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Estrategias de cultivo: comparativa de tipologías de lechuga en sistemas hidropónicos

Cultivation strategies: comparative analysis of lettuce typologies in hydroponic systems

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Palabras claves: cultivo, tipologías, lechuga, sistemas hidropónicos

Resumen

Introducción. Las tendencias de producción principalmente por la falta de tierras productivas cada día van cambiando, se buscan alternativas que sean amigables con el ambiente y los agricultores para producir alimentos sanos. La investigación se realizó en la comunidad de Pantaño provincia de Chimborazo. **Objetivo** La investigación tuvo como objetivo, evaluar la producción de tres tipologías de lechuga con dos soluciones nutritivas bajo un sistema hidropónico bajo invernadero en la comunidad de Pantaño. **Metodología.** El estudio consideró 3 variedades de lechuga V1: Jade, V2: Scarlet y V3: Starfighter y dos soluciones nutritivas. Se empleó el método NFT (Técnica de Película Nutritiva), se establecieron seis tratamientos, cada uno con tres repeticiones, utilizando un diseño completamente al azar (DBCA). Se realizó el análisis de varianza y se compararon las medias mediante separación de medias de Tukey al 5% de probabilidad. **Resultados.** Los resultados que destacaron en cuanto a la longitud de raíz a los 45 días, la V1 presento los mejores resultados con un promedio de 27,75 cm. La altura de la planta, las variedades V2 y V3 alcanzaron los mejores promedios, con 17,56 y 16,43 cm respectivamente. En términos de rendimiento se observó que la V1 respondió de mejor manera con la solución 2 obteniendo una media de 37612,5 kg ha^{-1}. **Conclusiones.** La V1 se destacó por su longitud de raíz a los 45 días y su rendimiento en peso fresco, obteniendo resultados superiores en comparación con las otras variedades. **Área de estudio general:** Agricultura, **Área de estudio específica:** Agricultura. **Tipo de articulo:** original.

Keywords: cultivation, typologies, lettuce, hydroponic systems

Abstract

Introduction. Production trends, due to the lack of productive land, are changing every day. Alternatives that are friendly to the environment and farmers are sought to produce healthy food. The investigation was conducted in the community of Pantaño, province of Chimborazo. Objective The objective of the research was to evaluate the production of three types of lettuce with two nutrient solutions under a hydroponic system under a greenhouse in the community of Pantaño. Methodology. The study considered 3 varieties of lettuce V1: Jade, V2: Scarlet and V3: Starfighter and two nutrient solutions. The NFT method (Nutrient Film Technique) was used, six treatments were established, each with three repetitions, using a completely randomized design (DBCA). The analysis of

variance was performed, and the means were compared using Tukey's separation of means at 5% probability. Results. The results that stood out in terms of root length at 45 days, V1 presented the best results with an average of 27.75 cm. In terms of plant height, varieties V2 and V3 achieved the best averages, with 17.56 and 16.43 cm respectively. In terms of yield, it was observed that V1 responded better with solution 2, obtaining an average of 37,612.5 kg ha-1. Conclusions. V1 stood out for its root length at 45 days and its fresh weight yield, obtaining superior results compared to the other varieties. General study area: Agriculture, Specific study area: Agriculture.

Introduction

Sustainable agriculture is currently going through critical circumstances, the decrease in arable land, the increase in urbanization, followed by water scarcity and climate change are of concern to farmers, technicians and scientists, as they can harm human and environmental health (Gruda, 2019).

Hydroponics is a technology of growing plants in nutrient solution (water containing fertilizer) with or without the use of artificial media (gravel, vermiculite, rock wool, peat, sawdust, coco coir dust, coconut fiber, etc.) in the absence of soil (Sharma et al., 2018). The nutrients required by plants for proper growth are provided by the nutrient solution (Lee et al., 2018; Hlophe et al., 2019).

Hydroponic systems require significantly less water compared to traditional growing methods. In fact, up to 90% of the water used in these systems can be recycled and reused, demonstrating exceptional water efficiency (Merling, 2020).

Furthermore, hydroponics offers the advantage of not requiring the use of agricultural machinery or great physical effort on the part of workers. This not only facilitates the cultivation process, but also contributes to greater cleanliness and food safety from sowing to harvest (Blanco-Capia et al., 2019).

Hydroponic systems are customized and modified based on recycling and reuse of nutrient solution and support media. Commonly used systems are wick, drip, reflux, deep water culture and nutrient film technique (NFT) (Sharma et al., 2018).

The best-known system is the NFT, which stands for nutrient film technique, which was developed in the late 1960s by Dr. Allan Cooper (Baixauli & Aguilar, 2002). It is a method for growing plants with roots that grow in layers of circulating, surface hydroponic

nutrients so that the plants can obtain sufficient water, nutrients and oxygen. The installation uses perfectly levelled channels, through which the solution is continuously circulated by a pump (Iswanto et al., 2020).

A wide range of marketable crops can be produced using these techniques, including tomatoes, peppers, cucumbers, strawberries, and green vegetables. Lettuce and spinach are the most promising species to grow in aquaculture and hydroponic systems due to their high growth and nutrient uptake capacity (Kumar et al., 2021).

Lettuce is one of the most popular horticultural crops worldwide, appreciated for its nutritional value and culinary versatility (Ayala et al., 2019; Lara-Izaguirre et al., 2020).

Hydroponic lettuce has a much shorter life cycle than lettuce grown using traditional methods. Growers can harvest hydroponic lettuce after only 35 to 40 days of growth and development, a significantly shorter period of time than that required for soil-grown lettuce (Sharma et al., 2018)..In the case of curly lettuce, its morphology and growth habit are particularly well adapted to hydroponic systems (Giaconi & Escaff, 2001).

The various agroclimatic problems, such as soil erosion, excessive use of pesticides, climate change and, especially, the smallholding system in our country, have led to the need to explore new alternatives for vegetable production. Among these alternatives is hydroponic production, which improves yields by increasing crop quality, reducing growth time and optimizing land use, since it requires smaller cultivation areas (Kumar et al., 2021).

Therefore, the study of hydroponic cultivation of curly lettuce is of great importance, both from a productive and economic and environmental point of view. By providing a sustainable alternative to traditional production, this type of research can contribute to improving food security and the profitability of horticultural systems (Ayala et al., 2019; Lara-Izaguirre et al., 2020).

The present investigation had as objectiveTo evaluate the production of three types of lettuce with two nutrient solutions under a greenhouse hydroponic system in the community of Pantaño.

Methodology

The research was carried out in the Pantaño community of the Chambo canton, Chimborazo province, which is located at an altitude of 2,750 meters above sea level, at 0.1°65' South Latitude and 79°40' West Longitude. The study was carried out in a greenhouse; for its implementation, two pyramid-shaped, automatic hydroponic modules were built under the recirculation system.

The research was applied at a purely experimental level.

Treatments under study

The treatments under study are shown in Table 1.

Table 1

List of treatments

Number	Treatment	Description
1	S1V1	Solution 1 (Ammonium nitrate 0.33 g/L; calcium nitrate 0.46 g/L; potassium nitrate 0.28 g/L and microelements 0.03 g/L) variety 1 (Jade – semi-green lettuce)
2	S1V2	Solution 1 (Ammonium nitrate 0.33 g/L; calcium nitrate 0.46 g/L; potassium nitrate 0.28 g/L and microelements 0.03 g/L) variety 2 (Red-leaf Scarlet)
3	S1V3	Solution 1 (Ammonium nitrate 0.33 g/L; calcium nitrate 0.46 g/L; potassium nitrate 0.28 g/L and microelements 0.03 g/L) variety 3 Starfighter green leaf
4	S2V1	Solution 2 (Ammonium nitrate 0.33 g/L; calcium nitrate 0.46 0.33 g/L; monopotassium phosphate 0.22 g/L and microelements 0.03 g/L) variety 1 (Jade – semi-green lettuce)
5	S2V2	Solution 2 (Ammonium nitrate 0.33 g/L; calcium nitrate 0.46 0.33 g/L; monopotassium phosphate 0.22 g/L and microelements 0.03 g/L) variety 2 (Red-leaf Scarlet)
6	S2V3	Solution 2 (Ammonium nitrate 0.33 g/L; calcium nitrate 0.46 0.33 g/L; monopotassium phosphate 0.22 g/L and microelements 0.03 g/L) variety 3 Starfighter green leaf

Experimental design

A completely randomized block design (CRBD) was used, which included three replications and six treatments, resulting in a total of 18 experimental units.

Variables evaluated

The following variables were evaluated: Plant height (cm), Root length (cm), Days to harvest, Yield (kg ha-1), Cost/benefit ratio

Statistical analysis

To contrast the data, a completely randomized block design analysis of variance was used at a significance level of 0.05 and 0.01 and the Tukey mean comparison test at a significance level of 0.05%.

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Results

Root length

Regarding root length, the evaluation was carried out every 15 days, obtaining the following results for the treatments studied.

*Initial stage (15 days):*The analysis of variance at this stage indicates that there are no significant differences between the solutions used. However, there are significant differences (p=0.0009) for the varieties, in range a there is V1 (Jade) with an average of 20.82 cm and the shortest root length is found in V2 and V3 with averages of 15.3 and 15.18 cm respectively as shown in figure 1.

Development stage (30 days): The analysis of variance at this stage indicates that there are no significant differences between the solutions. However, highly significant differences are observed between the varieties (p = 0.0008). At this stage it was possible to see that V2 and V1 had greater root length with means of 27.24 and 27.22 cm respectively with a range a, while in range b there is V1 with a mean of 22.63 cm as shown in figure 1.

*Final stage (45 days):*The analysis of variance at this stage showed that there were no significant differences between the solutions. However, highly significant differences were observed between the varieties (p = 0.0008). At this stage, it was possible to see that V2 and V1 had greater root length with means of 27.75 and 27.52 cm respectively, and V1, with a mean of 23.67 cm, had the lowest value, as can be seen in Figure 1.

Discussion

Tejada (2022), in his evaluation, obtained an average root length of 20.92 cm, taking into account that here it was studied under the substrate modality. Therefore, in our work it was evident that there was a greater development of the root zone because there was a better assimilation of nutrients and therefore a better development of the plant, this is manifested by(Iswanto et al., 2020).

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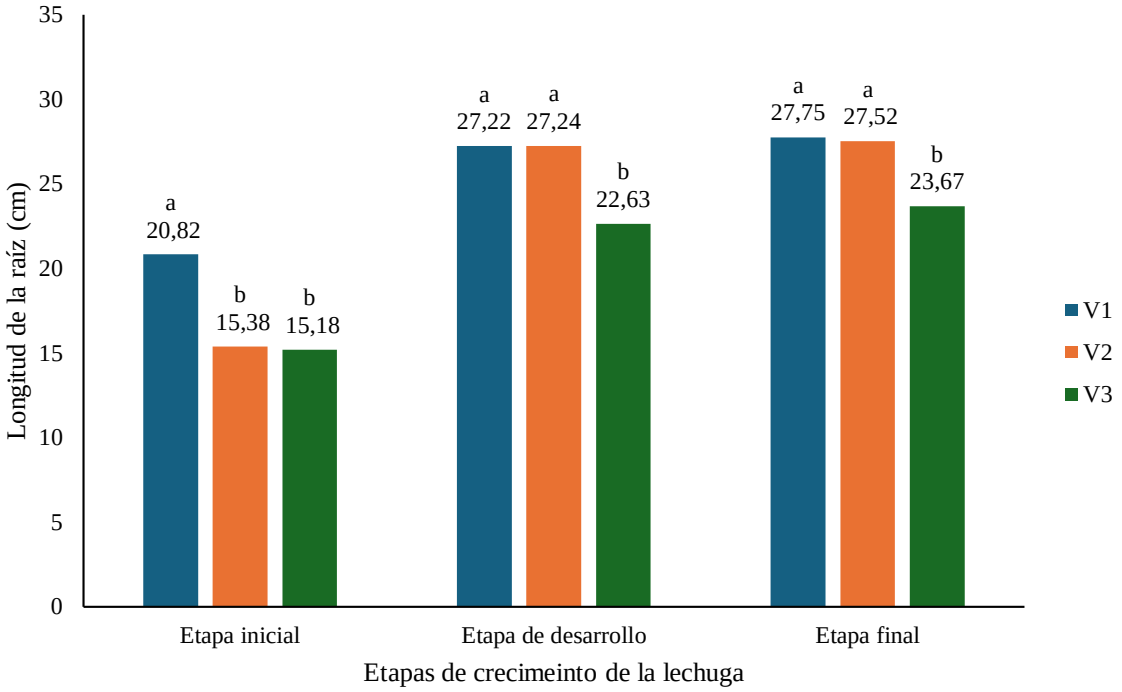
Figure 1

Root length at different stages with the three lettuce varieties



Note: The letters a and b correspond to the ranges that the Tukey mean separation test yielded at 5%. (a higher and b lower)

Plant height (cm)

Regarding plant growth, the height of the plant was evaluated in its different phenological stages, obtaining the following results:

*Initial stage (15 days):*The analysis of variance of the evaluated treatments indicates that there are significant differences (p=0.0013), varieties 3 and 1 with means of 12.95 and 9.87 cm being the highest values respectively, and V2 reached a height of 9.5 cm being the lowest, as shown in Figure 2.

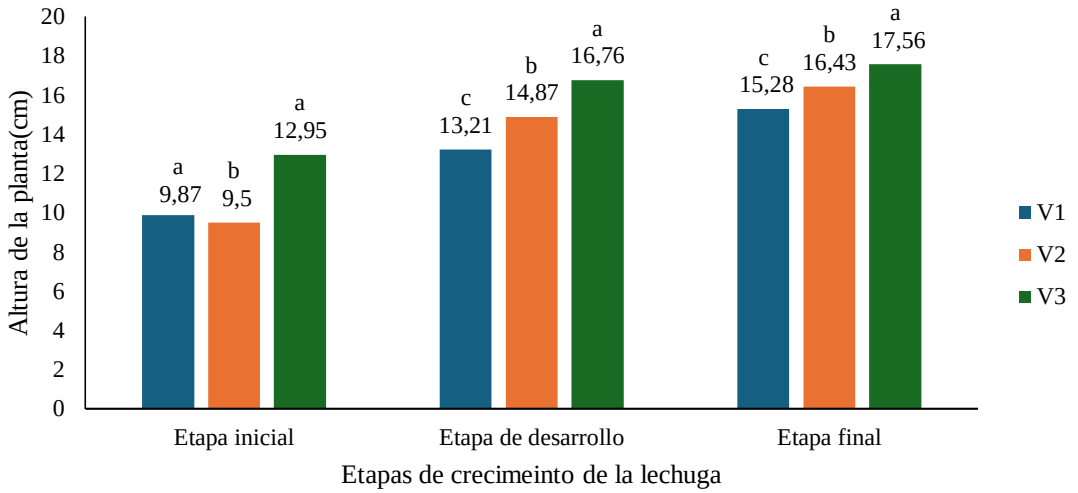
*Development stage (30 days):*At this stage, the variance analysis showed that there were significant differences between the solutions (p=0.0178) and highly significant differences between the varieties (p=0.002). V3 had an average height of 16.76 cm, being the highest value, and V1 reached 13.21 cm, corresponding to the lowest value, as observed in Figure 2.

*Final stage (45 DDT):*The analysis of variance for this stage tells us that there are significant differences for the solutions applied (p = 0.0062) and there are also highly

significant differences for the varieties (p = 0.0011). Figure 2 shows that the highest value is V3 with an average of 17.56 cm and the lowest value is V1 with a value of 15.28 cm.

Figure 2

Height in cm at different stages with the three varieties of lettuce



Note: Letters a, b and c correspond to the ranges that were obtained by Tukey's 5% mean separation test (a higher and c lower).

Discussion

The difference in height is clearly attributed to genetic differences between cultivated varieties; in the manifestation of the phenotypes, the environment is crucial for its development (Gonzales et al., 2013).

Throughout the days of observation, the V3 variety (Starfigther) showed on average a higher height compared to the other varieties, with a final height of 17.56 cm, exceeding the average of V2 and V1, which reached a height of 16.43 cm and 15.28 cm respectively. This significant difference of the Starfigther species over the others was compared with the study carried out by Chacha & Chávez (2020), where the plant reached an average height of 18.9 cm, there being a slight difference with that of the study.

During the course of the research, the V3 (Starfighter) variety showed a significantly higher average height compared to the other varieties evaluated. At the end of the experiment, the Starfighter variety reached an average height of 17.56 cm, exceeding the V2 and V1 varieties by 1.13 cm and 2.28 cm, respectively (V2: 16.43 cm; V1: 15.28 cm). This difference in height growth of the Starfighter variety in relation to the other varieties

studied is consistent with the results reported by Chacha & Chávez (2020), who found that this variety reached an average height of 18.9 cm under similar conditions, although slightly higher than that observed in the present study.

In this variable it was also possible to show that solution 2 (S2) presented significant differences with respect to solution 1 (S1). This is because monopotassium phosphate is considered one of the ideal fertilizers for hydroponic crops, since it plays a crucial role in various physiological processes of the plant.(Sharma et al., 2018).

According to Fathidarehnijeh et al. (2024), phosphorus is involved in energy transfer, strong root formation and photosynthesis, while potassium helps maintain water balance and leaf turgor.

Days to harvest

The average results obtained in the evaluated treatments indicated that the days needed to reach harvest were 40 and 45 days, respectively. This finding suggests that the variable "days to harvest" is fundamental for the different lettuce varieties, since no significant variation was observed in the data collected. This implies that, regardless of the treatment applied, the evaluated lettuce varieties present a similar behavior in terms of the time required for harvest, which highlights the importance of this variable in the selection and management of hydroponic crops. According to Díaz (2024), lettuce is a short-cycle crop that can be harvested between 30 and 40 days after transplanting, depending on the variety and growing conditions.

Pertierra & Quispe (2020), in their study, determined that increasing the temperature shortens harvest times, which is why they manage to harvest after 22 days on average with an average temperature of 29°C.

Furthermore, González et al. (2021) emphasize that time to harvest is a critical factor in lettuce production, as it directly influences crop planning and management.

Yield (kg ha-1)

For this variable, the analysis of variance determined highly significant differences in both the nutrient solutions and the lettuce varieties, with a p value of 0.0001 in both cases. The average yield was 23,808.5 kg ha-1, with a coefficient of variation of 9.01%, indicating moderate variability in the data.

Figure 3 shows the interaction that exists between the solutions and the varieties under study, then we can see that the best interaction is carried out by S2 with V1 (Jade), giving an average of 37,612.5 kg ha-1, while the lowest yields were found in the interaction 7,148.75 kg ha-1.

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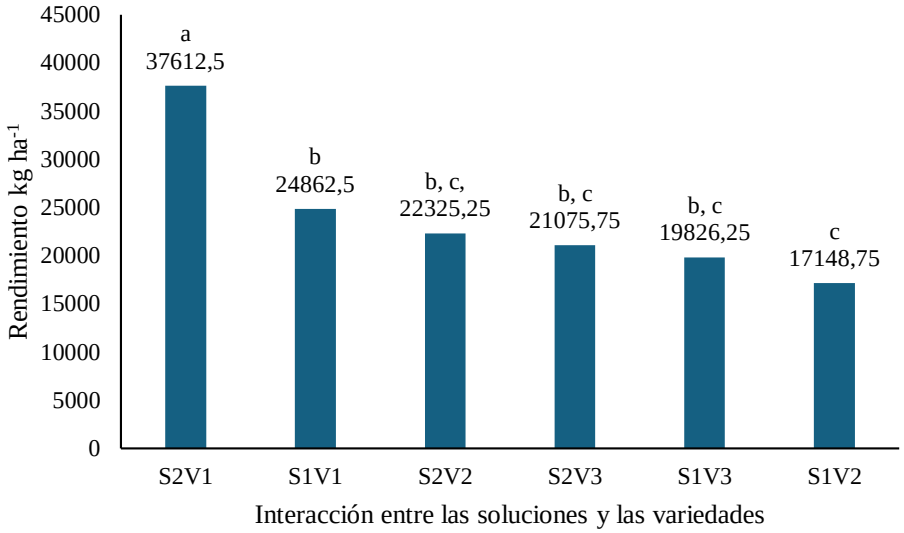
Figure 3

Performance of the Interaction of the Solutions with the Lettuce Varieties



Note: Letters a, b and c correspond to the ranges that were obtained by Tukey's 5% mean separation test (a higher and c lower).

Discussion

In terms of yield, the data from the study reveal that the V1 (Jade) variety, grown with nutrient solution 2, shows a significantly higher yield compared to the other combinations tested. This phenomenon can be explained by a combination of factors, including the genetic characteristics inherent to the variety and the specific benefits provided by the nutrient solutions used. The interaction between these elements suggests that the appropriate choice of variety and formulation of the nutrient solution are crucial to optimising yield in hydroponic cultivation systems.

Sakata (2023), in his manual on lettuce varieties, indicates that Jade is distinguished by a greater number of leaves per plant and an early elongation of these. These characteristics are essential to increase yield, since a greater leaf area allows for better capture of sunlight and greater efficiency in photosynthesis, an essential process for the production of carbohydrates and, therefore, for plant growth. Previous research has also shown that a greater leaf surface translates into a significant increase in biomass production (González et al., 2021).

In the study conducted by Chacha & Chávez (2020), the Starfighter variety showed a yield of 8,272 kg ha-1 in a NFT system. However, in the current research, this yield has been significantly exceeded, reaching 20,451 kg ha-1. This result highlights a notable

increase in the yield of the Starfighter variety in the context of the present study compared to previous research, suggesting that growing conditions and nutrient solution selection can have a profound impact on the productivity of lettuce varieties (González et al., 2021).

Cost/benefit ratio

In Table 2 we can see the cost/benefit ratio, the best benefit was obtained with V1 (Jade) 1.25; which means that, for every dollar invested, the initial investment is recovered and an additional profit of 25 cents is obtained. In second place is the V2 (Scarlet) treatment with a value of 1.16, which means that for every dollar invested, a profit of 16 cents is generated. On the other hand, the V3 (Starfighter) treatment did not achieve profitability, since the production costs exceeded the income obtained from sales, resulting in a loss for the producer.

Table 2

Cost-benefit ratio of the varieties under study

Varieties	Cost/ Benefit
Jade	1.25
Scarlet	1.16
Starfighter	0.98

Conclusions

- The research revealed that V1 Jade stood out for its root length at 45 days and its yield of 37,612.5 kg ha-1, obtaining superior results compared to the other varieties. It is important to mention that the Jade variety responded better with solution 2, suggesting greater adaptability to this specific nutrient solution.
- In terms of plant height, varieties V2 (Scarlet) and V3 (Starfighter) achieved the best averages, with 17.56 cm and 16.43 cm respectively.
- The main difference between the two nutrient solutions used in the study was their chemical composition. The presence of different compounds such as KNO_3 in Solution 1 and KH_2PO_4 in Solution 2 can influence the availability and proportion of essential nutrients for plant growth, which in turn can affect aspects such as root development, plant height and final yield in lettuce cultivation in a hydroponic system.

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