

Research Article



Growth and Production of Several Varieties of Strawberry (*Fragaria x ananassa*) in Dutch Bucket and Drip Irrigation Hydroponic Systems in the Lowlands

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Abstract

Strawberry (*Fragaria x ananassa*) is a fruit that many enjoy due to its high nutritional value and potential benefits. However, research on the growth and production of strawberries in lowland areas using greenhouses is limited. This study aims to identify the optimal growth and production of several strawberry varieties in a hydroponic system in lowland conditions. The research was conducted at the Smart Farming Greenhouse Alfa UG Technopark Zone from December 2024 to April 2025, using a complete group with a nested design. The experiment included the Dutch bucket hydroponic system (H1) and drip irrigation (H2). For the second factor, four strawberry varieties were examined: the Sagahonoka (S1), Sweet Charlie (S2), Red Giant (S3), and Earlibrite (S4). Data analysis was carried out using Analysis of Variance (ANOVA) and the Duncan Multiple Range Test (DMRT) at the $\alpha = 5\%$ level. Results indicated that both the dutch bucket and drip irrigation hydroponic systems influenced the vegetative phase (including plant height, number of compound leaves, total leaf count, and leaf area) as well as the generative phase (including number of stolons, flowering age, flower count, and sweetness levels). All four varieties—Sagahonoka (S1), Sweet Charlie (S2), Red Giant (S3), and Earlibrite (S4)—adapted well to the conditions. The best-performing varieties for the Dutch bucket system were Sagahonoka, Sweet Charlie, and Earlibrite. In contrast, the Earlibrite variety was the most suitable for the drip irrigation system.

Keywords: greenhouse, media, nutrition, cultivation system, strawberry



1. Introduction

Strawberries (*Fragaria x ananassa*) are widely cultivated horticultural crops, especially in countries such as Indonesia. These subtropical plants belong to the Rosaceae family and originate from the Americas (Humayiroh, 2020). Strawberries hold significant economic value in local and international markets due to their attractive color, refreshing taste, and uniform fruit shape and size (Oktarina *et al.*, 2017). Each 100 g of fresh strawberries contains 37 calories, 0.67 g of protein, 0.5 g of fat, 7.68 g of carbohydrates, 38 mg of calcium, 27 mg of phosphate, 0.8 mg of iron, 136 kJ of energy, 60 mg of vitamin A, 0.24 mg of vitamin B1, 0.022 mg of vitamin B2, 0.125 mg of vitamin B5, 89.9 g of water, and 2 g of fiber (USDA, 2018). Also, strawberries are rich in secondary metabolites such as anthocyanin pigments, which are potent antioxidants. According to Pamuji *et al.* (2023), the price of strawberries varies based on fruit size grade. Therefore, cultivating strawberries could represent a promising business opportunity on a national scale.

Data from the Badan Pusat Statistik (2024) indicates a decline in strawberry production. In 2021, production was 9.8 thousand tons, increasing to 28.9 thousand tons in 2022, before decreasing to 27.7 thousand tons in 2023. The reduction in production from 2022 to 2023 amounts to 1.7 thousand tons. This decline may be attributed to climate change factors, including variations in rainfall intensity, drought, temperature fluctuations, air humidity, and increased pressure from pests and diseases, which can cause fruit rot and pose significant challenges to strawberry cultivation (Hernandez *et al.*, 2023).

One potential solution to enhance the growth and production of strawberries in Indonesia is hydroponic cultivation, which can help mitigate the impact of pests and diseases. Strawberry varieties suitable for cultivation in Indonesia include the Sagahonoka variety, known for its large, attractive fruit, sweet taste, dense dark red flesh, and pungent aroma (Rahadatul *et al.*, 2024). Sweet Charlie produces orange to dark red fruit with a sweet flavor and intense strawberry aroma. Earlibrite yields dense fruit with a sweet taste, while Red Giant features large, bright red fruit with a sweet flavor.

2. Materials and Methods

This research was conducted from December 2024 to April 2025 at the Smart Farming Zone Greenhouse Alfa UG Technopark in Cianjur, West Java, at an altitude of 225 to 500 meters above sea level. The materials used included strawberry seeds of the Sagahonoka, Sweet Charlie, Red Giant, and Earlibrite varieties; AB Mix nutrients; cocopeat planting media; burnt rice husks; hydroton; rockwool; and water. The equipment employed comprised a Dutch bucket hydroponic system, drip irrigation, 300 L and 1500 L plastic drums, an 82 L nutrient box, digital twin technology, 40 x 40 cm polybags, water pumps, Brix refractometers, calipers, digital scales, scissors, 10 cm

The hydroponic system is a cultivation technique that uses water instead of soil. The Dutch bucket hydroponic system and drip irrigation are effective methods for strawberry cultivation, involving continuously delivering nutrient solutions to the plants. The Dutch bucket hydroponic system offers advantages such as water efficiency, improved humidity control of the growing medium, and adequate nutrient circulation (Saydi *et al.*, 2022). Research by Roberto (2003) demonstrates that tomato plants grown using the Dutch bucket hydroponic system can produce good yields with relatively low maintenance. Conversely, drip irrigation efficiently utilizes water and nutrients, increasing flowering, fruiting, and strawberry production (Susanto *et al.*, 2016). Therefore, it is essential to investigate the productivity levels of the highest-performing strawberry plants in both hydroponic systems. Furthermore, the nutritional content is closely related to both hydroponic systems. Nutrient availability is a key factor in successful hydroponic cultivation.

Given the advantages of both systems, it is essential to determine which method yields the highest productivity and best results in strawberry cultivation. This research aims to analyze the growth and production of strawberry plants in lowland areas using greenhouses by comparing the Dutch bucket hydroponic system and drip irrigation across four strawberry varieties: Sagahonoka, Sweet Charlie, Red Giant, and Earlibrite. However, limited information on the Dutch bucket hydroponic system presents a challenge, as there has been little direct comparison of hydroponically cultivated strawberry varieties. Therefore, a comparative analysis is necessary to identify which varieties achieve the best growth and yields using the Dutch bucket hydroponic system versus drip irrigation in lowland areas. The objective is to understand how variations in these two hydroponic systems and the different strawberry varieties affect growth and production under lowland greenhouse conditions.

net pots, TDS meters, measuring cups, stationery, and cellphone cameras.

The experimental design was a completely randomized group design with nested factors, incorporating two treatment factors. The main factors included two treatment levels: Dutch bucket hydroponics (H1) and drip irrigation hydroponics (H2). Four treatment levels corresponded to different strawberry varieties: Sagahonoka (S1), Sweet Charlie (S2), Red Giant (S3), and Earlibrite (S4). Thus, eight treatment combinations were created, each with five replications, and each replication contained three plant samples. Data analysis was performed using Analysis of

Variance (ANOVA) and Duncan's Multiple Range

Test (DMRT) with a significance level of $\alpha = 5\%$.



Figure 1. Comparison of the Dutch bucket and drip irrigation hydroponic systems (Source: Personal documentation, 2025)

The parameters observed in this study included both growth and production data. Growth parameters consisted of plant height (cm), number of compound leaves (blades), total number of leaves (blades), leaf area, and number of stolons. Production parameters included the time of first flower emergence (days after planting/DAP), flower age (DAP), number of flowers (buds), number of fruits, weight of individual fruit (g), total fruit weight (g), harvest period (weeks after planting/WAP), fruit diameter (mm), diameter of the largest fruit (mm), sweetness content (°brix), and harvest age (DAP).

Strawberry planting begins with preparing the greenhouse for sterilization. Sterilization is carried out using an insecticide containing the active ingredient profenofos. The planting medium of the Dutch bucket system is Hydroton. In the drip irrigation system, the

planting medium consists of a mixture of cocopeat and burnt rice husk in a 1:2 ratio, which is mixed and sterilized before use. The strawberry seeds used are two months old, with 120 seeds selected for uniform age and freedom from pests and diseases. Planting in both systems is conducted in the afternoon, at 2:00 PM WIB, to minimize plant stress caused by intense sunlight. Digital twin technology is then installed to monitor the greenhouse environment. Maintenance of the strawberry plants includes daily nutrient application and regular inspections to ensure plant health. Stolon pruning prevents competition among root plants during the generative phase. Flower thinning is also carried out to improve fruit quality. Finally, harvesting is done by observing the characteristics of fully ripened, bright red fruit.

3. Results and Discussion

Plant Height

The research results summarized in Table 1 reveal a significant difference in the effects of Dutch bucket and drip irrigation hydroponic systems on the height of strawberry plants at 9, 13, and 15 WAP. At 15 WAP, the drip irrigation method (H2) produced an average plant height of 14.58 cm, whereas the Dutch bucket system (H1) resulted in an average height of 11.09 cm. Notably, the Sweet Charlie variety (S2), when grown using the Dutch bucket system, exhibited greater growth. This outcome may be attributed to the Dutch bucket hydroponic system's adaptability to strawberry plants, as it continuously supplies nutrients through flowing water and utilizes hydroton media to prevent nutrient deficiencies. Additionally, ample daily sunlight supports optimal plant metabolic processes compared to other treatments.

Research by Rabbani *et al.* (2025) suggests that various hydroponic systems, including Dutch buckets, can maximize plant growth by providing a consistent nutrient supply through irrigation hoses. Environmental conditions also play a crucial role in plant growth. A wider root zone enhances a plant's ability to absorb nutrients, facilitating improved morphological development and efficient photosynthesis, contributing to strawberry plant growth. The hydroton medium used in the Dutch bucket system offers ample space for plant roots, promoting significant height growth in strawberries (Saydi *et al.*, 2022). These findings align with those of Susanto *et al.* (2016), who reported that drip irrigation systems foster superior growth during the vegetative phase of strawberry plants. Visually, plants receiving daily drip irrigation exhibit more vigorous growth, characterized by broad leaves, thick stems, and overall sturdiness.

Table 1. Plant height of several strawberry varieties in different hydroponic systems

Age	Variety	Plant height (cm)	
		dutch bucket	drip irrigation
3 WAP	Sagahonoka	6.93	6.20
	Sweet Charlie	5.87	6.07
	Red Giant	6.07	5.00
	Earlibrite	6.47	5.47
Average		6.34 ^a	5.69 ^a
6 WAP	Sagahonoka	7.07	9.93
	Sweet Charlie	6.73	11.40
	Red Giant	5.33	8.80
	Earlibrite	8.27	9.80
Average		6.85 ^a	9.98 ^a
9 WAP	Sagahonoka	7.73	11.60
	Sweet Charlie	8.27	11.53
	Red Giant	7.20	10.87
	Earlibrite	9.13	10.33
Average		8.08 ^b	11.08 ^a
13 WAP	Sagahonoka	9.93	16.20
	Sweet Charlie	11.53	14.53
	Red Giant	8.07	13.13
	Earlibrite	9.93	12.07
Average		9.87 ^b	13.98 ^a
15 WAP	Sagahonoka	10.87	15.00
	Sweet Charlie	11.27	16.40
	Red Giant	11.07	14.53
	Earlibrite	11.13	12.40
Average		11.09 ^b	14.58 ^a

Description: Numbers followed by the same letter within each week of observation and treatment indicate no significant differences, as determined by the DMRT test at the 5% level. The numbers followed by lowercase letters (a, b, c, d) indicate significantly different hydroponic systems; WAP refers to the number of weeks after planting.

Number of Compound Leaves and Total

According to the findings presented in Table 2, the choice between Dutch bucket and drip irrigation hydroponic systems significantly affects the number of compound leaves and the total leaf count of strawberry plants at 3, 9, 13, and 15 WAP. In the M15 treatment group, the drip irrigation system (H2) produced an average of 14.47 and 14.52 compound leaves, while the Dutch bucket system (H1) yielded averages of 11.09 and 11.25 leaves, respectively.

Number of Leaves

Furthermore, the Sagahonoka variety (S1) grown using the drip irrigation system exhibited more compound leaves than the Earlibrite variety (S4). These results indicate that the Dutch bucket system can enhance the number of compound leaves and the total leaf count. Additionally, the Sagahonoka and Earlibrite varieties showed improved growth when cultivated using the drip irrigation system.

Table 2. The number of compound leaves and the total number of leaves of various strawberry varieties in different hydroponic systems.

Age	Variety	Number of compound leaves (leaves)		Total number of leaves (leaves)	
		Dutch Bucket	Drip Irrigation	Dutch Bucket	Drip Irrigation
3 WAP	Sagahonoka	6.93	6.20	7.93	7.07
	Sweet Charlie	5.87	5.80	6.60	7.30
	Red Giant	6.07	5.00	7.40	6.40
	Earlibrite	6.47	5.47	7.13	7.00
Average		6.34 ^a	5.62 ^b	7.27	6.94
6 WAP	Sagahonoka	9.20	8.07	9.87	8.67
	Sweet Charlie	7.60	8.53	8.00	10.07
	Red Giant	8.07	7.67	8.53	8.73
	Earlibrite	8.20	8.27	10.13	9.73
Average		7.97 ^a	8.14 ^a	9.13 ^a	9.30 ^a
9 WAP	Sagahonoka	7.73	11.40	8.40	12.07
	Sweet Charlie	8.27	11.13	8.40	12.13
	Red Giant	7.20	10.87	8.33	12.07
	Earlibrite	9.13	10.33	9.53	11.20
Average		8.08 ^b	10.93 ^a	8.67 ^b	11.87 ^a
13 WAP	Sagahonoka	9.93	16.33	10.40	13.67
	Sweet Charlie	11.53	14.87	11.20	14.47
	Red Giant	8.07	13.13	8.93	13.47
	Earlibrite	9.93	12.07	11.53	12.33
Average		9.87 ^b	14.10 ^a	10.52 ^b	13.49 ^a
15 WAP	Sagahonoka	10.87	15.13	10.80	15.00
	Sweet Charlie	11.27	15.80	11.20	16.53
	Red Giant	11.07	14.53	12.00	14.13
	Earlibrite	11.13	12.40	11.13	12.40
Average		11.09 ^b	14.47 ^a	11.28 ^b	14.52 ^a

Description: Numbers followed by the same letter within each week of observation and treatment indicate no significant differences, as determined by the DMRT test at the 5% level. The numbers followed by lowercase letters (a, b, c, d) indicate significantly different hydroponic systems; WAP refers to the number of weeks after planting.

Planting using the Dutch bucket hydroponic system and drip irrigation is an effective cultivation method to increase the number of compound leaves and the total number of leaves on plants. The increase in the number of leaves is primarily influenced by the availability of nutrients supplied to the plant—the more nutrients absorbed—such as nitrogen, phosphorus, and potassium. The increase in leaf number is related to the rate of photosynthesis and nutrient absorption. Leaves play a crucial role in photosynthesis; when they grow and develop well,

the photosynthetic process can occur optimally, supporting overall plant growth. The results of this study are consistent with those of Susanto *et al.* (2016), who reported that using a drip irrigation system enhances the vegetative growth of strawberry plants.

Meanwhile, the number of leaves on strawberry plants grown using two hydroponic systems can be influenced by several factors, including exposure to sunlight for 8 hours—necessary for photosynthesis—and a balanced mix of nutrients, temperature, and

humidity within the greenhouse environment. According to research by Kumalasari *et al.* (2024), employing the Dutch bucket and drip irrigation hydroponic systems on various strawberry varieties resulted in optimal plant growth and yield. Nitrogen (N) plays a critical role in photosynthesis. As a macronutrient required in large quantities, nitrogen is an essential component of leaf chlorophyll and promotes vegetative growth, particularly leaf development (Arrasyid *et al.*, 2024). Providing a balanced nutrient mix to strawberry plants can enhance growth during both vegetative and generative phases, increasing parameters such as the number of leaves, leaf area, and fruit weight per plant compared to other fertilizer types (Prabowo & Sitawati, 2018). Variations in the number may result from suboptimal nutrient availability. Consistent daily sunlight is vital to support photosynthesis, and

balanced nutrition is equally important to promote healthy leaf growth in strawberry plants.

Leaf Area and Number of Stolons

The results presented in Table 4 indicate that the Dutch bucket and drip irrigation hydroponic systems have significantly different effects on leaf area, which ranged from 52.13 to 89.38 cm², and on the number of stolon emergences, which averaged 4.07. However, the four strawberry varieties did not show significant differences in either leaf area or the number of stolons. The variety with the highest number of stolons was Earlibrite, averaging 4.07 stolons. This suggests that leaf area across the different strawberry varieties is similar, likely due to consistent daily sunlight exposure, which supports the plants' photosynthesis process.

Table 4. Leaf area and number of stolons of various strawberry varieties in different hydroponic systems

Variety	Leaf area (cm ²)		Number of stolons (stolons)	
	Dutch Bucket	Drip Irrigation	Dutch Bucket	Drip Irrigation
Sagahonoka	51.65	86.41	3.73 ^{AB}	2.00
Sweet Charlie	50.47	94.13	2.93 ^{AB}	1.60
Red Giant	49.62	90.59	2.70 ^B	2.27
Earlibrite	56.79	86.39	4.07 ^A	2.07
Average	52.13 ^b	89.38 ^a	3.36 ^a	1.99 ^b

Description: Numbers followed by the same letter within each week of observation and treatment indicate no significant differences, as determined by the DMRT test at the 5% level. In contrast, numbers followed by capital letters (A, B, C) signify significantly different nested varieties, while numbers followed by lowercase letters (a, b, c, d) indicate significantly different hydroponic systems.

The Dutch bucket hydroponic system effectively responds to the leaf area and the number of plant stolons. Because nutrient delivery to plants is carefully controlled daily, the planting medium used for strawberries can store sufficient nutrients for the plants each day. Greenhouse humidity and temperature are regulated using ventilation and circulation systems, which maximize plant growth. Additionally, the regular daily provision of nutrients helps plants absorb the maximum essential elements. Higher temperatures and increased sunlight intensity promote the production of new seedlings.

Research conducted in a greenhouse located in the lowlands, at an elevation of 392 meters above sea level, indicates that temperatures range from 28.8 °C to 33.6 °C. Humidity levels average between 71% and 85%, while light intensity varies from 3916 to 6657 lux. Water availability is critical for promoting plant growth, affecting parameters such as plant height, leaf area, and fruit weight (Carsidi *et al.*, 2021). Furthermore, the increase in leaf area in strawberries is influenced by the level of water availability in the

growing medium, which subsequently impacts leaf size (Roos, 2018).

However, the rapid growth of stolons during the generative phase is believed to inhibit the flowering process. Stolons require assimilates from the parent plant to support their growth, reducing the supply of assimilates available for flower development (Daryono *et al.*, 2021).

Flower Emergence Time and Flower Age

Based on the results in Table 5, the difference between the Dutch bucket and drip irrigation hydroponic systems does not significantly affect the time of flower emergence. However, it substantially affects the flower's age, with 38 DAP in the Dutch bucket system and 42 DAP in the drip irrigation system. However, the four varieties used did not significantly affect either the time of flower emergence or the age of the flower.

Table 5. The time of flower emergence and the lifespan of several strawberry varieties in different hydroponic systems.

Variety	Flower emergence (DAP)		Flower Age (DAP)	
	Dutch Bucket	Drip Irrigation	Dutch Bucket	Drip Irrigation
Sagahonoka	15.87	19.93	45.73	38.80 ^B
Sweet Charlie	19.60	20.13	49.57	38.60 ^B
Red Giant	20.13	19.93	45.27	41.47 ^{AB}
Earlibrite	18.73	20.67	46.20	42.13 ^A
Average	18.58 ^a	20.17 ^a	46.69 ^a	40.25 ^b

Description: Numbers followed by the same letter in each week of observation and each treatment show significant differences in the DMRT test at the level of = 5%. In contrast, numbers followed by capital letters (ABC) indicate that the nested varieties are significantly different, and numbers followed by small letters (a, b, c) indicate that the hydroponic system is significantly different.

The timing of strawberry plant flowering indicates that the plant can adapt and produce fruit in environments such as lowlands. The local climate enables plants to grow optimally, progressing through vegetative and generative phases, including flowering. External factors are the most important determinants of plant growth: nutrient availability, water supply, sunlight intensity, temperature, humidity levels, and altitude.

According to the research findings of Susanto *et al.* (2016), consistent with the results obtained, the time of flower emergence in strawberry plants using a drip irrigation system showed no significant differences across treatments. The drip irrigation system generally results in relatively rapid flower emergence. However, the age of the flowers under the drip irrigation system has a significant effect. According to Ardo *et al.* (2021), strawberry plants with good vegetative growth tend to produce an optimal number of flowers, fruits, and greater fruit weight. This indicates that a healthy vegetative phase is a crucial foundation for the success of the generative phase in strawberry plants.

Number of Flowers and Number of Fruits

Table 6 shows that the difference between the Dutch bucket and drip irrigation hydroponic systems significantly affects the number of flowers, ranging

from 10.47 to 12.72. The number of fruits and varieties did not have a significant effect. The Earlibrite and Sweet Charlie varieties produced more flowers under the drip irrigation system than other treatments. Most fruits were found using the Dutch bucket system in the Earlibrite variety.

The number of strawberries harvested was lower than the number of flowers that appeared because not all flowers developed into ovaries. Ant pest attacks during the strawberry flowering phase can cause ovaries to fail to create or to fall off, as indicated by the drying of the pistil. Additionally, ants in the greenhouse can be attributed to humid environmental conditions and high temperatures caused by intense sunlight, with ant pest infestations reaching up to 25% (Yasmin *et al.*, 2018).

In addition, pruning stolons on strawberry plants can optimize flower formation by eliminating competition between flowers and stolons for essential nutrients. Providing adequate nutrition to the plants can increase the number of flowers produced. High temperatures reduce plants' photosynthesis rate by 44%, decrease crop yields, and lower the sugar content responsible for fruit sweetness. Elevated temperatures on the fruit surface can accelerate the ripening process, and faster ripening can shorten the harvest cycle (Khammayom *et al.*, 2022).

Table 6. Number of flowers and number of fruits of several strawberry varieties in different hydroponic systems

Variety	Number of flowers (buds)		Number of fruits (fruits)	
	Dutch Bucket	Drip Irrigation	Dutch Bucket	Drip Irrigation
Sagahonoka	13.40	13.13	8.75	8.26
Sweet Charlie	9.07	12.27	9.06	8.57
Red Giant	9.13	11.47	8.92	7.86
Earlibrite	10.67	14.00	9.46	7.99
Average	10.57 ^b	12.72 ^a	9.05 ^a	8.17 ^a

Description: Numbers followed by the same letter within each week of observation and treatment indicate no significant differences, as determined by the DMRT test at the 5% level. The numbers followed by lowercase letters (a, b, c, d) indicate significantly different hydroponic systems.

Fruit Weight per Fruit, Fruit Weight per Plant, and Total Fruit Weight

The difference between the Dutch bucket and drip irrigation hydroponic systems did not significantly affect fruit weight per fruit (g), fruit weight per plant (g), or total fruit weight (g). The highest average fruit weight per fruit was observed in the Sagahonoka variety, with an average of 8.10 g in the Dutch bucket hydroponic system. In contrast, the lowest average

fruit weight per fruit was recorded in the Red Giant variety, at 6.58 g. Meanwhile, the highest fruit weight per plant was achieved by the Earlibrite variety, averaging 45.37 g. At the same time, the lowest was found in the Sagahonoka variety, with an average of 33.27 g in the Dutch bucket system. The highest total fruit weight was also observed in the Earlibrite variety, reaching 136.10 g, as shown in Table 7.

Variety	fruit weight per fruit (g)		fruit weight per plant (g)		total fruit weight (g)	
	Dutch Bucket	Drip Irrigation	Dutch Bucket	Drip Irrigation	Dutch Bucket	Drip Irrigation
Sagahonoka	6.83	8.10	28.93	37.6	86.80	112.80
Sweet Charlie	7.41	7.35	43.00	38.80	129.00	116.40
Red Giant	7.02	6.58	33.70	39.67	92.80	119.00
Earlibrite	8.01	6.70	50.13	40.60	150.40	121.80
Average	7.32	7.18	38.94	39.17	114.75	117.50

Significant differences were observed in fruit weight per fruit, per plant, and total harvested fruit weight in lowland cultivation. The results varied notably when compared to fruit weights obtained in highland cultivation. These differences in strawberry fruit weight are closely related to local environmental conditions, such as temperature, humidity, and light intensity. The growth characteristics of strawberry plants can be optimized when the local environment is favorable, with ideal temperatures ranging from 17 to 20°C, humidity levels between 80% and 90%, and sunlight exposure of 8 to 10 hours per day (Desiana & Heddy, 2018). Environmental factors like temperature and humidity enhance strawberry growth, production, and photosynthesis, thereby enabling the development of larger fruit sizes. Additionally, fruit size can be influenced by greenhouse climate conditions and the nutrients supplied.

If these two factors align with the plant's characteristics and requirements, it can produce the desired fruit weight. Additionally, it is essential to consider removing the first flowers that appear on each plant to achieve a larger fruit size.

Fruit Diameter, Largest Fruit Diameter, and Fruit Sweetness

The difference between the Dutch bucket and drip irrigation hydroponic systems did not significantly

affect the fruit diameter or the largest fruit diameter. Among the varieties studied, Earlibrite exhibited the largest fruit diameter, measuring 19.51 mm. Fruit size in strawberries is a critical factor for the plant's success in adapting to environmental conditions necessary for producing large fruits, which vary among different varieties. Suboptimal fruit size can result from various factors, particularly climatic conditions such as temperature, humidity, and light intensity. Research by Simkova *et al.* (2023) highlights compositional differences between fruits of varying sizes and weights in two strawberry cultivars, Lycia and Clery. Larger fruits contained higher levels of ascorbic acid and sugar when measured per fresh weight. The Sweet Charlie variety produced the largest fruit diameter and the highest sweetness compared to other varieties. The hydroponic system used significantly influenced fruit sweetness. The Dutch bucket system achieved a higher sweetness level than the drip irrigation system, with sweetness reaching up to 9.05 °Brix. The Sweet Charlie variety demonstrated the highest average sweetness across all treatments. According to Dewi (2019), the Sweet Charlie variety typically produces sweetness levels between 8.0 and 9.0 °Brix in highland and medium-altitude areas. This suggests that the sweetness level of the Sweet Charlie strawberry variety remains relatively stable across diverse environmental conditions, including lowland areas.

Table 8. Fruit diameter (mm), largest fruit diameter (mm), and fruit sweetness (°Brix) of several strawberry varieties in different hydroponic systems.

Variety	Fruit diameter (mm)		Largest fruit diameter (mm)		Fruit sweetness (°Brix)	
	Dutch Bucket	Drip Irrigation	Dutch Bucket	Drip Irrigation	Dutch Bucket	Drip Irrigation
Sagahonoka	18.55	18.53	18.89	19.58	8.75	8.26
Sweet Charlie	18.66	18.99	18.84	19.83	9.06	8.57
Red Giant	18.13	18.60	18.52	19.70	8.92	7.86
Earlibrite	19.51	18.83	18.55	19.24	9.46	7.99
Average	18.71	18.74	18.70	19.59	9.05 ^a	8.17 ^b

Description: Numbers followed by the same letter within each week of observation and treatment indicate no significant differences, as determined by the DMRT test at the 5% level. The numbers followed by lowercase letters (a, b, c, d) indicate significantly different hydroponic systems.

The level of fruit sweetness is an indicator of the dissolved sugar content in the fruit, such as sucrose, fructose, and glucose. Various factors, including the selection of varieties, temperature, humidity, light intensity, and the availability and adequacy of nutrients obtained, influence the level of sweetness. The quality of fruit sweetness can be improved by ensuring regular provision of nutrients according to plant needs. Nitrogen (N), phosphorus (P), and potassium (K) nutrients play an important role in fruit formation. Providing nutrients regularly every day allows for optimal absorption of nutrients so that it has the potential to produce fruit with good size and high sugar content. The size of the strawberry fruit is an essential factor in the plant's success in adapting to the environment, depending on the characteristics of the variety. An unsupportive environment, such as high temperature and humidity in a greenhouse, can inhibit photosynthesis and reduce production efficiency, resulting in small and non-uniform fruit. In addition, selecting the right variety and providing appropriate nutrients also play a role in determining the final size of the fruit. According to the Department of Agriculture and Food (2020), lowland strawberry growth tends to produce heavy but small fruit. High ambient temperatures can accelerate fruit ripening, causing the fruit to turn red before reaching maximum size and volume.

Harvest Period and Harvest Age

The difference between the Dutch bucket and drip irrigation hydroponic systems did not significantly affect the harvest period and flower age. However, the Sagahonoka variety and the Earlibrite variety cultivated using the drip irrigation system showed a significant

difference in the frequency of the harvest period. Strawberry harvesting began from February to April. The number of fruit harvests obtained was ± 25 in the Dutch bucket system, while drip irrigation strawberry harvesting was carried out ± 30 .

The difference in harvest periods can be caused by the number of fruits from each fruit appearing differently in the two systems. This can be caused by climate factors that also affect the harvest period. Temperature, humidity, and light intensity are essential factors that must be considered in strawberry cultivation in greenhouses. According to the research results of Musayyanah et al. (2022), using greenhouse space in the fruit cultivation process, such as strawberries in lowland areas, can increase harvest productivity. Greenhouses can protect plants from the influence of external elements when cultivating them. Therefore, controlling the temperature and humidity in the greenhouse is an important aspect that must be considered to maintain the stability of the plant-growing environment.

Meanwhile, the harvest age of the four varieties does not significantly differ between varieties. The Sagahonoka variety has an average harvest age of 53 DAP, substantially different from the Earlibrite variety, which has an average harvest age of 45 DAP. In addition, there is a tendency for differences in harvest age to be produced in the two systems. The Dutch bucket system produces a shorter harvest age with an average of 47 DAP compared to the drip irrigation system with an average of 49 DAP. Variations in the differences in harvest age between varieties obtained are seen in both the Dutch bucket and drip irrigation hydroponic systems.

Table 9. Average harvest period and harvest age of several strawberry varieties in different hydroponic systems

Varietas	Harvest Period (WAP)		Harvest Age (DAP)	
	<i>Dutch Bucket</i>	<i>Drip Irrigation</i>	<i>Dutch Bucket</i>	<i>Drip Irrigation</i>
Sagahonoka	3.47	3.87 ^A	50.47	55.67 ^A
Sweet Charlie	4.73	3.07 ^{AB}	47.47	48.73 ^{AB}
Red Giant	3.70	3.87 ^{AB}	46.40	48.20 ^{AB}
Earlibrite	4.27	4.37 ^B	45.20	46.67 ^B
Average	4.04	3.80	47.39	49.82

Description: Description: Numbers followed by the same letter in each week of observation and each treatment show significant differences in the DMRT test at the level of = 5%. Numbers followed by capital letters (ABC) indicate that the nested varieties are significantly different.

The genetic characteristics of the variety used can influence differences in harvest age and variety in each strawberry system. The strawberry harvest season generally peaks at the beginning, namely between December and February, which is marked by abundant harvests (Gulf Coast Research and Education Center, 2024). In addition to various factors, the growth and development of strawberry plants are also influenced by climate conditions in the greenhouse, such as temperature, air humidity, and light intensity received by the plants. When the temperature and light intensity are insufficient, the photosynthesis process will be

inhibited, slowing the growth rate and resulting in delayed harvest age.

According to the Directorate of Fruit and Floriculture (2023), strawberries can be harvested when they have reached a perfect level of ripeness, which is marked by changes in the color of the fruit skin, texture, and other physical characteristics. Harvest time generally begins around 10 days after fruit formation or 60 DAP. In addition, using a drip irrigation system effectively distributes fertilizer directly to the root zone.

4. Conclusions

The study's findings on Dutch bucket and drip irrigation hydroponic systems revealed differences in the optimal growth of various plant varieties during both the vegetative and generative phases. In the vegetative phase, growth was assessed through plant height, the number of compound leaves, total leaf count, and leaf area. Conversely, the generative phase concentrated on the number of stolons, flowering age, flower count, and sweetness levels.

All four varieties—Sagahonoka, Sweet Charlie, Red Giant, and Earlibrite—thrived in lowland growing conditions at elevations ranging from 225 to 500 meters above sea level. The top-performing varieties in the Dutch bucket system were Sagahonoka, Sweet Charlie, and Earlibrite. However, the Earlibrite variety demonstrated excellent suitability for the drip irrigation system.

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