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Biomass and Chlorophyll Responses of Corn Plants (*Zea mays* L.) to Varying Abmix Concentrations in A Hydroponic Environment

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ABSTRACT

Corn (Zea mays L.) is the second most important agricultural commodity in Indonesia, after rice. Corn plays an important role as a raw material for animal feed, bioenergy (biofuel), and various other industrial products. However, corn productivity is highly dependent on the availability of nutrients in the growing medium. Therefore, this study aims to evaluate the effect of various AB Mix concentrations on the biomass and chlorophyll of corn (Zea mays L.) plants in a hydroponic system. The experimental design used a simple randomized complete block design (RCBD) with one factor, namely the AB Mix concentration (1/2x, 1x, and 2x) and correlation analysis using R-Studio version 2025. At 6 WAP, differences in shoot, root, and total biomass between treatments were still significant. 2x AB Mix concentration again produced the highest biomass, namely 29.67 g. Variations in AB Mix concentration have a significant effect on biomass yield (biomass of shoots at 5-6 WAP, biomass of roots at 6 WAP, and total weight at 5-6 WAP) and chlorophyll a, b content, chlorophyll a+b ratio in corn leaves.

Keywords:
Biomass; chlorophyll; concentration; corn; hydroponics

1. Introduction

Corn (*Zea mays* L.) is the second most important agricultural commodity in Indonesia, after rice. In fact, the annual production volume of corn exceeds the national production of other grains (Pusdatin Pertanian, 2024). This plant belongs to the monocot group, with the edible part being the seeds arranged on cobs originating from the same fruit (Patel et al., 2024). In various parts of the world, corn is not only a staple food source but also plays a vital role as a raw material for animal feed, bioenergy (biofuel), and other industrial products. However, corn productivity is highly dependent on nutrient availability in the growing medium (Stewart et al., 2022).

Unreported deficiencies have occurred in various agricultural fields worldwide, directly impacting the yield and quality of products (Ranum et al., 2014). Nutrient deficiencies can disrupt various plant physiological processes, including vascular system development, root growth, sugar transport, carbohydrate combustion, nucleic acid synthesis, and pollen viability.

Conversely, excess nutrients can have toxic effects, reduce fertility, and inhibit corn kernel formation and filling (Kumar et al., 2019). An imbalance of nitrogen (N) and phosphorus (P), for example, can affect the absorption of other elements such as zinc (Zn), iron (Fe), copper (Cu), and magnesium (Mg), ultimately leading to defective kernel formation and reduced cob quality (Bojtor et al., 2021a). Proper nutrient management is crucial, especially in soilless agricultural systems, where all essential elements must be supplied using carefully formulated nutrient solutions.

One crucial aspect of a hydroponic system is nutrient formulation and concentration, which replaces the nutrients normally absorbed by plants from the soil. AB Mix is a nutrient solution widely used in hydroponics because it contains macronutrients (such as N, P, and K) and micronutrients (such as Fe, Mn, and Zn) necessary for optimal plant growth (Irwansyah et al., 2025). However, the effectiveness of AB Mix in supporting plant growth and development, including its physiological structure, is highly dependent on the concentration.

The floating hydroponic system is a practical and simple cultivation method suitable for various scales, including household-scale applications (Sucahyo et al., 2023; Sari et al., 2022). This system is effective for growing a variety of leafy vegetables, such as lettuce (*Lactuca sativa*), mustard greens, water spinach, and pak choi, even in suboptimal lands or coastal areas affected by tidal flooding and salinity (Ariananda et al., 2020; Handriatni, 2021; Supriyadi et al., 2019).

The success of this cultivation method depends heavily on the proper application of nutrients. The use of AB Mix nutrient solutions is crucial, as incorrect concentrations can inhibit plant growth (Ifanto & Suprihati, 2019; Dalli et al., 2023). Studies have also shown that the type of growing medium, such as synthetic foam, coconut fiber, rice husks, and rock wool, can significantly influence plant development (Susila & Koerniawati, 2004). Moreover, hydroponic systems can be integrated with automated monitoring and control systems for nutrient levels, water height, and pH, which help address challenges such as excessive evaporation (Kurniawan & Lestari, 2020; Prawira et al., 2023).

The implementation of floating hydroponic systems has also expanded as a tool for education and community outreach. In various regions, training and extension programs have been conducted to educate communities about this modern cultivation technique, aiming to promote sustainable agricultural entrepreneurship and increase the availability of healthy vegetables (Sari et al., 2022; Sucahyo et al., 2023).

Previous research has shown that differences in nutrient solution concentration can significantly affect plant morphology and physiological growth. For example, Pangaribuan et al. (2018) reported that increasing AB Mix concentration increased the plant height and biomass of bok choy, but this effect was not always linear. Putri et al. (2024) also noted that in three mustard green varieties, AB Mix concentration affected chlorophyll content, which directly impacted the photosynthetic efficiency. The application of AB Mix nutrient solution at doses ranging from 15 to 20 mL/L tends to produce positive responses, such as increased plant height, number of leaves, and fresh weight in red spinach (*Amaranthus tricolor* L.) (Hidayanti & Kartika, 2019).

However, there is limited research specifically examining the impact of AB Mix concentration on corn plants in hydroponic systems, particularly those integrating growth and physiological aspects. However, physiological analyses, such as chlorophyll a and b content, the chlorophyll a/b ratio, and chlorophyll (a+b), are crucial for understanding plant conditions under varying environmental nutrients. Therefore, this study aims to highlight the effect of various AB Mix concentrations on the biomass and physiological structure of corn (*Zea mays* L.) in hydroponic systems. We hope that the results of this study will provide a scientific basis for more precise hydroponic nutrient management to increase corn productivity in limited environments.

2. Materials and Methods

2.1 Location and Environment

The experiment was conducted in a greenhouse at the Lower Cikabayan Garden, IPB, Bogor, Indonesia (-6.551339, 106.714735) at an altitude of 234 m asl. The average rainfall was 399 mm/month, average temperature was 26 °C, and humidity was approximately 80%.

2.2 Tools and materials

The planting materials used were corn seeds, an AB Mix solution, and water. The tools used in this experiment were a basin, flannel cloth, small plastic tub (as a seeding place), scissors, ruler, and digital scale. The tools and materials used for observing leaf anatomy included a microscope, plant leaves, nail polish, razor blade, tape, and camera. The tools and materials used for observing chlorophyll levels were plant leaves, acetate, marbles, a cool box, a micropipette, clear plastic, a scale, a test tube, a mortar, a vortex mixer, a spectrophotometer, and a centrifuge.

2.3 Experimental design

The experimental design used a simple randomized complete block design (RCBD) with one factor, namely, the AB Mix concentration. The treatments consisted of three concentration levels: 1/2, 1, and 2 times the AB Mix concentration. Each treatment was repeated six times, resulting in a total of 18 experimental units.

2.4 Research procedure

Corn seeds were sown for one week before being transferred to a hydroponic system. One seed was placed in each Rockwool box. Each group received 30 seeds for sowing purposes. The plants and rockwool were transplanted in the second week from the nursery to a hydroponic tank. Corn seedlings were selected based on good vigor and the emergence of two leaves. Corn seeds were sown for two weeks before being transferred to a hydroponic system. One seed was placed in each Rockwool box. Each group received 30 seeds for sowing purposes.

The AB Mix hydroponic solution was composed of two types of stock solutions: solution A, which contained macronutrients, and solution B, which contained micronutrients, both prepared according to the instructions on the product label. These stock solutions were used as nutrient sources for planting containers with a capacity of 4 L each. The standard dosage for each solution was 5 mL/L of water. The treatments in this study consisted of three concentration levels: half (½×), standard (1×), and double (2×) the standard dosage. In the ½× treatment, 5 mL per liter of both solutions A and B were added. For the 1× treatment, each solution was added at 10 mL per liter, whereas in the 2× treatment, the volume used was 20 mL per liter for both solutions A and B.

Corn seedlings were selected based on good vigor and the emergence of two leaves. Transplanting was carried out by placing rockwool and flannel cloth in minipots, ensuring that the flannel cloth touched the solution and rockwool. Each tank had eight planting holes, and 18 tanks with different concentrations served as treatments in this experiment. The concentrations of the AB Mix solution were 1/2, 1, and 2 times the original concentration. The volume of the nutrient solution in the tank was checked. If the volume decreases, add the AB Mix solution according to the treatment. Inspect the condition of plants to control pests and diseases. In the event of an attack, fungicides, bactericides, and insecticides should be applied. The nutrient tank and net pots were cleaned of sediment or moss. The plants were harvested five and six weeks after sowing.

2.5 Observation procedure

Plant biomass was determined by placing the plants in an oven at 60 °C for approximately 3-4 days until a constant weight was achieved. Plant parts, such as shoots and roots, were weighed and recorded for data collection.

Chlorophyll content was measured by taking samples from the sixth or seventh leaf in the morning and storing them in a cool box. A 0.02 g leaf sample was weighed, finely ground, and 1 mL of acetate was added. The mortar was rinsed with acetate to a volume of 2 mL and collected in a microtube. The mixture was then centrifuged at 14,000 rpm for 10 min. The supernatant (1 mL) was transferred to a test tube, followed by 3 mL of acetate. The test tube was sealed with a marble and vortexed. Absorbance measurements were performed using a spectrophotometer at wavelengths of 470, 537, 647, and 663 nm (Sims and Gamon 2002). Chlorophyll was calculated using the following formula:

Chlorophyll a = (0.01373 x A663 – 0.000897 x A537 – 0.003046 x A647) x Dilution factor/leaf weight

Chlorophyll b = (0.02405 x A647 – 0.004305 x A537 – 0.005507 x A663) x Dilution factor/leaf weight

2.6 Data analysis

Data were analyzed using Analysis of Variance (ANOVA) to determine the effect of the treatment, followed by a Least Significant Difference (LSD) test at the 5% level to determine differences between treatments. Correlation analysis was performed using R-Studio version 2025 (Tyner et al., 2017).

3. Result and Discussion

3.1 Shoot biomass

The results shown in Table 1 indicate that different AB Mix concentrations significantly affected the biomass of hydroponically cultivated corn shoots, both 5 and 6 weeks after planting (WAP). A trend toward increasing shoot biomass was observed with increasing AB Mix concentrations. At 5 WAP, treatment with 2x AB Mix concentration produced the highest shoot biomass of 7.23 g, which was significantly different from the other treatments. Meanwhile, treatment with 1x AB Mix concentration produced a biomass of 5.98 g, and 1/2x AB Mix concentration produced the lowest biomass, at 4.72 g. This indicates that higher nutrient availability during the early vegetative phase can increase biomass accumulation in the plant canopy (Ariananda et al., 2020).

At 6 weeks after planting (WAP), the same pattern was observed. The 2x AB Mix treatment again showed the highest shoot biomass at 23.05 g, which was significantly different from the 1/2x AB Mix treatment (9.28 g) and partially different from the 1x AB Mix treatment (14.62 g). This confirms that adequate nutrient intake in hydroponic systems can accelerate growth and increase corn biomass production (Hidayatullah et al., 2025). Plants treated with 1/2x AB Mix consistently showed the lowest shoot growth at both observation times. This is thought to be due to nutrient limitations that inhibit the crucial metabolic process of photosynthesis, thus disrupting growth and ultimately reducing plant biomass accumulation (Ali et al. 2024). This finding aligns with the theory that in hydroponic systems, plants are highly dependent on the availability of water-soluble nutrients because of the absence of a nutrient-storing soil medium. Therefore, providing nutrients in the correct amounts and compositions is crucial for supporting optimal growth. Previous research has also stated that increasing nutrient concentrations to a certain point can increase plant growth due to increased nutrient absorption efficiency (Bojtor et al., 2021b).

Table 1. Biomass of corn plant shoots at various AB Mix concentrations.

Treatment	Shoot biomass (g)	
	5 WAP	6 WAP
1/2x concentration AB Mix	4.72c	9.28b
1x concentration AB Mix	5.98b	14.62ab
2x concentration AB Mix	7.23a	23.05a
LSD 5%	*	*

Note: Value on the same column followed by similar alphabet do not significantly different after LSD test 5%; *significant different

3.2 Root biomass

Based on the data obtained, it was found that the effect of AB Mix concentration on root biomass was significantly affected at 6 weeks after planting (Table 2). At 5 weeks after planting, although there was no statistically significant difference between the treatments, there was a tendency for root biomass to increase with increasing nutrient concentration.

Table 2. Biomass of corn plant roots at various AB Mix concentrations.

Treatment	Root biomass (g)	
	5 WAP	6 WAP
1/2x concentration AB Mix	1.23a	2.97b
1x concentration AB Mix	1.45a	4.12ab
2x concentration AB Mix	1.66a	6.68a
LSD 5%	ns	*

Note: Value on the same column followed by similar alphabet do not significantly different after LSD test 5%; ^{ns}non significant different, *significant different

At 6 WAP, the 2x AB Mix treatment significantly produced the highest root biomass, at 6.68 g, significantly different from the 1/2x concentration treatment (2.97 g) and only slightly different from the 1x concentration treatment (4.12 g). This indicates that increasing the nutrient concentration in the AB Mix solution positively affected corn root development during the advanced growth phase. The lowest root biomass was found in the 1/2x AB Mix treatment at 6 WAP. This indicates that nutrient deficiencies inhibit root growth, which ultimately impacts water and nutrient uptake, and reduces the overall physiological efficiency of the plant (Salma et al., 2019).

These results are consistent with the basic principle of plant physiology, which states that root growth is strongly influenced by environmental nutrient conditions. In hydroponic systems, roots not only function as plant support but also as centers for nutrient absorption; therefore, the availability of nutrients in the solution is crucial for successful root growth. According to Ma et al. (2020), the adequate availability of nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), directly promotes cell division and elongation in the root meristem tissue. Phosphorus is essential for ATP formation, which is used in metabolic processes and biomolecule synthesis in root tissues (Naciri et al., 2022). Nitrogen is important for protein and amino acid synthesis, which supports the development of new roots, whereas potassium helps regulate water transport, influencing root volume and mass (Liu et al., 2024).

3.3 Total biomass

Table 3 shows the effect of various AB Mix solution concentrations on the total biomass of corn plants at 5 and 6 weeks after planting (Table 3). At 5 weeks after planting (WAP), plants treated with 2x AB Mix concentration had the highest total biomass, at 9.63 g, which was significantly different from those treated with 1x concentration (7.75 g) and 1/2x concentration (5.86 g). This increase in total biomass indicates that higher nutrient availability supported the accumulation of overall plant biomass in both shoots and roots from the early growth phase. At 6 weeks after planting (WAP), the difference in total biomass between the treatments remained significant. The 2x AB Mix concentration again produced the highest biomass (29.67 g), followed by the 1x concentration (18.74 g), and the lowest was achieved with the 1/2x concentration (12.25 g). This pattern is consistent with previous observations, indicating that increasing nutrient concentrations are associated with increasing total plant biomass.

The significant increase in total biomass in the 2x AB Mix treatment can be explained by the availability of sufficient nutrients to support essential physiological processes, such as photosynthesis, respiration, cell division, and tissue formation. In hydroponic systems, where the soil does not provide nutrients, the composition and concentration of the nutrient solution are the primary determinants of plant growth and development (Sachay et al., 1991). These results reinforce the understanding that optimal nutrient delivery is crucial for overall plant productivity in hydroponic systems. A balanced combination of shoot and root growth is key to achieving the maximum total biomass.

Table 3. Total biomass of corn plants at various AB Mix concentrations

Treatment	Total biomass (g)	
	5 MST	6 MST
1/2x concentration AB Mix	5.86c	12.25b
1x concentration AB Mix	7.75b	18.74b
2x concentration AB Mix	9.63a	29.67a
LSD 5%	**	*

Note: Value on the same column followed by similar alphabet do not significantly different after LSD test 5%; *significant different

3.4 Chlorophyll content of corn leaves

Table 4 shows that the AB Mix concentration significantly affected the chlorophyll a, chlorophyll b, chlorophyll a/b ratio, and total chlorophyll (a+b) content in hydroponically grown corn leaves. For chlorophyll a, the highest value was obtained in the 2x AB Mix concentration treatment at 0.0019 mmol g^{-1}, followed by the 1x concentration (0.0015 mmol g^{-1}), and the lowest was at the 1/2x concentration (0.0009 mmol g^{-1}). Similarly, for chlorophyll b, the 2x concentration treatment produced the highest content (0.0006 mmol g^{-1}), which was significantly different from the other treatments (Table 4). This indicates that increasing nutrient availability from the AB Mix solution can stimulate higher chlorophyll formation in the leaf tissue.

The chlorophyll a/b ratio also increased with increasing nutrient concentration, with the highest value in the 2x AB Mix treatment (3.30), which was significantly different from the 1/2x treatment (3.03). The chlorophyll a/b ratio is an indicator of photosynthetic efficiency, with a higher ratio reflecting more intense photosynthetic activity (Ahmed et al., 2021).

Meanwhile, total chlorophyll (a+b) showed that plants fed 2x the AB Mix concentration produced the highest value (0.0025 mmol g^{-1}), which was significantly different from the 1x (0.0020 mmol g^{-1}) and 1/2x (0.0011 mmol g^{-1}) treatments. This indicates an increase in the overall photosynthetic ability of the plants.

Table 4. Chlorophyll content of corn plants at various AB Mix concentrations

Treatment	Chlorophyll content			
	Chlorophyll a (mmol g^{-1})	Chlorophyll b (mmol g^{-1})	Chlorophyll ratio a/b	Chlorophyll a+b (mmol g^{-1})
1/2x concentration AB Mix	0.0009b	0.0002c	3.03b	0.0011c
1x concentration AB Mix	0.0015a	0.0005b	3.27a	0.0020b
2x concentration AB Mix	0.0019a	0.0006a	3.30a	0.0025a
LSD 5%	**	**	**	**

Note: Value on the same column followed by similar alphabet do not significantly different after LSD test 5%; *significant different

Chlorophyll plays a crucial role in photosynthesis, particularly in light absorption (Zhao et al., 2015). The higher availability of macronutrients, such as nitrogen and magnesium, in AB Mix allows for more effective chlorophyll synthesis, as these elements are key components of the chlorophyll molecular structure and cofactors for enzymes in chlorophyll biosynthesis (Uruç Parlak, 2016). These results indicate that nutrient availability influences plant physiological activity, particularly chlorophyll synthesis, which is closely related to photosynthetic efficiency and biomass productivity (Daghan, 2018). In hydroponic systems, where the nutrient supply is fully controlled, increasing the concentration of AB Mix has been shown to improve the physiological quality of corn plants.

3.5 Correlation between biomass and chlorophyll

Figure 1. Pearson's correlation in this study showed a very strong relationship between the physiological and morphological parameters of corn plants grown in a hydroponic system and varying AB Mix concentrations.

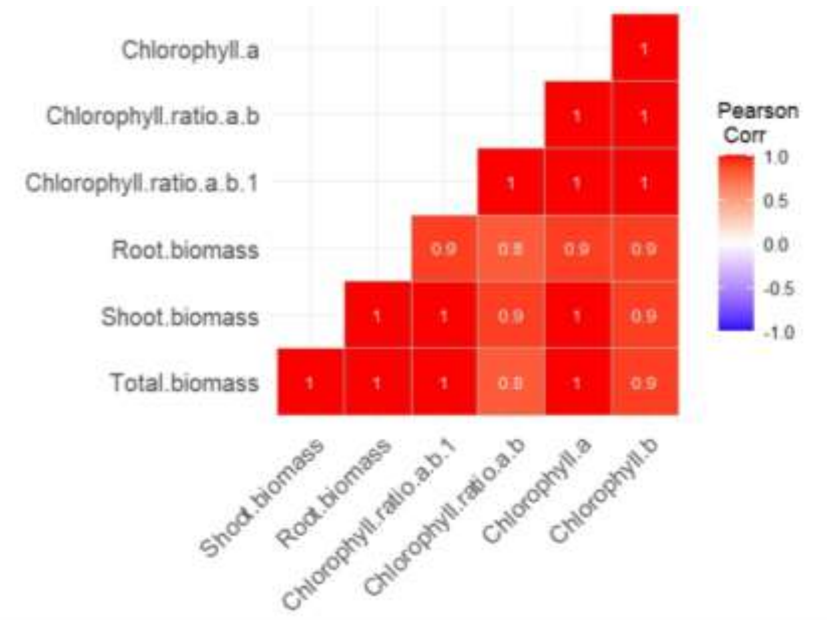

Figure 1. Correlation between biomass of shoots, roots, and total and chlorophyll a, b content, chlorophyll ratio, total chlorophyll of corn leaves

The analysis showed that total plant biomass was highly correlated with shoot biomass (r = 1.0) and root biomass (r = 0.9), indicating that the total biomass increase was largely determined by shoot and root growth. Furthermore, chlorophyll a, chlorophyll b, and total chlorophyll (a+b) content showed a strong positive correlation (r = 0.9–1.0) with all biomass parameters. This confirms that an increase in chlorophyll content, which plays a role in photosynthesis, directly supports plant biomass accumulation. The chlorophyll a/b ratio also showed a high correlation (r = 0.9) with other parameters, indicating the important role of chlorophyll balance in photosynthetic efficiency of the plant. Overall, these results indicate that increasing the AB Mix concentration can increase the chlorophyll content, ultimately positively impacting the growth and biomass of corn plants in hydroponic systems.

4. Conclusion

Variations in AB Mix concentration significantly affected biomass yield (shoot biomass at 5-6 WAP, root biomass at 6 WAP, and total weight at 5-6 WAP) and chlorophyll a and b content, and the chlorophyll a+b ratio in corn leaves. Treatment with 2x AB Mix concentrations resulted in 50-100% higher biomass weight (shoot biomass at 5-6 WAP, root biomass at 6 WAP, and total weight at 5-6 WAP) than that with 1x AB Mix concentration. Corn leaf chlorophyll a, b content, and the chlorophyll a+b ratio were higher in the 2x AB Mix treatment. We suggested to explore a wider range of AB Mix concentrations to determine the most efficient and safe optimal dose on *Zea mays* L.

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