Effect of hydroponic cultivation methods and agriculture medium on the anatomical traits of Chinese cabbage (*Brassica rapa var.chinensis*).

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Abstract:

Hydroponics is a modern technique for growing plants without soil, using nutrient solutions. The experiment was conducted at the Mohammed Nursery in Kirkuk province for the 2024-2025 season to study two factors: the planting method (horizontal, deep) and the second factor: the agricultural medium (palm peat, coconut, perlite). The experiment was designed using the split-plot system within a randomized complete block design (RCBD). The cultivation method was applied to the main plot (main plot) and the culture medium to the secondary plot (sup plot) with three replicates at a 5% probability level. The results showed that deep-seeded cultivation increased the number of stomata in the lower surface/average length, the number of stomata in the lower surface/average width, the average thickness of the cuticle layer/upper surface, the average thickness of the cuticle layer/lower surface, and the average thickness of the mesophyll tissue. Regarding the effect of the agricultural medium, the palm peat medium showed a significant increase in the number of stomata in the lower surface/average length, the number of stomata in the lower surface/average width, the average thickness of the cuticle layer/upper surface, the average thickness of the cuticle layer/lower surface, and the average thickness of the mesophyll tissue. Meanwhile, the interaction between the deep-seeded cultivation method and the palm peat medium increased the number of stomata in the lower surface/average length, the number of stomata in the lower surface/average width, the average thickness of the cuticle layer/upper surface, the average thickness of the cuticle layer/lower surface, and the average thickness of the mesophyll tissue.

Keywords: Chinese cabbage, hydroponics, growing medium, deep-water culture.

Introduction

Technology has become an integral part of our daily lives in all its details. Technology has contributed to making our lives easier and has touched various vital sectors, including agriculture. However, modern technologies in the agricultural sector have remained distant from our local markets and farms. However, with the increasing challenges facing farmers and the accumulation of problems associated with traditional farming methods, along with declining resources, evolving market needs,

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and the emergence of demand for varieties or products that traditional farming methods could not support the cultivation and production of, it has become necessary to search for solutions and technologies that were not previously available. Based on this principle, the research aimed to localize modern agricultural technologies and provide them in the simplest ways and at the lowest possible costs. Chinese cabbage (*Brassica rapa var*. chinensis), bok choy, or pak choi, is a member of the Brassicaceae family. It is a winter leafy vegetable. Although it is not widely cultivated in Iraq, it is cultivated in various countries around the world, such as the United States and Southeast Asia, due to its high nutritional value and rapid growth [7]. Chinese cabbage is a biennial herbaceous plant, similar to other cruciferous plants in that it is annual in areas with mild winters. It produces heads resembling romaine lettuce, but much larger and more compact. The leaves are slightly wrinkled, deeply veined, and green in color. The midrib is broad and light green. The stem is short in the first growing season, bearing crowded leaves, which then elongate and bear flowers in the second growing season. The basal leaves are large, glossy, and have thick, white petioles. The flowers are light yellow and cross-pollinated by insects [16]. Chinese cabbage is cultivated for its large, light yellow to dark green leaves, which are consumed fresh, in salads, or after cooking. Chinese cabbage resembles lettuce in appearance, but its taste is similar to that of arugula, with a mild flavor and crunchy texture. The plant is rich in vitamins such as vitamin A, vitamin C, and vitamin K, as well as minerals such as calcium, potassium, and iron. It is low in calories and rich in dietary fiber. It also contains antioxidants such as flavonoids and carotenoids, which help fight inflammation and reduce the risk of chronic diseases such as cancer and heart disease. It also has antiseptic, antibacterial, and anti-allergy properties, making it highly nutritious and healthy [4].

Hydroponics is a modern agricultural technology used in many European countries and some Arab countries, particularly the Gulf states. Hydroponics is one of the proposed alternatives to reduce the food deficit and increase self-sufficiency in the most important strategic food crops [18]. Hydroponics has many advantages: it allows for intensive plant cultivation because water and nutrients are readily available, while significantly reducing agricultural operations such as tillage and weed control, saving 80% of the water used in traditional agriculture [5].

Soil degradation over time is a problem facing farmers. The natural composition of soil deteriorates as a result of the continuous use of high-concentration fertilizers to achieve high yields. Salts accumulate, leading to soil salinization and the widespread spread of diseases and pests, reducing the potential for growing the same crops in the soil [6]. These factors have led us to explore alternative solutions for soil use, such as hydroponic systems, in which plants are grown in medium other than soil, which rely primarily on a nutrient solution and the medium used to stabilize and support the plant. Growing medium such as peat moss and perlite are common components of hydroponic systems. It is well known that the type of growing medium has a direct relationship with plant yields, such as germination [8], as well as its impact on growth [15]. One such medium is peat moss, which is formed naturally as a result of the accumulation of plant material in poorly drained areas under varying conditions of temperature, humidity, and light. The type of plant material and its degree of decomposition significantly determine the value of peat moss as a growing medium. Perlite, on the other hand, is composed of silica elements from volcanic sources that are ground and crushed, then heated until they react with water vapor

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and become granular and light weight and uniformity of perlite particles make it highly beneficial for aeration and drainage [14]. Hydroponics is primarily classified according to the type of nutrient supply to the plant (whether the roots are partially or fully submerged in the nutrient solution), such as nutrient film technology, deep flow technology, and aeroponics [17]. In the context of climate change, reducing the environmental impact of agriculture has become increasingly important. To ensure sustainable food production, it is essential to adopt agricultural technologies that increase resource efficiency, particularly in the use of water and nutrients. Nutrient Film Technology (NFT) is a hydroponic system designed to optimize water and nutrient use, making it a valuable tool for sustainable agriculture. Rapid population growth, increased housing density, and urbanization in general have increased the need for urban agriculture to provide food sources for the population. One innovative approach to urban agriculture, vertical hydroponics, is a prominent example of urban agriculture, which can be implemented in areas with limited space [13]

The hydroponic growing medium is an alternative to soil, in which plants can grow naturally, just as they would in soil. The type and quality of the growing medium is an important factor affecting the success of any agricultural production and is directly related to the quality of the materials used in the hydroponic growing medium. Therefore, choosing the appropriate hydroponic growing medium is essential for promoting optimal crop growth [10]. Growing medium provide support for plants while retaining moisture. They introduce the nutrient solution to the root zones, thus providing all the nutrients necessary for plant growth. This is the most common form of hydroponics, which involves growing plants in these medium [20]. Some of these growing medium are much better than soil, especially in terms of their ability to retain water and supply oxygen to the root zone [9].

Materials and Methods:

This research was conducted in Kirkuk province/Mohammed Nursery during the 2024/2025 growing seasons. The aim was to study the impact of hydroponic cultivation using several methods (nutrient film technique, deep planting technique), and growing medium (palm peat, coconut, perlite). Nine tubes were created and placed horizontally on iron supports. Each tube was 3 meters long, 4 inches in diameter, and perforated with 10 holes, corresponding to the number of plants grown in each tube. The tubes were connected to each other using plastic connectors. The tubes were also connected to a 250-liter tank filled with the nutrient solution (basma solution)as shown in Table (1) that fed the tubes. At the end of the tubes, a tank was placed to collect the nutrient solution coming out of the system, known as the Nutrient Film Technique (NFT) system. The deep water culture (DWC) technique involved constructing nine basins, each measuring 50 x 1.20 m², and covering them with opaque plastic (tarpaulin) to provide a soil-like opaque environment. This system relies on cultivating plants by fully submerging their roots in a nutrient solution. This is accomplished by planting plants in basins 20 cm deep, with cork sheets floating on top of the water. Holes were drilled in the cork, and the seedlings were placed inside special anvils in various medium (palm waste (peat), coconut, perlite), with their roots directly submerged in the water. An oxygen pump was used to supply the solution with oxygen. The distance between the holes for both types of cultivation was 25 cm, depending on the size of the pots used, which was 7 cm. The seeds were planted in 60-hole plastic trays in a wooden canopy. Peat moss was used as a growing medium in these trays, with one seed placed in each tray on September 1, 2024. The seedlings were

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transferred into the tubes and basins on October 15, 2024. The tubes and basins were sterilized using Avecuor fungicide at a concentration of 50 mg/L-1 two days before the seedlings were transferred into the tubes and basins. The experiment included two factors: the hydroponic cultivation method (horizontal S1, deep S2), and the second factor was the cultivation medium (palm peat B1, coconut B2, perlite B3). The experiment was designed according to a Randomized Complete Block Design (RCBD) with a split-plot system in three replicates. The cultivation method in the main plot and the agricultural medium in the sub-plot were considered the most important, with three replicates. The results were then analyzed by SAS program was used by [11], and the averages were compared using Duncan's multiple range test (DMRT) at $p \leq 0.05$.

Results and Discussion

Number of stomata in the lower surface/average length and width

The results obtained from this research, shown in Figure (1) and Figure (2), indicate that hydroponic systems have a significant effect on the number of stomata in the lower surface/average length and width. The Deep Water Culture Technique (S2) system outperformed and recorded the highest number of stomata in the lower surface/average length and width, with a significant difference from the horizontal tube culture system (Nutrient Film Technique, NFT) (S1), which recorded the lowest number of stomata in the lower surface/average length and width. The results also show that hydroponic medium have a significant effect on the number of stomata in the lower surface/average length and width. The palm peat medium (B1) outperformed and recorded the highest number of stomata in the lower surface/average length and width, while the lowest number of stomata in the lower surface/average length and width was recorded by the use of perlite medium (B3). The interaction between the culture systems and hydroponic medium had a significant effect on the number of stomata in the lower surface/average length and width ratio of Chinese cabbage , where the highest number of stomata in the lower surface/average length and width ratio was recorded from the deep culture system using palm peat medium (S2B1), while the lowest number of stomata in the lower surface/average length and width ratio was recorded from the horizontal culture system using perlite medium (S1B3).

Cuticle Thickness Rate/Upper and Lower Surface

The results obtained in Figures (3) and (4) indicate that hydroponic systems have a significant effect on the cuticle thickness rate/upper and lower surface. The Deep Water Culture Technique (S2) system outperformed and recorded the highest cuticle thickness rate/upper and lower surface, with a significant difference from the horizontal tube culture system (Nutrient Film Technique, NFT) (S1), which recorded the lowest cuticle thickness rate/upper and lower surface. The results also show that hydroponic medium have a significant effect on the cuticle thickness rate/upper and lower surface. The palm peat medium (B1) outperformed and recorded the highest cuticle thickness rate/upper and lower surface, while the lowest cuticle thickness rate/upper and lower surface was recorded by the use of perlite medium (B3). The interaction between the cultivation systems and hydroponic medium also had a significant effect. Chinese cabbage had a significant effect on the cuticle/upper and lower surface thicknesses. The highest cuticle/upper and lower surface thicknesses were recorded in the deep culture system using palm peat medium (S2B1), while the lowest cuticle/upper and lower surface thicknesses were recorded in the horizontal tube culture system using perlite medium (S1B3).

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Average Mesophyll Thickness

The results shown in Figure (5) indicate that hydroponic systems have a significant effect on average mesophyll thickness. The deep cultivation system (S2) outperformed and recorded the highest average mesophyll thickness, with a significant difference from the horizontal tube culture system (NFT) (S1), which recorded the lowest average mesophyll thickness. The results also show that hydroponic medium have a significant effect on average mesophyll thickness. The palm peat medium (B1) outperformed and recorded the highest average mesophyll thickness, while the lowest average mesophyll thickness was recorded using perlite (B3). The interaction between the cultivation systems and hydroponic medium for Chinese cabbage yang had a significant effect on average mesophyll thickness. The highest average mesophyll thickness was recorded in the deep cultivation system using palm peat medium (S2B1), while the lowest average mesophyll thickness was recorded in the horizontal tube culture system using perlite (S1B3).

The excelled of the deep culture system (S2) on the horizontal tube culture system (S1), and the excelled of the palm peat medium (B1) on the coconut medium (B2) and perlite medium (B3), may be due to increased vegetative growth, increased cell division, and an increased number of stomata. This study is consistent with the study by [3], which showed that increasing the number of stomata in the upper and lower epidermal layers has an effect on growth rate. It may also be due to the increased size of guard cells due to the increase in chloroplasts in the guard cells and their high content of chlorophyll [1]. The reason for the difference in the thickness of the cuticle layer between the upper and lower epidermis, and the variation in its thickness from one treatment to another, is attributed to the environmental factors surrounding the plant, such as light intensity, heat, and wind. The presence of the cuticle is one of the plant's adaptations to reduce water loss because it is composed of the waxy substance cutin, which reduces water loss from the leaves. The cuticle layer also prevents pathogens and pests from penetrating the plant leaves [2]. The results of the study also showed that the mesophyll tissue of the leaves was also affected by the cultivation system and the cultivation medium. This is attributed to the abundance of plastids found in the meristematic tissue, which positively reflects the increase in chlorophyll in the leaves, increasing the metabolic process and vegetative growth, in addition to increasing the number of cell divisions, their expansion, and tissue formation [21]. These results are consistent with the findings of [12, 19].

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Table 1. Basma solution 2023

Element concentration %	Type of element	weight g.l $^{-1}$	Chemical compound	Type of
Stock A				
12	nitrogen	850	K	Higl potassi 12:10:36
10	Phosphorus			
36	potassium			
0.53	magnesium			
0.70	sulfur			
0.02	boron			
0.05	copper			
0.10	iron			
0.01	manganese			
0.05	zinc			
13	nitrogen	300	KNo_3	Potassi nitra
46	potassium			
10	magnesium	400	MgSo4	Magnes sulfa
13	sulfur			
8.50	Magnesium oxide	40	Microplex	micronut
1.40	zinc			
3.80	iron			
3.80	manganese			
1.40	copper			
0.40	boron			
0.09	molybdenum			
5.00	amino			
Stock B				
15	Total nitrogen	1000	$Ca(No_3)_2$	Calciu nitra
1.5	Ammonia nitrogen			
14	nitrate			
26.5	Calcium oxidase			
6	iron	70	Fe-EDDHSA 6%	Iron che

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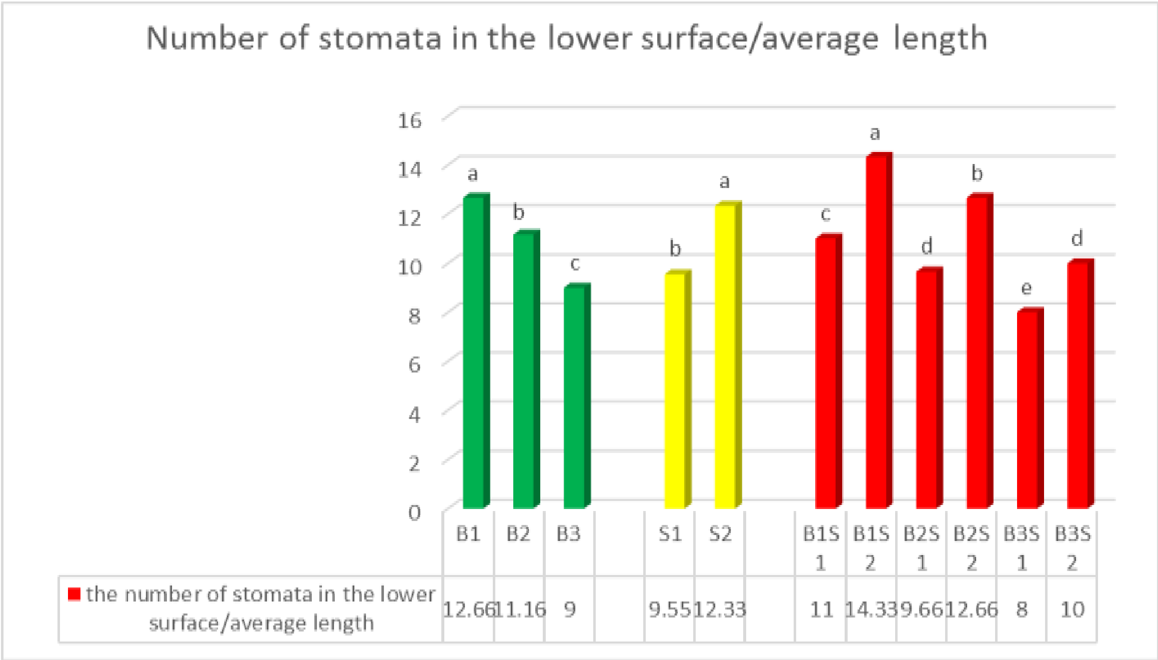

Figure 1. Effect of culture systems and hydroponic medium on the number of stomata in the lower surface/average length.

* Means that share the same alphabetical letter are not significantly different from each other according to Duncan's multiple range test at the probability level of 0.05 $p < 0.05$. S1 = NFT, S2 = DWT, B1 = palm peat medium, B2 = coconut medium, and B3 = perlite medium.

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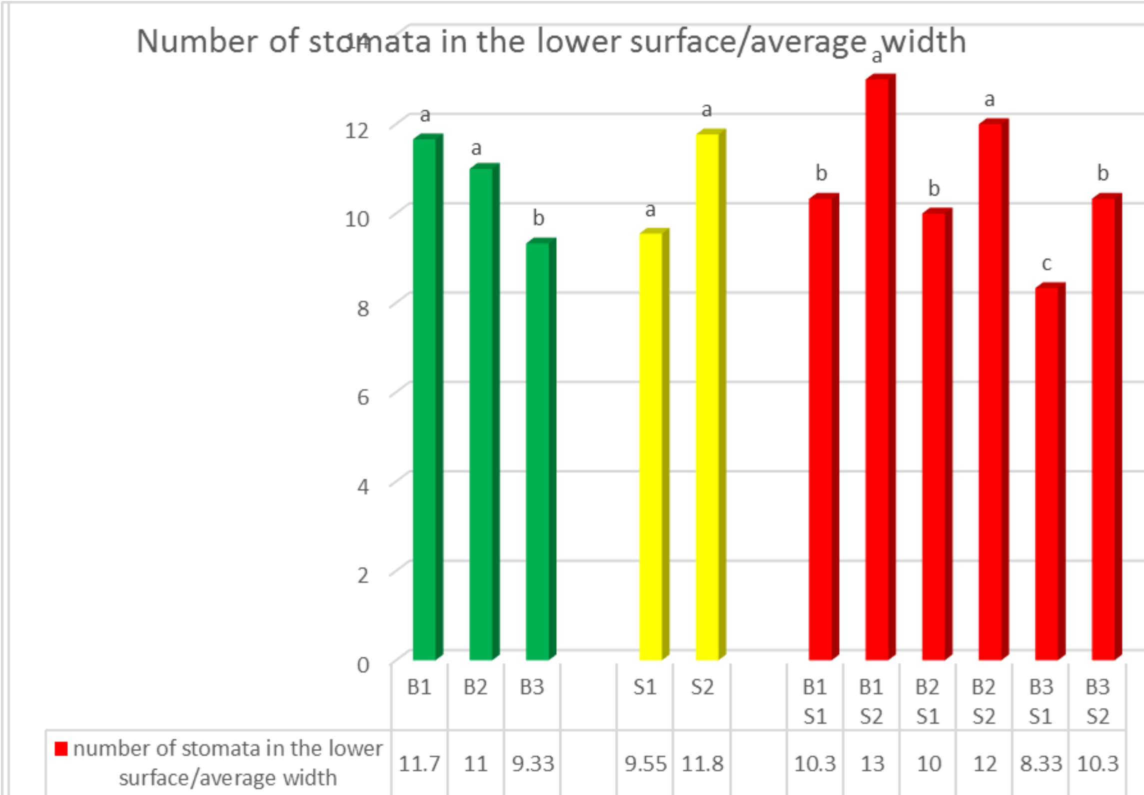

Figure 2. Effect of culture systems and hydroponic medium on the number of stomata in the lower surface/average width.

* Means that share the same alphabetical letter are not significantly different from each other according to Duncan's multiple range test at the probability level of 0.05 $p < 0.05$. S1 = NFT, S2 = DWT, B1 = palm peat medium, B2 = coconut medium, and B3 = perlite medium.

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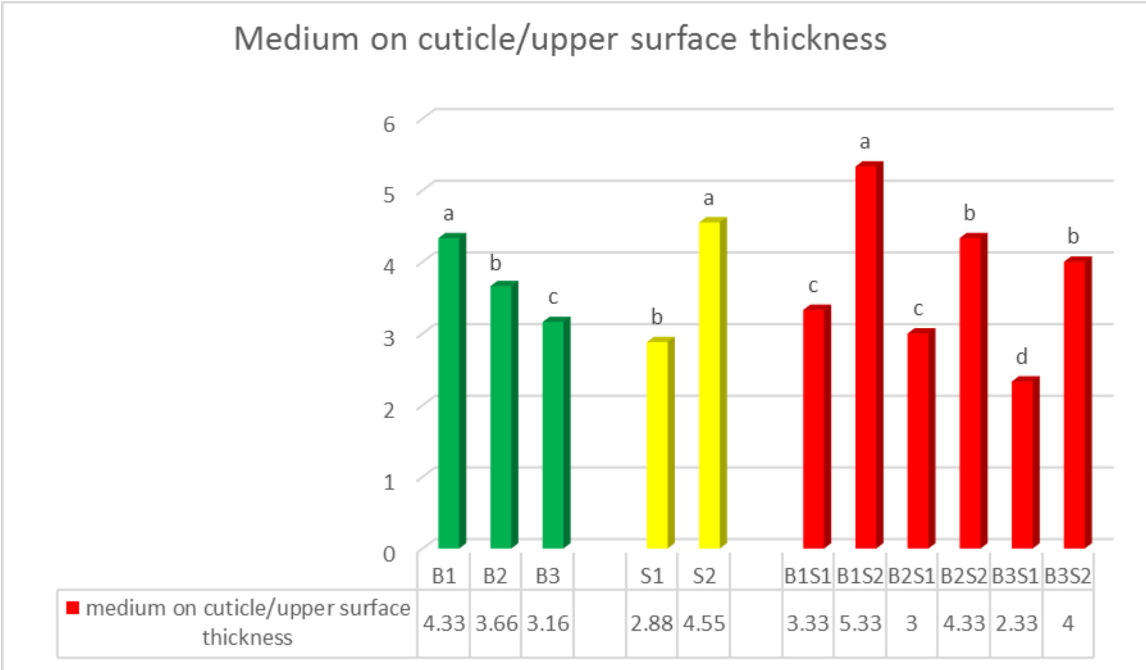

Figure 3. Effect of culture systems and hydroponic medium on cuticle/upper surface thickness.

* Means that share the same alphabetical letter are not significantly different from each other according to Duncan's multiple range test at a probability level of 0.05. S1 = NFT hydroponic technology, S2 = DWT hydroponic technology, B1 = palm peat medium, B2 = coconut medium, and B3 = perlite medium.

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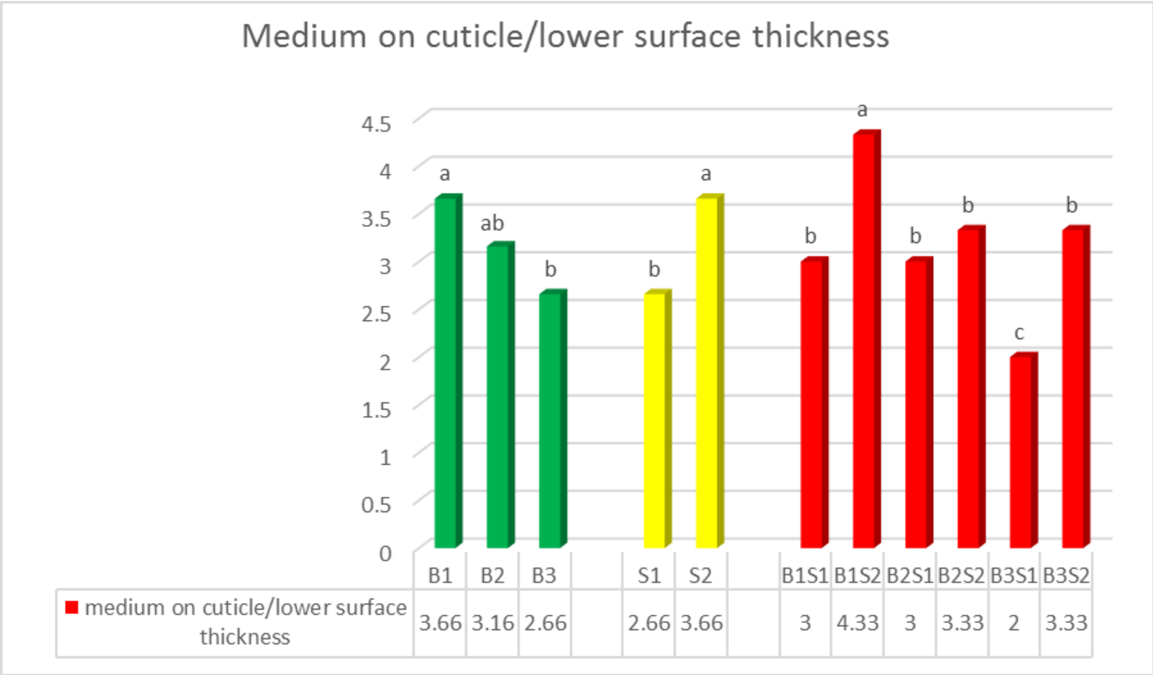

Figure 4. Effect of culture systems and hydroponic medium on cuticle/lower surface thickness.
* Means that share the same alphabetical letter are not significantly different from each other according to Duncan's multiple range test. Duncan's multinomial at the probability level of 0.05 ≥P. Where S1 = NFT, S2 = DWT, B1 = palm peat medium, B2 = coconut medium, and B3 = perlite medium.

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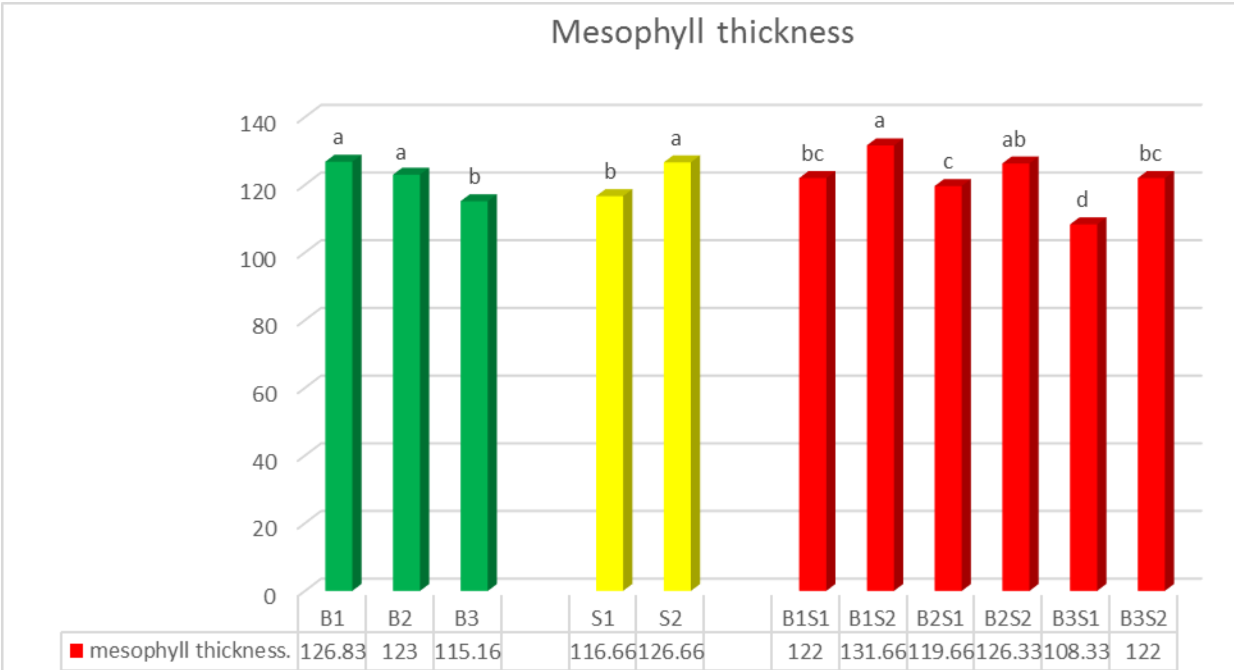

Figure 5. Effect of culture systems and hydroponic medium on mesophyll thickness.

*Means sharing the same alphabetical letter are not significantly different from each other according to Duncan's multiple range test at a probability level of 0.05 $p < 0.05$. S1 = NFT hydroponic technology, S2 = DWT hydroponic technology, B1 = palm peat medium, B2 = coconut medium, and B3 = perlite medium.

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Conclusions

The experiment concluded that the deep cultivation method (S2) significantly outperformed the treatment in terms of the number of stomata in the lower surface/average length, the number of stomata in the lower surface/average width, the average thickness of the cuticle layer/upper surface, the average thickness of the cuticle layer/lower surface, and the average thickness of the mesophyll tissue. The culture medium showed that the use of palm peat medium (B1) showed excelled in terms of the number of stomata in the lower surface/average length, the number of stomata in the lower surface/average width, the average thickness of the cuticle layer/upper surface, the average thickness of the cuticle layer/lower surface, and the average thickness of the mesophyll tissue, and significantly over the culture medium treatment. As for the interaction treatment, the deep cultivation method using palm peat medium (S2B1) showed a significant excelled in terms of the number of stomata in the lower surface/average length, the number of stomata in the lower surface/average width, the average thickness of the cuticle layer/upper surface, the average thickness of the cuticle layer/lower surface, and the average thickness of the mesophyll tissue. Cuticle thickness/upper surface, average cuticle thickness/lower surface, average mesophyll thickness.

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