preparation of Nutrient Solutions

Fermented rice water (FRW) was prepared and diluted prior to application to prevent excessive nutrient concentration and potential phytotoxic effects. The standard dilution used for FRW consisted of 25 mL of fermented rice water mixed with 250 mL of

distilled water, equivalent to a 1:10 dilution ratio. This dilution served as the basis for the FRW concentration treatments, namely 5%, 10%, 15%, and 20%, which were adjusted proportionally from the stock fermented rice water solution.

The commercial nutrient solution was prepared following the manufacturer's recommended dilution rate. Specifically, 2.5 mL of commercial nutrient solution was diluted in 250 mL of distilled water, corresponding to a 1:100 dilution ratio. The plain water treatment consisted of 250 mL of distilled water only, with no added nutrients, and served as the negative control. All treatments received equal solution volumes to ensure consistency across experimental setups.

Germination Monitoring

Seeds were monitored daily for the first 14 days after planting. A seed was considered germinated upon the visible emergence of the radicle from the seed coat. The number of germinated seeds was recorded for each replicate and summarized per treatment to determine germination rate and percentage.

The germination rate was calculated using the formula:

$$\text{Germination Rate (\%)} = \frac{\text{Number of Germinated Seeds}}{\text{Total Seeds Planted}} \times 100$$

B. Measurement of Overall Growth of Basil (*Ocimum basilicum*)

Basil plants were grown hydroponically using coconut coir as the growing medium. Overall plant growth was evaluated by measuring plant height and counting the number of true leaves. Plant height was measured from the surface of the coconut coir to the highest point of the plant using a calibrated ruler or digital caliper, with measurements recorded in millimeters. The number of true leaves was determined by counting only fully developed leaves and excluding the cotyledons (seed leaves). Growth measurements were conducted on Days 7, 14, and 21 after planting to monitor early, mid, and later stages of seedling development.

Fig. 2. Step-by-Step Measurement of Plant Height and Leaf Development.

1. This figure illustrates the procedure used to measure overall growth of hydroponic basil seedlings.
2. A basil seedling was selected from the assigned treatment group.
3. A digital caliper was positioned vertically at the surface of the coconut coir.
4. Plant height was measured from the coir surface to the highest point of the plant.
5. Height measurements were recorded in millimeters (mm) or inches.
6. The number of true leaves was counted, excluding cotyledons.
7. Measurements were conducted on Days 7, 14, and 21.

C. Chlorophyll Measurement Using a Chlorophyll Meter

Leaf chlorophyll content of basil (*Ocimum basilicum*) seedlings was measured using a portable chlorophyll meter (SPAD meter). This non-destructive method allowed repeated measurements on the same plants without causing damage. Prior to use, the chlorophyll meter was turned on and cleaned to ensure accurate readings. A healthy, fully expanded basil leaf was selected from each plant, and the leaf was carefully placed inside the meter, avoiding the main leaf vein. The SPAD value displayed on the screen was recorded. Three readings were taken per plant, and the mean SPAD value was calculated to represent the chlorophyll content of each replicate. Chlorophyll measurements were conducted on Day 14 and Day 21 after planting to assess changes in leaf chlorophyll content during seedling development.

Fig. 3. Step-by-Step Chlorophyll Content Measurement Using a SPAD Meter.

This figure presents the non-destructive procedure used to measure leaf chlorophyll content.

1. The portable chlorophyll meter was turned on and prepared for use.
2. A healthy, fully expanded basil leaf was selected.
3. The leaf was inserted into the sensor slot, avoiding the main leaf vein.
4. The SPAD value displayed on the screen was recorded.
5. Three readings per plant were taken and averaged.
6. Chlorophyll measurements were performed on Days 14 and 21.

Results and Discussion

Results

The results showed that fermented rice water, particularly at 10% concentration, significantly improved germination, plant height, leaf development, and chlorophyll content of hydroponic basil. FRW 10% performed comparably to commercial nutrient solutions, while plain water consistently resulted in the lowest performance.

A. Germination Rate of Basil Seeds (Day 14 / Day 21)

Table 1. Germination Rate of Basil Seeds

Treatment Code	Treatment	Total Seeds	Germinated Seeds	Germination (%)
T1	FRW 15%	9	5	55.56
T2	Commercial nutrient	9	7	77.78
T3	FRW 5%	9	3	33.33
T4	FRW 20%	9	8	88.89
T5	Plain water	9	2	22.22
T6	FRW 10%	9	8	88.89

Germination rate varied among treatments. FRW 10% and FRW 20% showed the highest germination (88.89%), while plain water had the lowest (22.22%). This indicates that nutrient treatment affected seed germination.

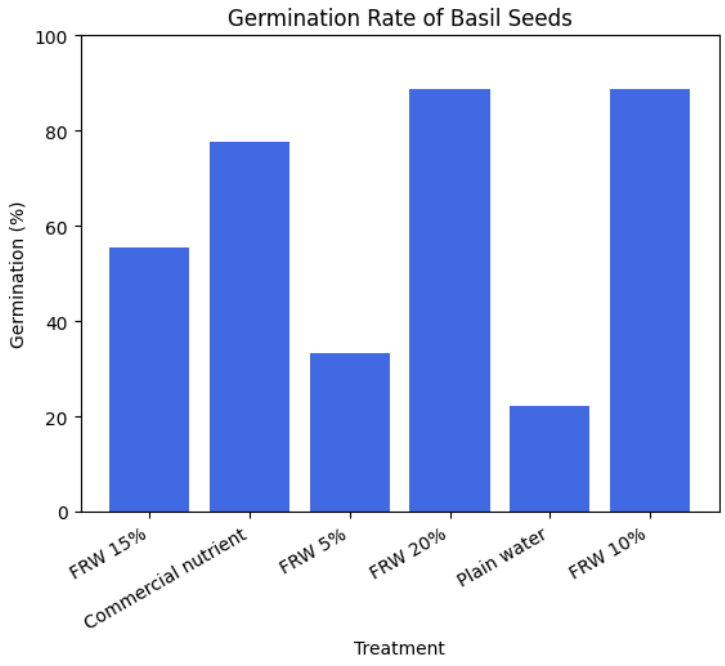
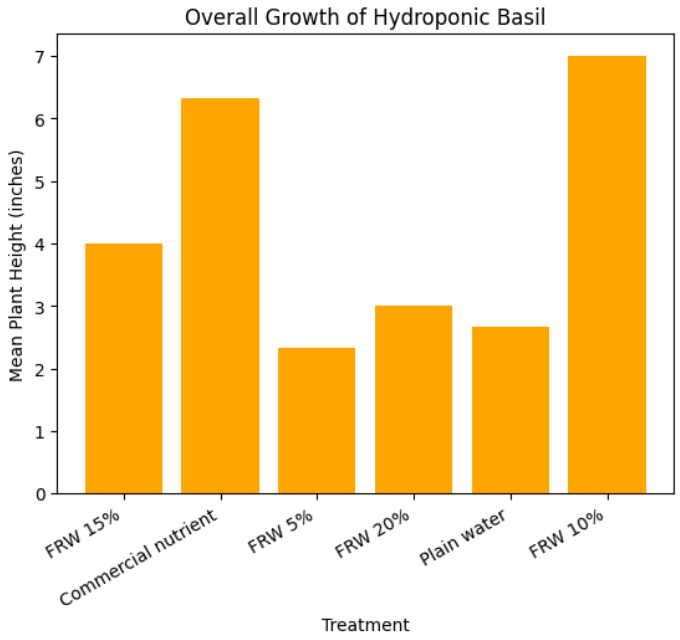


Figure 1 shows the germination rate of basil seeds under different nutrient treatments. Treatments FRW 10% and FRW 20% produced the highest germination, while plain water resulted in the lowest germination rate.

B. Overall Growth of Basil Plants (Height)

Table 2. Plant Height of Basil (in inches)

Treatment	R1	R2	R3	Mean Height (in)
FRW 15%	4	4	4	4.00
Commercial nutrient	7	6	6	6.33
FRW 5%	4	1	2	2.33
FRW 20%	4	3	2	3.00
Plain water	3	2	3	2.67
FRW 10%	8	6	7	7.00



One-way ANOVA showed a significant difference in plant height among treatments ($p < 0.05$). Basil plants treated with FRW 10% had the greatest mean height, while FRW 5% and plain water showed the lowest growth.

Figure 2 illustrates the mean height of basil plants grown hydroponically under different treatments. FRW 10% resulted in the greatest plant height, indicating improved overall growth.

C. Leaf Development (Chlorophyll Indicator)

Table 3. Number of Leaves per Basil Plant

Treatment	R1	R2	R3	Mean No. of Leaves
FRW 15%	8	8	4	6.67
Commercial nutrient	12	8	8	9.33
FRW 5%	4	5	4	4.33
FRW 20%	4	4	5	4.33
Plain water	2	4	2	2.67
FRW 10%	7	5	6	6.00

Leaf development differed among treatments. Commercial nutrient produced the highest leaf number, followed by FRW 15%. Plain water resulted in the lowest leaf production, indicating poor plant health.

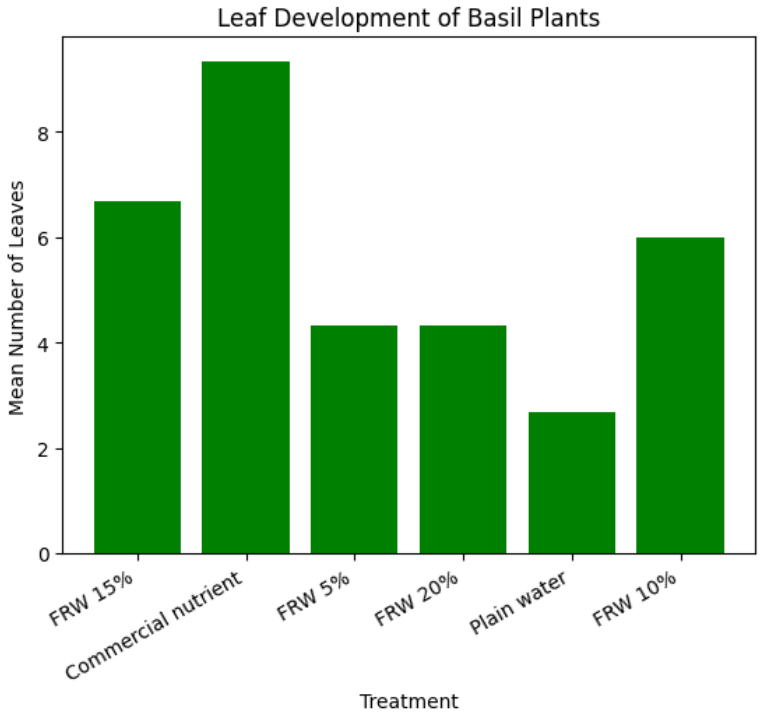


Figure 3 presents the mean number of leaves per basil plant. Commercial nutrient and FRW 10% treatments produced more leaves, indicating healthier vegetative growth

D. Chlorophyll Content (SPAD Values)

Table 4. Mean Chlorophyll Content of Basil Leaves

Treatment	Mean SPAD (Day 14)	Mean SPAD (Day 21)
FRW 15%	32.1	36.4
Commercial nutrient	36.1	41.2
FRW 5%	29.7	33.9
FRW 20%	27.9	30.2
Plain water	24.8	26.9
FRW 10%	33.9	38.9

Chlorophyll content increased from Day 14 to Day 21 in all treatments. Commercial

nutrient and FRW 10% showed the highest SPAD values, indicating better photosynthetic activity.

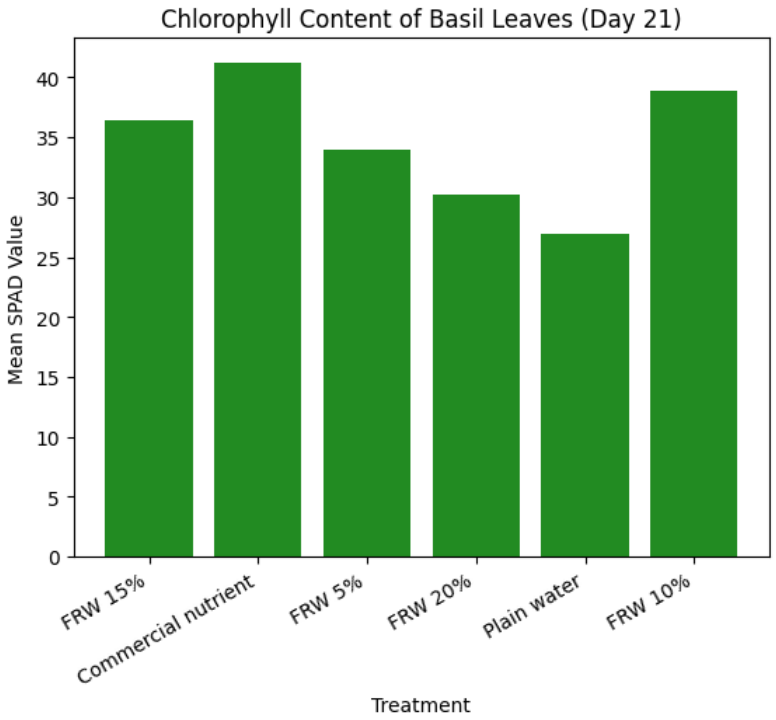


Figure 4 shows the mean chlorophyll content of basil leaves measured on Day 21. Plants treated with FRW 10% showed high chlorophyll content comparable to commercial nutrient solutions.

Discussion

This study investigated the effects of fermented rice water (FRW) on the germination, growth, and chlorophyll content of basil plants grown in a hydroponic system. The results showed that different nutrient treatments influenced how well the basil plants developed.

Germination Rate

The germination results showed that basil seeds treated with FRW at 10% and 20% concentrations had the highest germination rates, while seeds grown with plain water had the lowest. This suggests that nutrients present in fermented rice water helped improve seed germination compared to water alone. Nutrients such as nitrogen and other minerals are

known to support early seed development and root emergence (Taiz et al., 2018). However, treatments with very low or very high concentrations showed lower germination, indicating that the correct amount of nutrients is important for optimal seed growth (Tesfaye & Taye, 2017).

Overall Growth (Plant Height)

Plant height measurements showed that basil plants grown with 10% fermented rice water were the tallest among all treatments. This suggests that a moderate concentration of fermented rice water provided sufficient nutrients to support healthy plant growth. Adequate nutrient availability allows plants to grow taller by supporting cell division and stem elongation (Taiz et al., 2018). In contrast, plants grown with FRW 5% and plain water were shorter, likely due to limited nutrient availability, which restricted their growth (Mattson & Peters, 2014).

Leaf Development

Leaf development varied among treatments, with basil plants grown using commercial nutrient solution producing the highest number of leaves, followed closely by plants treated with FRW 10%. Leaves are important because they are the main sites of photosynthesis, where plants produce food for growth. Studies have shown that nutrient-rich solutions promote leaf formation and expansion, leading to healthier plants (Resh, 2013). Basil plants grown with plain water produced the fewest leaves, showing signs of poor growth and limited nutrient support.

Chlorophyll Content

Chlorophyll content was highest in basil plants treated with commercial nutrient solution and FRW 10%. Chlorophyll is essential for photosynthesis because it allows plants to absorb light energy. Higher chlorophyll levels indicate better photosynthetic activity and healthier plants (Lichtenthaler & Wellburn, 1983). Plants grown with plain water had the lowest chlorophyll content, which suggests nutrient deficiency and reduced ability to produce food. These findings support previous research showing that organic liquid

fertilizers can improve chlorophyll content when applied at appropriate concentrations (Yadav & Christopher, 2016).

Overall, the results indicate that fermented rice water, when properly diluted, can support the germination, growth, and chlorophyll development of basil plants in a hydroponic system. Among all treatments, FRW at 10% concentration produced the most balanced and consistent results, showing performance comparable to commercial nutrient solutions. This supports the idea that fermented rice water can serve as a low-cost, eco-friendly nutrient alternative for hydroponic plant production (Shoji & Hirano, 2020).

Conclusions

This study showed that fermented rice water (FRW) influenced the germination, growth, and chlorophyll content of basil plants grown in a hydroponic system. Basil seeds treated with fermented rice water, especially at a 10% concentration, had higher germination rates than seeds grown with plain water, indicating that FRW supported better seed sprouting. Plants grown with FRW 10% were also taller and produced more leaves compared to most other treatments, showing improved overall growth. In addition, basil plants treated with FRW 10% and the commercial nutrient solution had higher chlorophyll content than those grown with plain water, suggesting healthier photosynthesis and plant development. These findings support the alternative hypothesis and showed that fermented rice water at a 10% concentration is an effective, low-cost, and eco-friendly nutrient option for growing basil in a hydroponic system.

WHY OUR RESULTS IMPORTANT

Sustainable Agriculture:

The results show that fermented rice water can support basil growth in a hydroponic system, offering a low-cost and eco-friendly alternative to commercial nutrient solutions.

Cost-Effective Gardening:

Using a household by-product like fermented rice water can reduce expenses for schools and small growers while still maintaining healthy plant growth.

STEM Learning:

This study promotes hands-on scientific investigation, helping students develop skills in experimentation, data analysis, and problem-solving through real-world applications.

Environmental Impact:

Exploring organic nutrient alternatives supports sustainable farming practices and reduces reliance on chemical fertilizers, benefiting both communities and the environment.

Future Plans/ Recommendation

Future studies may extend the growing period to observe flowering, leaf yield, and harvest quality. Other leafy plants, such as lettuce, cilantro, and spinach, may also be tested using fermented rice water to determine if similar results can be achieved. Further research may explore additional fermented rice water concentrations and compare them with other organic nutrient solutions. Measuring water quality factors, such as pH and nutrient levels, could help explain how fermented rice water affects plant growth and improve its use in hydroponic systems.

References

Lichtenthaler, H. K., & Wellburn, A. R. (1983). Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. *Biochemical Society Transactions, 11*(5), 591–592. https://doi.org/10.1042/bst0110591

Mattson, N. S., & Peters, C. (2014). A recipe for hydroponic success. *American Scientist, 102*(5), 364–371. https://doi.org/10.1511/2014.110.364

Resh, H. M. (2013). *Hydroponic food production: A definitive guidebook for the advanced home gardener and the commercial hydroponic grower* (7th ed.). CRC Press.

Shoji, K., & Hirano, Y. (2020). Organic nutrient management in hydroponic cultivation: Challenges and opportunities. *Horticulturae, 6*(3), 48. https://doi.org/10.3390/horticulturae6030048

Taiz, L., Zeiger, E., Møller, I. M., & Murphy, A. (2018). *Plant physiology and development* (6th ed.). Sinauer Associates.

Tesfaye, A., & Taye, M. (2017). Effects of organic liquid fertilizers on plant growth and chlorophyll content. *African Journal of Agricultural Research, 12*(4), 273–280. https://doi.org/10.5897/AJAR2016.11806

Yadav, B. K., & Christopher, L. (2016). Liquid organic fertilizers: A review on their effects on plant growth and soil fertility. *Journal of Plant Nutrition, 39*(9), 1344–1356. https://doi.org/10.1080/01904167.2015.1109102