

Effects of Various Disinfectants for Algae Control in Hydroponic Nutrient Solution

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ABSTRACT

Climate change continues to threaten traditional agriculture. As a result, there has been an increased interest in hydroponics as an alternative to the future food supply. However, algae growth in hydroponic systems presents a significant challenge to plant health and productivity. For one, algae growth leads to depleted oxygen and nutrient levels and root rot, notably decreasing the efficiency of vegetation growth. This matter must be addressed by finding a means of controlling the algae blooms within a hydroponic system to yield productive vegetation growth. We hypothesized that adding disinfectants to hydroponic water could be an effective solution to solve this problem. To test our solution, we compared algae growth in a control hydroponic nutrient solution with solutions containing 1% of either 99.5% ethanol, 99% isopropyl alcohol (IPA), 3% bleach, and 3% hydrogen peroxide (H₂O₂). Solutions were prepared in 500 mL beakers and exposed to sunlight, with photos taken every 12 hours over 4 days to observe and document the algae growth. Out of four different common disinfectants, H₂O₂ was the most effective in inhibiting algae growth. Our findings will enable a cheaper method to control algae growth in hydroponics using commonly available disinfectant which is 3% H₂O₂.

Keywords: hydroponics; algae; hydrogen peroxide; disinfect; mold; nutrient solution

INTRODUCTION

The world is experiencing climate change which threatens every life on the planet including animals,

plants, and humans. If the carbon dioxide (CO₂) levels continue to rise at the present rate, scientists predict that there will be an increase in atmospheric temperature, changes in pH of the ocean, and more frequent storms (1). Despite widespread efforts to raise awareness about climate change, we remain dangerously unprepared for the increasingly intense storms and frequent floods it will bring (2). Furthermore, the population in the world is predicted to increase to 9 billion by 2025, and this could

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potentially create food shortage issues, along with the worsening living conditions due to climate change (3). The United States of America agriculture alone contributes more than 750 million dollars and feeds more than 10 billion people around the world (4, 5). Even though we can still feed more than 10 billion people, climate change can bring dramatic effects: changing farming conditions. Consequently, climate change can cause significant problems in agriculture as farmers will experience spontaneous and extreme temperatures. Furthermore, frequent flooding will make land almost impossible to plant crops and vegetables (6). Crops and vegetables require stable temperatures and favorable conditions to grow; thus, people are looking for sustainable methods to grow food as climate change arises.

Hydroponics is becoming increasingly popular due to its ability to grow plants without soil. Hydroponics is a soilless plant cultivation that relies on water-based nutrient solutions and inert substrates such as coconut coir, foam, or perlite (7). It offers several advantages over conventional soil-based agriculture, with a reduction in water usage up to 90% compared to traditional farming methods. In addition, it enables control over environmental parameters such as temperature and humidity as plants are typically conducted indoors. The controlled environment contributes to higher crop yields and reduces the requirement of labor and maintenance (8). Since planting and growing can be done throughout the whole year in any location, the market will reach a value of 58.3 billion dollars by 2030 from 35.2 billion dollars in 2022 (9).

Despite all the advantages of hydroponics, there are

still problems to be solved. Hydroponic systems still face challenges such as high set-up cost, electricity requirements, contracting waterborne diseases very easily, root rot, and mold and algae growth (10, 11). Since algae and mold easily target and rot plant roots, people are constantly checking root conditions every day. In fact, if the root rots, healing the root is extremely difficult and cannot be reversed; therefore, plants are discarded most of the time (12) (Figure 1) (13). Algae affect the environment in various ways. Algae often contribute to nutrient cycling, aiding aquatic systems in retaining nutrients and preventing contamination. (14) However, when bodies of water receive excessive nutrient enrichment, a process called eutrophication occurs where the algae population grows rapidly (a phenomenon known as algal blooms) (15). Algae blooms induce a depletion of oxygen in the hydroponic system; therefore, plants cannot receive enough nutrients to grow. (16) Furthermore, certain algae, such as cyanobacteria, emit toxins that threaten the plant's health (17).

Additionally, algae growth increases pest attraction leading to fungus gnat and shore fly spawns which further inhibits plant growth due to wilting and disease transmission (18). To deal with algae blooms, individuals have resorted to manually cleaning out hydroponic systems regularly. Additionally, filters and shrimp are additional means of algae control (19). Another experiment from the University of Washington noted that grapefruit seed extract was also another means of eliminating algae without harming other vegetation (20). Even though there are many methods to control algae, using household disinfectants can be inexpensive and

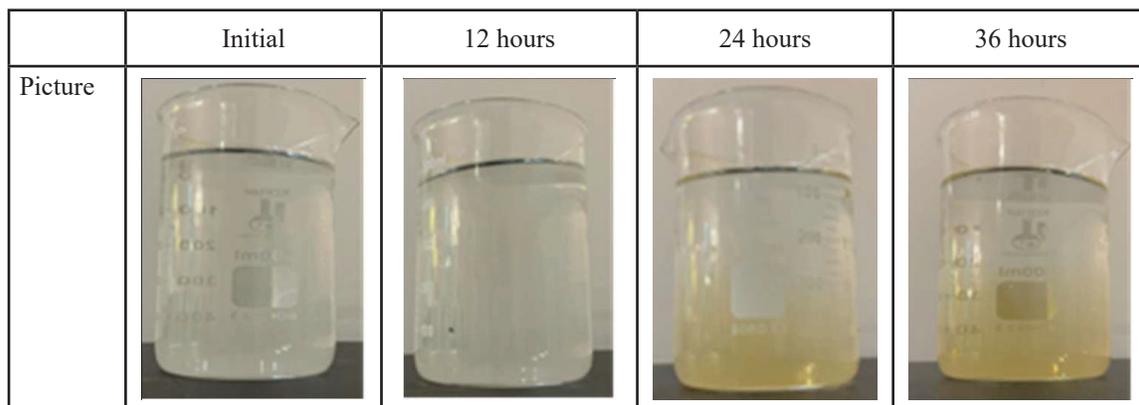


Figure 1. Picture of Control solution. Picture was taken every 12 hr to see the progression of algae growth. The solution shows no cloudiness, but algae and mold growth are clearly present. Until 48 hr, cloudiness barely changed, after 48 hr distinctive algal colonies and mold growth appeared.

easily accessible. Disinfectants have traditionally been used to fight microorganisms on surfaces, both living and non-living. Disinfectants are a blend of chemical compounds also known as biocides, and when different biocides are blended, a new type of disinfectant is created (21). Due to antimicrobial effects from disinfectants, we hypothesized that by adding small amounts of common household disinfectants in the hydroponic water, we can control the algae population. After successful experiments, 3% hydrogen peroxide (H_2O_2) was able to reduce algae growth for a good amount of time.

METHODS AND MATERIALS

Preparation of hydroponic nutrient water

We purchased liquid plant food from amazon (TPS NUTRIENTS, 8 ounces, model # LIQUIDPF8OZ) as a liquid hydroponic nutrient. We added 1 tsp of the nutrient in the 1 L of beaker containing 500 mL of water and swirled with stirring rod (EISCO, Model # CH0757C) for 15 minutes to mix the nutrient thoroughly in the water. The mixed solution was ready to add different disinfectants for the experiments. For each trial, one beaker is used for each condition-control, isopropyl alcohol (IPA), bleach, ethanol, and H_2O_2 -resulting five beakers per trial.

Preparation of hydroponic nutrient solution (Control)

The control condition consisted of tap water mixed with the hydroponics food at the same dosage as all other treatments, but without any disinfectant added. The 500 mL of premade hydroponic nutrient water was transferred to a 1 L beaker and was covered with plastic food wrap (Glad store from amazon, 100 square feet, model # B00KKC6C21) with a small hole in the center of the covered wrap to let air get in. The solution was placed right next to the window to receive a good amount of sunlight. Picture was taken every 12 hours for data purposes.

Preparation of hydroponic nutrient solution with ethanol for algae control

In the hydroponic nutrient solution we made, we added (5 mL 1% v/v) of 99.5% denatured ethanol (Natural Cosmetic Labs Store in amazon, model # B09DGVL4ML) and swirled with a stirring rod for 15 minutes. After swirling, the beaker was covered with plastic food wrap (Glad store from amazon, 100 square foot, model # B00KKC6C21) with a small hole in the center of the covered wrap to let air get in. The solution

was placed right next to the window to receive a good amount of sunlight. Picture was taken every (12 hours) for data purposes.

Preparation of hydroponic nutrient solution with IPA for algae control

In the hydroponic nutrient solution we made, we added (5 mL 1% v/v) of 99% IPA (Amazon basics, 16 Fluid oz, model #B07NFSFBXQ) and swirled with a stirring rod for 15 minutes. After swirling, the beaker was covered with plastic food wrap (Glad store from amazon, 100 square feet, model # B00KKC6C21) with a small hole in the center of the covered wrap to let air get in. The solution was placed right next to the window to receive a good amount of sunlight. Picture was taken every (12 hours) for data purposes.

Preparation of hydroponic nutrient solution with hydrogen peroxide for algae control

In the hydroponic nutrient solution we made, we added (5 mL 1% v/v) of 3% H_2O_2 (Amazon basics, 32 Fl Oz, model # B09HHDW53K) and swirled with a stirring rod for 15 minutes. After swirling, the beaker was covered with plastic food wrap (Glad store from amazon, 100 square feet, model # B00KKC6C21) with a small hole in the center of the covered wrap to let air get in. The solution was placed right next to the window to receive a good amount of sunlight. Picture was taken every 12 hours for data purposes.

Preparation of hydroponic nutrient solution with bleach for algae control

In the hydroponic nutrient solution we made, we added (5 mL 1% v/v) of Bleach (Zivigo from amazon, 121 oz, model # B0C2SCX61D) containing 7.4% sodium hypochlorite and swirled with a stirring rod for 15 minutes. After swirling, the beaker was covered with plastic food wrap (Glad store from amazon, 100 square foot, model # B00KKC6C21) with a small hole in the center of the covered wrap to let air get in. The solution was placed right next to the window to receive a good amount of sunlight. Picture was taken every 12 hours for data purposes.

Data analysis

The entire experiment has been repeated three times to show reliability of the research, and the turbidity values were averaged with a standard deviation of $\pm 3\%$ was calculated. Error bars in all analyses are represented with $\pm 3\%$ standard deviation.

RESULTS

First, we added ½ teaspoon of plant nutrient into 500 mL of tap water into a 500 mL beaker. We then took photos every 12 hours to observe the growth of algae and mold over the period of 4 days (Control) (Figure 1). As for the disinfectants, we prepared the solution using the same procedure as the control and then added desired disinfectants to the hydroponic nutrient solution. We chose 99.5% ethanol and added 1% v/v to the hydroponic nutrient solution and stirred another 15 minutes to thoroughly mix the disinfectant while covering the top with wrap. We left the solution under sunlight to initiate growth of algae and took a picture every 12 hours to capture images of algae and mold growth (Figure 2). We also prepared another sample by using

3% bleach and added 1% v/v to the hydroponic nutrient solution and stirred 15 minutes more to thoroughly mix the disinfectant. We then left the solution under sunlight covered with wrap. Once again, a picture was taken every 12 hours to collect algae and mold growth (Figure 3). To make the IPA hydroponic nutrient water, we added 1 tsp of the hydroponic liquid nutrient into the 1 L beaker containing 500 mL of water. After, we added 1% v/v of 99% IPA into the pre-made hydroponic nutrient solution and took pictures every 12 hours to see when mold & algae will appear (Figure 4). Last, to make the H₂O₂ added hydroponic nutrient water, we added 1 tsp of the hydroponic liquid nutrient into the 1 L beaker containing 500 mL of water. After, we added 1% v/v of 3% H₂O₂ (Figure 5). We analyzed the turbidity of each solution using a spectrophotometer. Control and

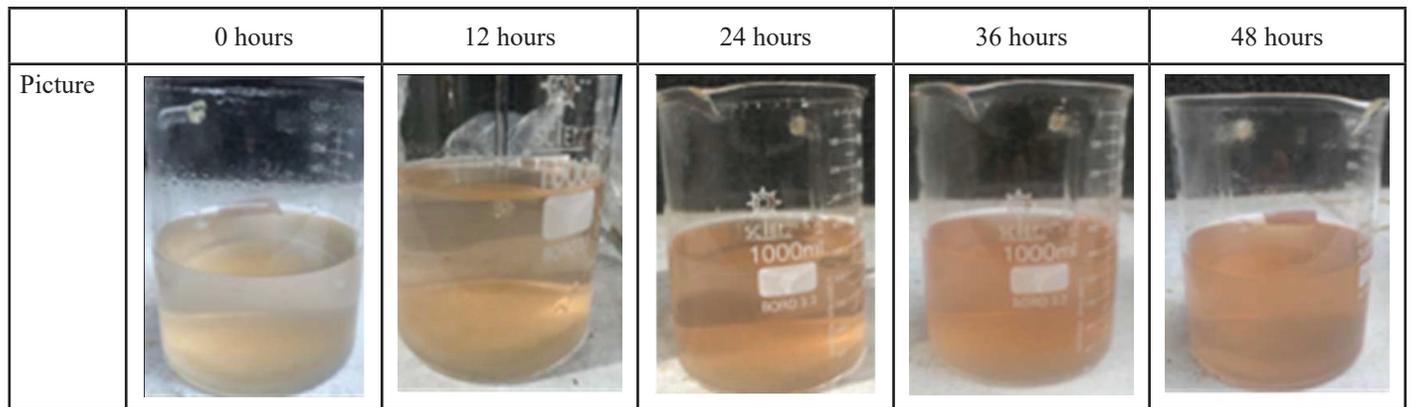


Figure 2. Picture of Ethanol solution. Picture was taken every 12 hr to observe the progression/regression of algae growth within an ethanol-based solution. The color of the solution has changed, and cloudiness of the solution is present, showing that the Ethanol failed to effectively disinfect algae and bacteria in the hydroponic solution.

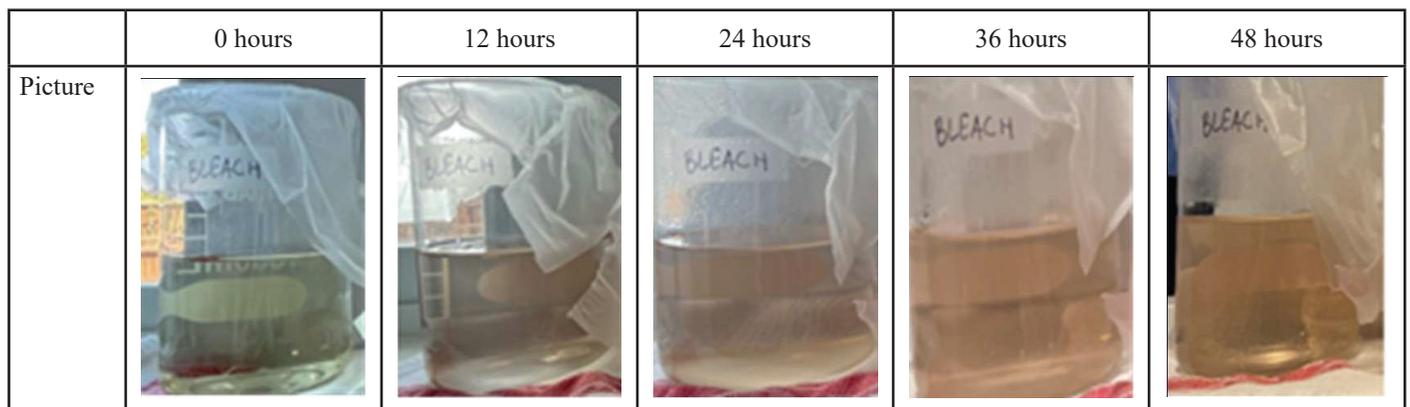


Figure 3. Picture of Bleach solution. Picture was taken every 12 hr to see the progression of algae growth in the bleach-based solution. It looked disinfected until 12 hours, but after that the solution showed changes in cloudiness and color. This means the disinfection effect of bleach was short-term and not effective to control algae and mold.

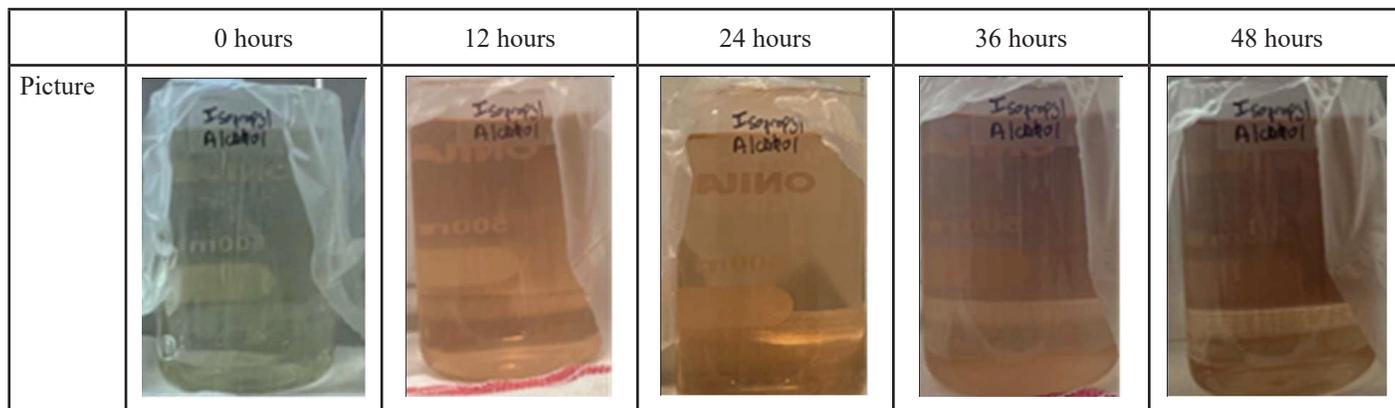


Figure 4. Picture of IPA solution. Picture was taken every 12 hr to see the progression of algae growth within the IPA-based solution. The color of the solution has changed, and cloudiness of the solution is present. Representing the IPA couldn't control the mold and algae groups.

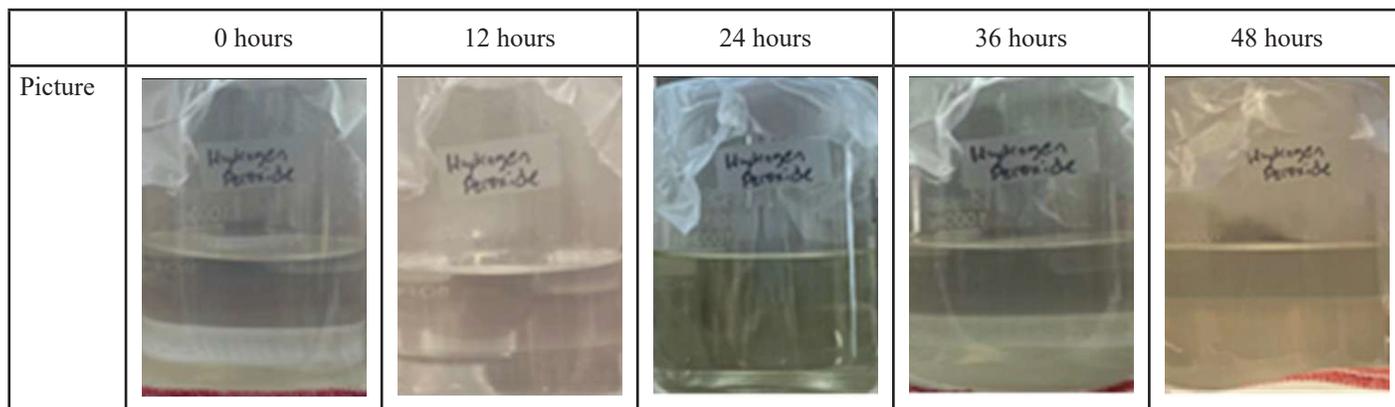


Figure 5. Picture of H₂O₂ solution. Picture was taken every 12 hr to see the progression of algae growth within the hydrogen peroxide-based solution. There is no drastic color change within the solution and very minimal cloudiness. This means that the 3% of hydrogen peroxide was effective to control molds and algae in hydroponics nutrient solution unlike other disinfectants.

other disinfectants, excluding H₂O₂, show constant algae growth. This shows that IPA, bleach, and ethyl alcohol have almost no impact on controlling algae growth. However, H₂O₂ was able to halt algae growth for 1 day. Our results suggest that even at small concentration, H₂O₂ was effective in controlling algae growth of hydroponic nutrient water. Furthermore, our figure indicates hydrogen peroxide as potentially promising in controlling algae growth compared to other disinfectants because there was not much cloudiness or color change compared to other disinfectants (Table 1). However, this study was limited as a small-scale and short period observation experiment, and larger-scale, long-term replicated trials are needed to evaluate its applicability.

Table 1. Turbidity after given hours

Measured Hour	Control	Hydrogen Peroxide	IPA	Bleach	Ethyl Alc
0	2	2.1	5.7	8.7	12.5
12	5.8	2.5	22.6	13.5	25.7
24	37.4	5.7	35.7	22.4	31.1
36	65.7	15.8	65.9	42.2	67.9
48	101.2	31	99.1	84.3	94.7

Turbidity was measured using visible spectrometer to analyze algae growth in hydroponic nutrient water. Turbidity values are the mean ±3% standard deviation from three independent trials.

DISCUSSION

We decided to use 99.5% ethanol, 99% IPA, 3% bleach, and 3% H₂O₂ for our experiments because they are easily accessible and inexpensive. Furthermore, those chemicals are not very toxic to the environment, thus eco-friendly. To obtain experimental data, we made a base solution to which each disinfectant will be added to. Based on the results of our experiment, IPA, ethanol and bleach had little effect on the controlling algae growth in nutrient solution (Figures 2, 3, 4). While H₂O₂ showed very promising data on controlling algae growth (Figure 5). For those three disinfectants, the color of the solution turned red slowly and cloudiness appeared after 12 hrs. The H₂O₂ solution showed a change from slight cloudiness to clear solution during the first 12 hours. If algae were growing initially, the solution would become much cloudier; therefore, we concluded that it was not algae but perhaps H₂O₂ not mixing with solution well initially. After a couple hours, the H₂O₂ added solution became transparent. Only the H₂O₂ was able to inhibit algae growth while other common household disinfectants were either ineffective or had very minimal effects. Control, IPA, bleach, and ethanol solutions all exhibited a steady increase in turbidity, indicating they are not effective for disinfectants for algae growth in hydroponic solutions (Table 1). We believe that the H₂O₂ was especially potent compared to the other disinfectants due to its powerful properties as an oxidative agent, and enhanced processes from the UV energy. In this experiment, H₂O₂ photolysis is displayed, where UV energy from sunlight causes H₂O₂ to break into two hydroxyl radicals, a reactive oxygen species that breaks down organic pollutants in water. This equation can be represented as $H_2O_2 + hv = 2 \cdot OH$. This chemical has high reactivity, and destroys cell membranes, proteins, and DNA by oxidizing them. Furthermore, the chemicals that make up bleach most likely lose their effectiveness under the sunlight, as the UV radiation from the light breaks down the sodium hypochlorite in bleach. In addition to ethanol and IPA being alcohols, which do not inhibit algae growth and act as general biocides, their effectiveness is likely further decreased by sunlight. Sunlight increases oxidation, which degrades both substances over time. Additionally, the ethanol, IPA, and bleach perhaps aren't as effective as disinfectants within a solution compared to H₂O₂.

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We also acknowledge the limitations of our study, including the short experiment duration, small scale experiments, and limited range of disinfectants and concentrations tested.

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CONFLICT OF INTEREST

The authors: Annice Han, Bailee Kim, James Lim, Clara Chung, Jiyeon Hwang, Jasmine Liu, Woojoo Park, Elisha Kim, Miguel Shim, and David Kim declare that there are no conflicts of interest regarding the publication of this article.

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