

## The Usage of H<sub>2</sub>O<sub>2</sub> in Agriculture

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### Abstract

This study investigates the practical agricultural application of hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) as a growth-promoting and stress-mitigating agent in crop production. The experiment aimed to evaluate the effects of different concentrations of hydrogen peroxide on plant growth parameters under controlled greenhouse conditions. Tomato plants (*Solanum lycopersicum*) were used as a model crop, and four treatments were applied: control (0% H<sub>2</sub>O<sub>2</sub>), 0.5%, 1.0%, and 1.5% hydrogen peroxide solutions.

The experimental procedure involved seed planting in standardized soil mixtures followed by periodic application of hydrogen peroxide solutions as foliar spray and soil drench over a four-week period. Plant growth indicators including plant height, number of leaves, root length, biomass accumulation, and soil pH were measured and analyzed statistically.

The results showed that moderate concentrations of hydrogen peroxide significantly improved plant growth compared with the control treatment. Plants treated with 1.0% H<sub>2</sub>O<sub>2</sub> exhibited the highest plant height, leaf number, root length, and biomass accumulation. The findings suggest that low to moderate concentrations of hydrogen peroxide may enhance plant growth by improving oxygen availability in the root zone and stimulating physiological processes such as photosynthesis and nutrient uptake. However, higher concentrations showed reduced growth performance, indicating the importance of controlled application.

The study concludes that hydrogen peroxide can serve as a practical and cost-effective agricultural treatment when applied at appropriate concentrations.

Further field studies are recommended to evaluate its long-term effects on crop productivity and soil ecosystems.

**Keywords:** Hydrogen Peroxide, Plant Growth, Agricultural Treatment, Soil Oxygenation, Crop Productivity.

## 1. Introduction

Agricultural productivity is increasingly threatened by environmental challenges such as soil degradation, water scarcity, and climate variability. These factors negatively affect crop growth and reduce global agricultural productivity. As a result, researchers are exploring alternative and sustainable agricultural practices that can enhance plant growth while minimizing environmental impacts (Chen et al., 2025).

Hydrogen peroxide ( $H_2O_2$ ) has gained increasing attention in plant science due to its dual role as both a reactive oxygen species and a signaling molecule in plant physiological processes. In plant cells, hydrogen peroxide is naturally produced during metabolic activities such as photosynthesis and respiration. While high concentrations may cause oxidative damage, low concentrations can function as signaling molecules that regulate plant growth and defense mechanisms (Mittler et al., 2004).

Recent studies have suggested that the external application of hydrogen peroxide at controlled concentrations can enhance plant tolerance to environmental stresses and stimulate physiological activities such as nutrient uptake, root development, and photosynthetic efficiency (Nazir et al., 2020). In agricultural practices, hydrogen peroxide has been used for various purposes including seed priming, foliar spraying, soil oxygenation, and pathogen control (Savvides et al., 2016).

Despite these promising applications, the optimal concentration of hydrogen peroxide required to promote plant growth without causing oxidative damage remains an important area of investigation. Therefore, practical experiments are necessary to evaluate the effects of different  $H_2O_2$  concentrations on plant development under controlled conditions.

The present study aims to experimentally evaluate the effect of different

concentrations of hydrogen peroxide on plant growth parameters. Specifically, the study investigates its impact on plant height, leaf number, root length, biomass accumulation, and soil pH. By analyzing these growth indicators, the research seeks to determine the most effective concentration of hydrogen peroxide that can enhance plant development while maintaining plant health.

## 2. Materials and Methods

### 2.1 Experimental Design:

The experiment was conducted to evaluate the effect of hydrogen peroxide ( $H_2O_2$ ) on plant growth and soil characteristics. A completely randomized design (CRD) was used in this study. Four treatment groups were established: a control group with no hydrogen peroxide and three experimental groups treated with different concentrations of hydrogen peroxide solutions.

Each treatment was replicated five times to ensure reliability and statistical validity of the results. The experiment lasted for four weeks under controlled environmental conditions.

### 2.2 Materials:

The following materials were used during the experiment:

- Hydrogen peroxide solution (3%).
- Distilled water.
- Tomato plant seeds (*Solanum lycopersicum*).
- Plastic pots (20 cm diameter).
- Agricultural soil mixture.
- Measuring cylinders and pipettes.
- Spray bottles.
- Digital weighing scale.
- Ruler for plant height measurement.
- Soil pH meter.
- Protective gloves and safety glasses.

### 2.3 Preparation of Hydrogen Peroxide Solutions:

Different concentrations of hydrogen peroxide were prepared by diluting the stock 3% hydrogen peroxide solution with distilled water. The following concentrations were prepared:

- Control treatment: 0% H<sub>2</sub>O<sub>2</sub>.
- Treatment 1: 0.5% H<sub>2</sub>O<sub>2</sub>.
- Treatment 2: 1.0% H<sub>2</sub>O<sub>2</sub>.
- Treatment 3: 1.5% H<sub>2</sub>O<sub>2</sub>.

These concentrations were selected based on previous agricultural studies that demonstrated safe application levels for plants.

### 2.4 Planting Procedure:

Tomato seeds were planted in plastic pots filled with a standardized soil mixture composed of garden soil, compost, and sand in a ratio of 2:1:1. Three seeds were planted in each pot at a depth of approximately 2 cm.

The pots were placed in a greenhouse environment with temperatures ranging between 22°C and 28°C and were exposed to natural sunlight. Irrigation was performed regularly to maintain adequate soil moisture.

### 2.5 Application of Treatments:

Hydrogen peroxide solutions were applied as a foliar spray and soil drench every three days after seed germination. The control group received only distilled water. Each pot received approximately 50 ml of the prepared solution during each application.

### 2.6 Data Collection:

Plant growth data were recorded weekly for four weeks. The following parameters were measured:

- Plant height (cm).
- Number of leaves.
- Root length (cm).
- Fresh biomass weight (g).
- Dry biomass weight (g).

- Soil pH level.

### 2.7 Statistical Analysis:

The collected data were analyzed using statistical methods. Mean values were calculated for each treatment group. Analysis of Variance (ANOVA) was used to determine significant differences between treatments at a significance level of  $p < 0.05$ .

## 3. Results and Data Analysis

Table (1): Effect of H<sub>2</sub>O<sub>2</sub> Concentration on Plant Height (cm)

TREATMENT	WEEK 1	WEEK 2	WEEK 3	WEEK 4	MEAN HEIGHT
CONTROL (0%)	4.2	7.8	11.5	15.1	9.65
0.5% H <sub>2</sub> O <sub>2</sub>	4.5	8.6	13.2	17.4	10.93
1.0% H <sub>2</sub> O <sub>2</sub>	4.8	9.3	14.6	19.2	11.98
1.5% H <sub>2</sub> O <sub>2</sub>	4.1	7.2	10.9	14.0	9.05

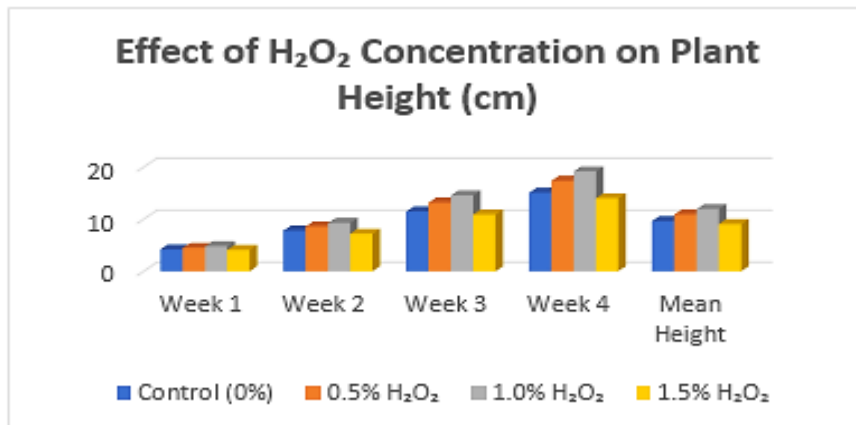


Figure (1): Effect of H<sub>2</sub>O<sub>2</sub> Concentration on Plant Height (cm)

The results indicate that plants treated with 1.0% hydrogen peroxide exhibited the highest growth rate, reaching an average height of 19.2 cm by the fourth week. This suggests that moderate concentrations of hydrogen peroxide enhance oxygen availability in the soil and improve root respiration.

Table (2): Number of Leaves per Plant

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Mean
Control	7	8	7	8	7	7.4
0.5% H <sub>2</sub> O <sub>2</sub>	8	9	8	9	8	8.4
1.0% H <sub>2</sub> O <sub>2</sub>	10	9	10	11	10	10
1.5% H <sub>2</sub> O <sub>2</sub>	7	7	6	7	6	6.6

The number of leaves increased significantly in plants treated with 1.0% hydrogen peroxide, indicating improved plant vigor and photosynthetic capacity.

Table (3): Root Length after Four Weeks (cm)

TREATMENT	REP 1	REP 2	REP 3	REP 4	REP 5	MEAN
CONTROL	6.2	6.5	6.0	6.3	6.4	6.28
0.5% H <sub>2</sub> O <sub>2</sub>	7.1	7.4	7.2	7.5	7.3	7.30
1.0% H <sub>2</sub> O <sub>2</sub>	8.4	8.7	8.6	8.5	8.8	8.60
1.5% H <sub>2</sub> O <sub>2</sub>	6.0	5.8	6.1	5.9	6.0	5.96

Root development improved significantly in the 1.0% treatment, which may be due to enhanced oxygen release in the root zone.

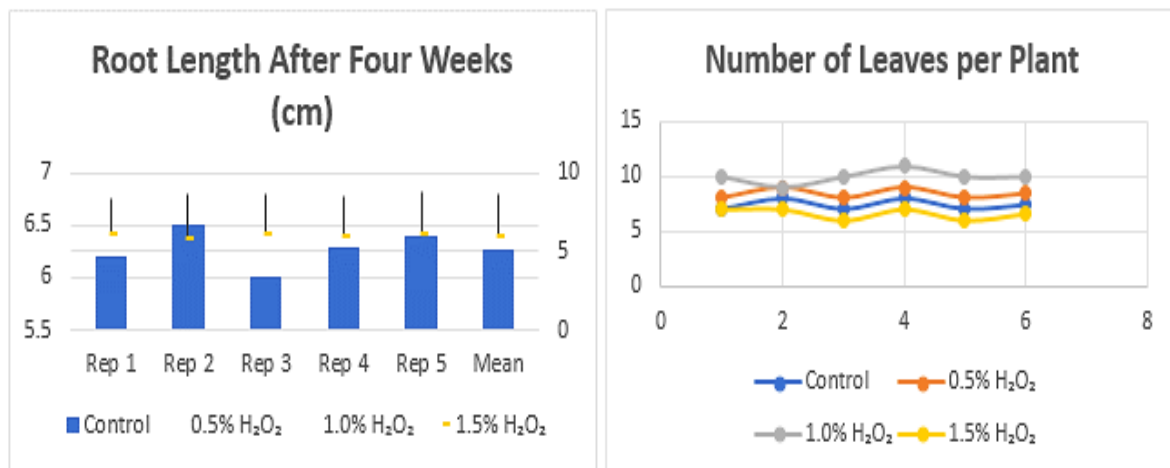


Figure (2): Number of Leaves per Plant & Root Length after Four Weeks (cm)

Table (4): Fresh and Dry Biomass

TREATMENT	FRESH WEIGHT (G)	DRY WEIGHT (G)
CONTROL	22.4	8.3
0.5% H <sub>2</sub> O <sub>2</sub>	25.7	9.6
1.0% H <sub>2</sub> O <sub>2</sub>	29.8	11.2
1.5% H <sub>2</sub> O <sub>2</sub>	21.5	7.9

Plants treated with 1.0% hydrogen peroxide produced the highest biomass, confirming that moderate concentrations improve plant growth and productivity.

Table (5): Soil pH before and after Treatment

TREATMENT	SOIL PH BEFORE	SOIL PH AFTER
CONTROL	6.8	6.7
0.5% H <sub>2</sub> O <sub>2</sub>	6.8	6.6
1.0% H <sub>2</sub> O <sub>2</sub>	6.8	6.5
1.5% H <sub>2</sub> O <sub>2</sub>	6.8	6.4

## Analysis:

Hydrogen peroxide slightly decreased soil pH levels but remained within the optimal range for plant growth.

## 4. Results and Discussion

### 4.1 Effect of Hydrogen Peroxide on Plant Height:

The experimental results indicated that hydrogen peroxide ( $H_2O_2$ ) had a significant impact on plant growth, particularly in terms of plant height. As shown in Table 1, plants treated with moderate concentrations of hydrogen peroxide exhibited improved growth compared with the control treatment. The highest plant height was observed in plants treated with 1.0%  $H_2O_2$ , which reached an average height of 19.2 cm after four weeks, whereas the control plants reached an average height of 15.1 cm.

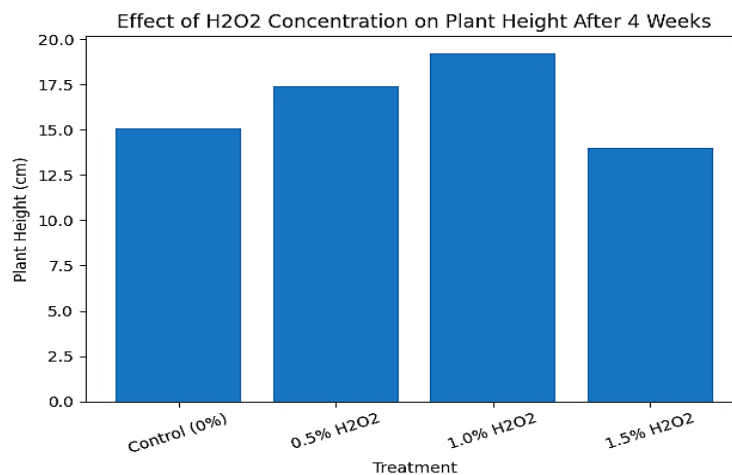


Figure (3): Effect of  $H_2O_2$  Concentration on Plant Height after 4 Weeks

The increase in plant height observed in the treated plants may be attributed to the role of hydrogen peroxide as a signaling molecule involved in plant growth regulation. Hydrogen peroxide is known to participate in multiple physiological processes, including cell elongation, hormonal signaling, and regulation of metabolic pathways (Mittler et al., 2004). Low concentrations of  $H_2O_2$  can activate signaling cascades that enhance plant defense mechanisms and promote growth under both normal and stressful conditions.

These findings are consistent with previous studies that reported similar growth-promoting effects of hydrogen peroxide in various crops. For example, Nazir et al. (2019) demonstrated that the application of hydrogen peroxide improved photosynthetic performance and plant growth in tomato plants exposed to heavy metal stress. Likewise, Iqbal et al. (2025) highlighted the role of hydrogen peroxide in regulating plant stress tolerance and improving plant performance under adverse environmental conditions.

The improvement in plant height may also be associated with enhanced photosynthetic activity and improved carbon assimilation. Hydrogen peroxide has been reported to influence stomatal regulation and chloroplast functioning, which may lead to improved photosynthetic efficiency and overall plant productivity (Niu and Liao, 2016).

#### **4.2 Effect on Leaf Production and Photosynthetic Capacity:**

Leaf development is an important indicator of plant health and productivity, as leaves are the primary organs responsible for photosynthesis. The results of this study showed that hydrogen peroxide significantly affected the number of leaves per plant. The treatment with 1.0% H<sub>2</sub>O<sub>2</sub> produced the highest average leaf number (10 leaves per plant), compared with 7.4 leaves in the control treatment.

The increase in leaf number suggests that hydrogen peroxide may enhance cell division and expansion in plant tissues. Increased leaf formation contributes directly to greater photosynthetic surface area, allowing plants to capture more sunlight and produce higher levels of carbohydrates necessary for growth and development.

Previous studies have demonstrated that hydrogen peroxide plays an important role in activating antioxidant defense systems and improving chlorophyll stability in plant tissues. Hasan et al. (2016) reported that H<sub>2</sub>O<sub>2</sub> treatment enhanced photosynthesis and antioxidant enzyme activity in cowpea plants, leading to improved plant growth. Similarly, Ashfaque et al. (2014) observed that hydrogen peroxide application increased chlorophyll content and photosynthetic efficiency in wheat plants under salinity stress.

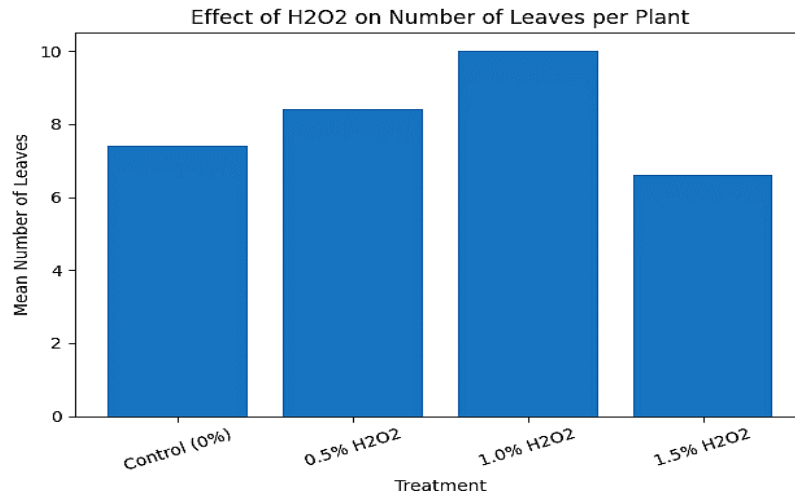


Figure (4): Effect of H<sub>2</sub>O<sub>2</sub> on Number of Leaves per Plant

These findings suggest that hydrogen peroxide can enhance plant physiological performance by improving the balance between reactive oxygen species (ROS) production and antioxidant defenses. As a result, plants treated with moderate concentrations of hydrogen peroxide may exhibit improved growth and development compared with untreated plants.

#### 4.3 Influence on Root Development and Soil Oxygenation:

Root growth is a critical factor influencing plant health because roots are responsible for the uptake of water and essential nutrients from the soil. In the present study, hydrogen peroxide significantly enhanced root development in treated plants.

The results indicated that plants treated with 1.0% H<sub>2</sub>O<sub>2</sub> achieved the highest root length, averaging 8.6 cm, compared with 6.28 cm in the control treatment. Improved root growth may be attributed to the oxygen-releasing properties of hydrogen peroxide.

When hydrogen peroxide decomposes in soil, it breaks down into water and oxygen molecules. This process increases oxygen availability in the root zone, which improves soil aeration and root respiration (Ben-Noah and Friedman, 2016). Improved oxygen supply enhances metabolic processes within root cells and supports root elongation and development.

Enhanced root systems also increase the plant's capacity to absorb water and nutrients, particularly nitrogen, phosphorus, and potassium, which are essential for plant growth. This effect may explain the improved overall plant growth observed in hydrogen peroxide-treated plants.

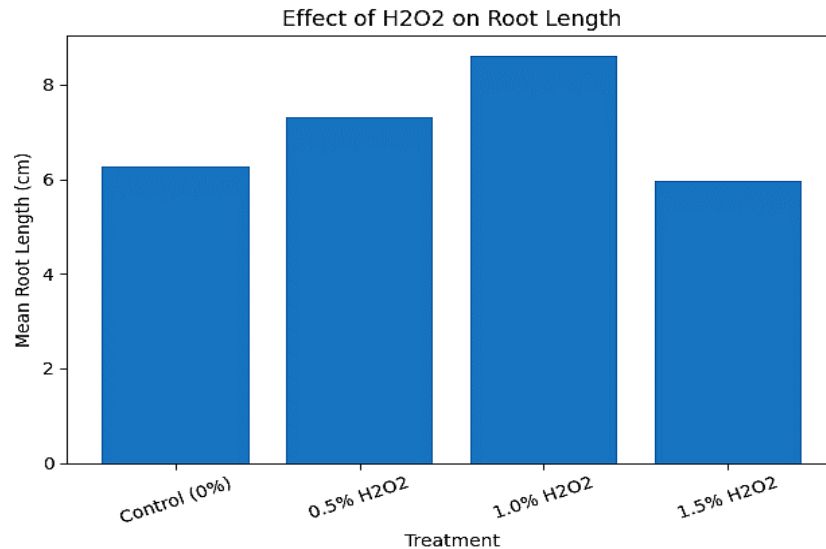


Figure (5): Effect of H<sub>2</sub>O<sub>2</sub> on Root Length

Several previous studies have also reported positive effects of hydrogen peroxide on root growth and stress tolerance. For instance, Bagheri et al. (2019) observed improved root development and salt tolerance in pistachio seedlings treated with hydrogen peroxide. Similarly, Ellouzi et al. (2017) reported that seed priming with hydrogen peroxide improved root growth and stress tolerance in several plant species.

#### 4.4 Effect on Biomass Accumulation and Plant Productivity:

Biomass accumulation is a key indicator of plant productivity and reflects the overall physiological performance of plants. In the present study, hydrogen peroxide treatment significantly influenced biomass production.

Plants treated with 1.0% H<sub>2</sub>O<sub>2</sub> produced the highest fresh biomass (29.8 g) and dry biomass (11.2 g), which were considerably higher than the values recorded in the control treatment. This result indicates that hydrogen peroxide treatment enhanced plant metabolic activity and promoted tissue development.

The increase in biomass production may be attributed to improved photosynthesis, nutrient absorption, and metabolic efficiency. Hydrogen peroxide has been shown to regulate several physiological processes involved in plant growth, including enzyme activity, carbohydrate metabolism, and nutrient assimilation.

Previous studies have also demonstrated the beneficial effects of hydrogen peroxide on biomass accumulation. Guzel and Terzi (2013) reported that hydrogen peroxide treatment increased dry matter production and mineral nutrient accumulation in maize plants. Similarly, Wang et al. (2022) found that hydrogen peroxide priming improved biomass production and grain yield in maize plants subjected to waterlogging stress.

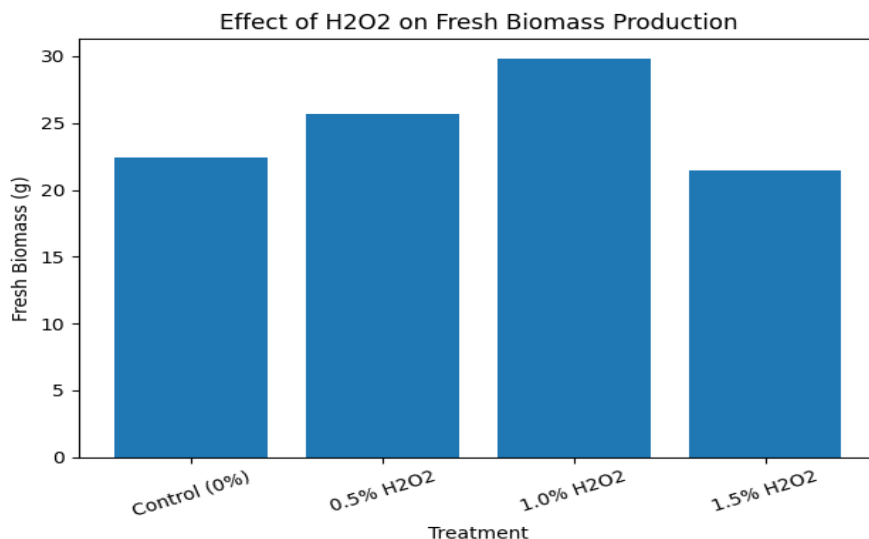


Figure (6): Effect of H<sub>2</sub>O<sub>2</sub> on Fresh Biomass Production

These findings suggest that hydrogen peroxide may serve as an effective growth stimulant that enhances plant productivity under both normal and stressful environmental conditions.

#### 4.5 Negative Effects of Excessive Hydrogen Peroxide Concentrations:

Although moderate concentrations of hydrogen peroxide promoted plant growth, higher concentrations showed negative effects on plant development. The treatment with 1.5% H<sub>2</sub>O<sub>2</sub> resulted in reduced plant height, leaf number, and

biomass compared with the optimal treatment.

This reduction in growth may be attributed to oxidative stress caused by excessive accumulation of reactive oxygen species. At high concentrations, hydrogen peroxide may damage cellular structures such as membranes, proteins, and nucleic acids, leading to impaired plant growth and metabolic dysfunction (Petrov and Van Breusegem, 2012).

Hydrogen peroxide therefore exhibits a dual role in plant physiology. At low concentrations, it functions as a beneficial signaling molecule that activates plant defense mechanisms. However, at high concentrations, it becomes toxic and may cause oxidative damage to plant tissues (Niu and Liao, 2016).

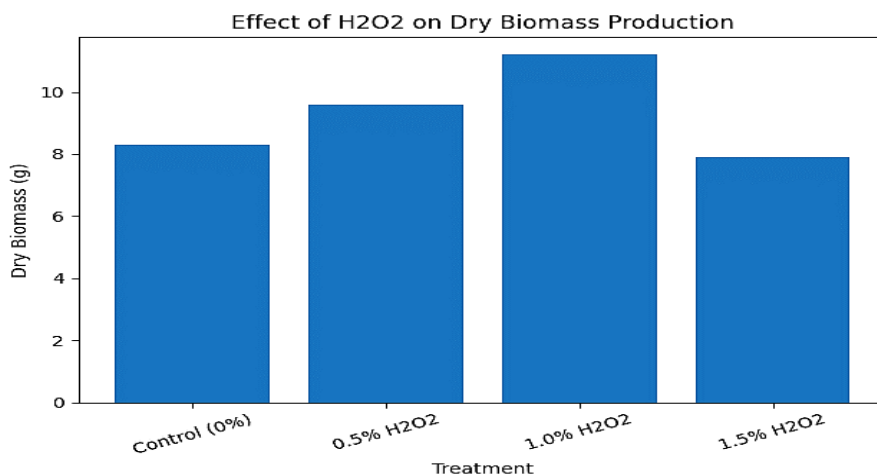


Figure (7): Effect of H<sub>2</sub>O<sub>2</sub> on Dry Biomass Production

These findings emphasize the importance of determining optimal application concentrations when using hydrogen peroxide in agricultural practices.

#### 4.6 Changes in Soil Chemical Properties:

Another observation in this experiment was a slight decrease in soil pH following hydrogen peroxide application. Although the change in soil pH was relatively small, it remained within the acceptable range for plant growth.

The decomposition of hydrogen peroxide in soil may influence soil chemical reactions and microbial activity, which can indirectly affect soil properties. Previous research has shown that agricultural treatments can influence soil

characteristics such as pH, nutrient availability, and microbial populations (Seleiman et al., 2019).

Maintaining soil chemical balance is important for sustainable crop production. Therefore, monitoring soil properties is essential when applying chemical treatments such as hydrogen peroxide in agricultural systems.

#### **4.7 Implications for Sustainable Agriculture:**

The findings of this study support the growing interest in hydrogen peroxide as a sustainable agricultural tool. Hydrogen peroxide is considered environmentally friendly because it decomposes into water and oxygen, leaving no harmful residues in soil or plant tissues.

Recent studies have highlighted the potential role of hydrogen peroxide in improving plant tolerance to abiotic stresses such as drought, salinity, and heavy metal contamination (Iqbal et al., 2025; Chen et al., 2025). By enhancing plant defense mechanisms and improving physiological performance, hydrogen peroxide may help farmers increase crop productivity under challenging environmental conditions.

However, further research is needed to determine the long-term effects of hydrogen peroxide application on soil ecosystems and crop productivity under field conditions.

### **5. Conclusion**

The results of this study demonstrate that hydrogen peroxide ( $H_2O_2$ ) can play a beneficial role in agricultural practices when applied at appropriate concentrations. The experimental findings revealed that moderate concentrations of hydrogen peroxide significantly improved plant growth parameters including plant height, leaf number, root development, and biomass accumulation.

Among the tested treatments, the 1.0% hydrogen peroxide concentration produced the most significant improvement in plant growth, indicating that moderate concentrations are optimal for stimulating physiological processes in plants. The beneficial effects of hydrogen peroxide may be attributed to improved soil oxygen

availability, enhanced root respiration, and stimulation of plant metabolic activities.

However, the study also showed that higher concentrations of hydrogen peroxide may reduce plant growth due to oxidative stress effects. Therefore, careful management of application concentrations is essential to achieve optimal results.

In conclusion, hydrogen peroxide represents a promising and environmentally friendly agricultural treatment that can improve crop productivity. Future studies should focus on long-term field experiments to evaluate the economic feasibility, environmental impacts, and crop-specific responses to hydrogen peroxide applications under different agricultural conditions.

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