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Response of Four Lettuce Varieties to the NFT Hydroponic System with 3% H_2O_2 Application

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Abstract
Root health disorders are among the primary constraints in hydroponic lettuce cultivation, especially under conditions of suboptimal aeration, high temperatures, and fluctuating humidity. Hydrogen peroxide (H2O2) is commonly used to increase dissolved oxygen availability, suppress certain pathogens, and promote root health. This study aimed to evaluate the response of four lettuce varieties grown in a Nutrient Film Technique (NFT) hydroponic system with the application of 3% H2O2 and to identify the variety with the best agronomic performance. The research was conducted from October to December 2023 at Kebun Sayur 24 Hidroponik, Bojongsari Village, Alian District, Kebumen Regency. The experiment was arranged in a nonfactorial completely randomized design with four varieties—RZ Junction, Romaine, Mondai, and Rex—each replicated six times. The observed variables included plant height, root length, number of leaves, fresh plant weight, dry plant weight, fresh root weight, dry root weight, and leaf area at harvest, 45 days after sowing. Data were analyzed using analysis of variance followed by the 5% Honestly Significant Difference test. The results showed that varietal differences had a highly significant effect on plant height, number of leaves, dry plant weight, fresh root weight, dry root weight, and leaf area, but had no significant effect on root length and fresh plant weight. Romaine showed the best performance in plant height (14.37 cm), fresh root weight (9.17 g), dry root weight (0.66 g), and leaf area (671 cm²), whereas Rex produced the highest number of leaves (15.50). Therefore, Romaine was the most promising variety for NFT hydroponic lettuce cultivation under 3% H2O2 application.

Keywords: H2O2, *Lactuca sativa*, NFT Hydroponics, Root Health, Varietal Response,

1. Introduction

Lettuce (*Lactuca sativa* L.) is a leafy horticultural commodity that is widely consumed fresh and has a fairly high economic value. Demand for lettuce continues to increase along with the development of healthy food consumption patterns, modern market needs, and urban food systems (Nguyen et al., 2022; Rohman & Aprilia, 2025). To meet these needs, hydroponic cultivation has become a widely implemented alternative because it can produce more uniform products, is relatively hygienic, and is more efficient in land use (Aprilia & Fatmawati, 2020; Sublett et al., 2018). One hydroponic system widely used in leafy vegetable production is the Nutrient Film Technique (NFT), because it can provide a continuous flow of nutrients and support plant growth more efficiently. However, the success of hydroponic lettuce cultivation is still greatly influenced by environmental growing conditions, nutrient availability, and the ability of the variety to adapt to the cultivation system used (Balliu et al., 2021; Sublett et al., 2018; Thakulla et al., 2021).

One of the major challenges in hydroponic lettuce cultivation is root health issues, particularly under suboptimal aeration conditions, high ambient temperatures, and fluctuating growing conditions. These conditions can reduce the availability of dissolved oxygen in the root zone, disrupt root respiration, and reduce the roots' ability to absorb water and nutrients, resulting in suboptimal plant growth and yield (Baiyin et al., 2021; Balliu et al., 2021; Nitu et al., 2024). In cultivation practices, hydrogen peroxide (H2O2) is often used as an additive or sanitizer to increase dissolved oxygen, help suppress certain microbes or biofilms, and support root health. However, its effectiveness is greatly influenced by the concentration and timing of application, as excessively high doses can be

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phytotoxic and suppress plant growth (Hendrickson et al., 2022; Lau & Mattson, 2021). In addition, plant responses to H2O2 application are not always the same because they are also influenced by differences in genetic characteristics between varieties, as shown in a study of two hydroponic lettuce genotypes that responded differently to H2O2 elicitation (Wang et al., 2023).

Each lettuce variety has different physiological abilities in adapting to the growing environment, utilizing nutrients, forming a canopy, developing a root system, and accumulating biomass. These differences can be reflected in growth and yield components, such as plant height, number of leaves, leaf area, root development, fresh weight, and dry weight of the plant. In hydroponic lettuce cultivation, the influence of variety has been reported to significantly contribute to yield, biomass, quality, nutrient absorption, leaf and root length, and the root-shoot ratio. Therefore, selecting the right variety is a crucial factor in the success of hydroponic lettuce cultivation, especially under certain cultivation conditions involving additional materials such as H2O2, because growth responses and plant quality can also differ between lettuce genotypes. (Rohman & Aprilia, 2025; Sapkota et al., 2019; Sublett et al., 2018; Wang et al., 2023) .

Previous research has extensively discussed the growth and yield of hydroponic lettuce under various nutrient compositions, environmental conditions, and cultivar differences. Several studies have also shown that H2O2 can increase dissolved oxygen and support root health in hydroponic systems. However, studies specifically comparing the response of several lettuce varieties in NFT hydroponic systems with 3% H2O2 application under field cultivation conditions are still limited. Therefore, the novelty of this study lies in the comparative evaluation of four lettuce varieties in NFT hydroponic systems with 3% H2O2 application to identify the most adaptive and prospective varieties under these cultivation conditions.

Based on the description, this study aims to evaluate the response of four lettuce varieties in the NFT hydroponic system with 3% H2O2 application and to determine the varieties that show the best growth and yield performance under these cultivation conditions.

2. Material and Methods

2.1. Time and Place

The research was conducted in October–December 2023 at the 24 Hydroponic Vegetable Garden, Bojongsari Village, Alian District, Kebumen Regency, Central Java, Indonesia, located at latitude -7.6629338424731985 and longitude 109.71049051958667. With an average temperature of 37.45 ^{o}C, an average humidity of 31.35% RH, and a Light Intensity of 3431.67 Lux, cultivation was carried out in a greenhouse using the Nutrient Film Technique (NFT) hydroponic system. This research focused on evaluating differences in responses between varieties under cultivation conditions with 3% H2O2 application.

2.2. Materials and Tools

The materials used included four varieties of lettuce seeds: RZ Junction, Romaine, Mondai, and Rex, rockwool seedling media, AB mix nutrients, 3% hydrogen peroxide (H2O2), and water. The tools used included an NFT hydroponic installation, seedling trays, net pots, a 10L nutrient solution tank, nutrient tubing, a digital scale, a pH meter, a TDS meter, a thermometer, a hygrometer, an oven, and other observation tools.

2.3. Experimental Design

The experiment was designed using a nonfactorial completely randomized design. The treatments tested were lettuce varieties, consisting of four levels, namely RZ.

Junction, Romaine, Mondai, and Rex. Each treatment was replicated six times, resulting in 24 main experimental units. Based on the original document, a total of 72 plants were prepared, including embroidered plants. Seeds were sown on rockwool media, then transferred to the NFT hydroponic installation after the seedlings were ready to plant. A 3% H2O2 application was carried out once, along with the nutrient solution, with a dose of 5 mL per 236 mL of water, then applied through a 10 L nutrient solution tank that was used uniformly in all experimental units. During the study, plant maintenance, AB mix nutrient application, H2O2 application, and the embroidery of plants that did not grow normally were carried out, along with observations until harvest.

2.4. Observation Variables and Data Analysis

Observations were conducted until harvest, 45 days after sowing. Growth variables included plant height, root length, and number of leaves. Yield variables included fresh plant weight, dry plant weight, fresh root weight, dry root weight, and leaf area.

Leaf area was measured using the gravimetric method. Meanwhile, plant dry weight and root dry weight were obtained after the samples were dried in an oven at 80°C until they reached a constant weight. Data were analyzed using analysis of variance (F test) at the 1% and 5% levels, and variables that showed significant differences were continued with the BNJ test at the 5% level (Marini, 2024) using IBM SPSS Statistics version 30.0.

To maintain the accuracy of scientific interpretation, the results of this study are presented as the response of varieties to cultivation conditions with 3% H2O2 application, so that statistical inference is limited to differences between varieties under these conditions, not to comparisons with systems without H2O2 or with different H2O2 concentrations (Bello et al., 2018).

2.5. Research Flowchart

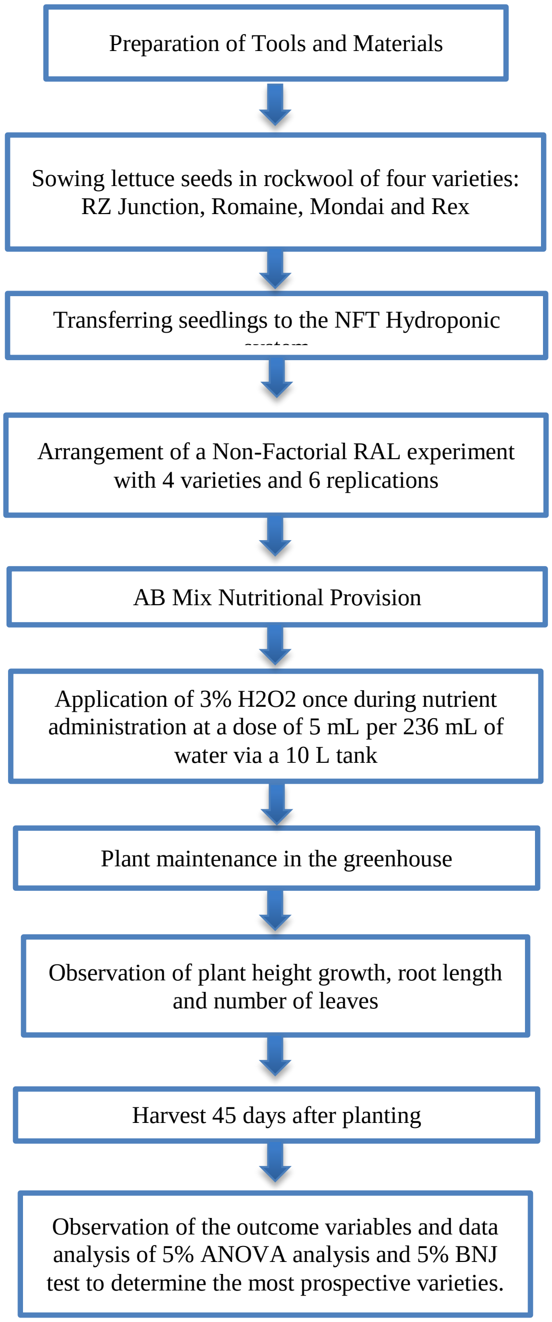

Figure 1. Research flow diagram

3. Results and Discussion

Analysis of variance showed that the response of varieties was significantly different in most growth and yield variables.

3.1. Lettuce plant growth under 3% H2O2 application conditions

Varietal differences in hydroponic lettuce cultivation using 3% H2O2 significantly affected plant height and leaf number, but not root length. Romaine produced the highest plant height, while Rex produced the highest number of leaves. These results indicate differences in growth strategies between varieties, with Romaine being more prominent in crown elongation, while Rex was stronger in leaf formation. A similar pattern was also seen in the study by Rohman and Rennanti Lunnadiyah Aprilia, which showed that the superiority of lettuce varieties can differ according to the observed growth and yield variables (Rohman & Aprilia, 2025). The lack of differences in root length in this study is thought to be related to the relatively uniform root environment and less-than-ideal greenhouse microclimate conditions, so that differences in root response between varieties did not emerge clearly. In line with Khodijah and Kusmiadi, hydroponic lettuce research shows that not all growth variables respond uniformly to treatment (Khodijah & Kusmiadi, 2021). Therefore, the results of this study are more appropriately interpreted as an evaluation of variety adaptation of varieties to a cultivation system with 3% H2O2, where Romaine excels in plant height and Rex excels in leaf number (Wang et al., 2023).

3.2. Components of lettuce yield under 3% H2O2 application conditions

Varietal differences in hydroponic lettuce cultivation with 3% H2O2 application did not significantly affect fresh plant weight, but significantly affected dry plant weight, fresh root weight, dry root weight, and leaf area. The Rex (V4) variety showed the highest dry plant weight numerically, namely 2.06 g, but it was still in the same group as Romaine (V2) statistically. Meanwhile, Romaine showed the best performance in fresh root weight, dry root weight, and leaf area, respectively, at 9.17 g, 0.66 g, and 671 cm^2. These results indicate that varietal differences under research conditions are more clearly reflected in dry biomass accumulation, root development, and leaf expansion than in total fresh biomass at harvest. The absence of differences in fresh plant weight between varieties indicates that fresh biomass accumulation at the end of harvest is still in a relatively similar range.

However, dry plant weight showed a very significant difference, suggesting that varietal differences were more pronounced in dry matter accumulation or structural biomass than in fresh weight, which is still strongly influenced by tissue water content. This pattern is common in hydroponic lettuce, as yield variables do not always respond uniformly to treatment or varietal differences. Khodijah and Kusmiadi reported that in hydroponic lettuce, some variables showed a significant response, while others did not (Khodijah & Kusmiadi, 2021). Similarly, Ahmed also showed that in hydroponic lettuce, fresh mass, root fresh mass, dry mass, and leaf area can exhibit different response patterns depending on nutrient solution conditions (Ahmed et al., 2021). Thus, Rex's superiority in dry plant weight indicates a better biomass accumulation capability, although no significant difference was observed in total fresh weight. Romaine's superiority in fresh root weight, dry root weight, and leaf area indicates that this variety performs better in components related to nutrient uptake and canopy formation. High fresh root weight reflects better root system development, while dry root weight reflects more stable root biomass accumulation.

Table 1. Average growth components of four lettuce varieties in hydroponic cultivation with H2O2 application 3%

Variety	Observation Variables	
	Plant height (cm)	**Number of leaves (blades)**
RZ Junction (V1)	10.10 ± 0.53a	8.17 ± 0.48 b
Romaine (V2)	14.37 ± 0.60c	10.33 ± 0.49 c
Mondai (V3)	10.23 ± 0.52 a	7.33 ± 0.56 a
Rex (V4)	12.72 ± 0.82 b	15.50 ± 0.43 d

Note: Data are presented as mean ± standard error (SE). Numbers followed by the same letter in the same column indicate no significant difference according to the 5% BNJ test.

In hydroponic lettuce cultivation, good root development is crucial because roots are the primary organ for water and nutrient absorption, which subsequently supports canopy growth. The larger leaf area of Romaine varieties is also agronomically important because it increases the surface area for light interception for photosynthesis, thus contributing to dry matter production. The results of this study align with those of Ahmed et al. (2021), who demonstrated a relationship between hydroponic nutrient conditions and root mass, dry mass, and leaf area in lettuce, and with those of Rohman and Aprilia (2025), who reported that different lettuce varieties can produce distinct advantages in growth and yield components.

The superiority of the Romaine variety in this study was demonstrated by a fresh root weight of 9.17 g plant^{-1}, a dry root weight of 0.66 g plant^{-1}, and a leaf area of 671 cm^2, while Rex produced the highest dry plant weight, namely 2.06 g plant^{-1}. Compared to other varieties in this study, Romaine's fresh root weight was 44.9% higher than RZ Junction and 79.1% higher than Mondai, while its leaf area was 9.1% larger than Rex and 108.4% larger than RZ Junction. This trend of superiority of the romaine type is in line with Matysiak et al. (2023), who reported that the romaine cultivar in an aquaponic system produced an average fresh head weight of 86 g, about 23% higher than leaf lettuce 'Nordice', which was only 70 g. However, in absolute terms, the fresh root weight of Romaine in this study was still lower than the fresh root mass of lettuce in a hydroponic system reported by Ahmed et al. (2021), which was 36.1–37.9g plant^{-1}. Conversely, the leaf area of Romaine in this study was higher than the leaf area of 172.32–181.37 cm^2 reported by Ahmed et al. (2021). These differences are thought to be related to differences in genotype, cultivation system, nutrient source, harvest age, and growing environmental conditions. Thus, Romaine can be seen as the most consistent variety in yield components related to root and leaf expansion, while Rex is more prominent in the accumulation of plant dry biomass (Ahmed et al., 2021; Matysiak et al., 2023; Rohman & Aprilia, 2025).

This difference confirms that their respective genetic characteristics strongly influence the response of varieties in hydroponic systems. In the context of H2O2, Wang et al. reported that the growth and quality responses of two hydroponic lettuce genotypes to H2O2 were genotype-dependent. Hence, the performance differences between Romaine and Rex in this study are biologically relevant. However, because all study units were under the same 3% H2O2 application conditions, these results cannot be interpreted as evidence of a causal effect of 3% H2O2 compared to no H2O2, but rather as differences in response between varieties under these cultivation conditions (Wang et al., 2023).

RZ Junction Romaine Mondai Rex

Figure 2. Visual appearance of four lettuce varieties at 28 HST in the NFT hydroponic system with 3% H2O2 application.

Table 2. Average yield components of four lettuce varieties in hydroponic cultivation with 3% H2O2 application

Variety	Observation Variables			
	Dry plant weight (g)	Fresh root weight (g)	Dry root weight (g)	Leaf area (cm²)
RZ Junction (V1)	0.46 ± 0.07 a	6.33 ± 0.56 b	0.48 ± 0.03 a	322 ± 5.87 a
Romaine (V2)	1.52 ± 0.33 b	9.17 ± 0.54 c	0.66 ± 0.03 c	671 ± 7.17 d
Mondai (V3)	0.31 ± 0.02 a	5.12 ± 0.96 a	0.41 ± 0.03 a	399 ± 2.96 b
Rex (V4)	2.06 ± 0.43 b	8.83 ± 0.75 c	0.62 ± 0.04 b	615 ± 17.33 c

Note: Data are presented as mean ± standard error (SE). Numbers followed by the same letter in the same column indicate no significant difference according to the 5% BNJ test.

4. Conclusion

Lettuce varieties showed different responses to hydroponic cultivation with 3% H2O2 application. Romaine provided the most consistent performance, particularly in plant height, fresh root weight, dry root weight, and leaf area, while Rex excelled numerically in leaf number and dry plant weight. Thus, Romaine was the most promising variety under the cultivation conditions of this study.

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