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Article

Effect of Nutrient Solution Levels, Culture Quantities and Water Quality Added on Barley Production Hordeum *vulgare* L. Culture

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Abstract: A laboratory experiment was conducted in the hydroponics laboratory of the Field Crops Department at the College of Agriculture, University of Basra, for the academic year 2020-2021, aimed at understanding the effect of seed quantity. water quality and the concentration of the added nutrient solution on the production of barley culture. The study included three factors, the first factor is the use of a plant nutrient NPK with a concentration of 30% N, 12% P, 8% K, where three levels of the nutrient were used and symbolized by the symbols w1, w2 andw3, while the second factor is the quantities of culture, which are (125, 150 and 175) g dish^{-1} And its symbol with the symbol (S1 , S2 , S3) w1 , w2 and w3, while the third factor includes two types of water and a symbol for it with the symbol m1 and m2, the experiment was carried out using the complete random design CRD and two repeaters .The following qualities have been studied (plant height, wet and dry weight of vegetative total , wet and dry weight of root system, protein ratio in the vegetative and root part and protein yield), The results of the experiment showed the following superiority of S2 treatment in all study traits, as well as the W2 concentration of the nutrient solution gave the highest average in the plant height and wet and dry weight of the vegetative total of 20.57 cm, 215.67 and 37.33 g.Plate^{-1} for interaction Between the quantities of culture, nutrient solution concentrations and water quality, they were significant in all the characteristics of the study, and the results also showed that the concentration of the solution W2 gave a protein ratio of 21.32% to the vegetative total , and the highest protein yield was 1.352 kg m^{-1}.

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1. Introduction

Hydroponics, also known as barley culture or landless farming, is an ancient technique that has been modernized to produce fresh green fodder with high nutritional value at any time of the year and under various environmental conditions. This method operates without restrictions, optimizing space and water usage in a healthy environment free from chemicals and pesticides [1]. The cultivation technique has been utilized for centuries, particularly in East Asian countries, to enhance the nutritional feed derived from barley, wheat, oats, and other cereals. The Animal Feed Consultative Center, based in Texas, USA, has noted that barley ranks as the fifth largest grain crop globally and is the most nutritious, with over half of the current barley production being used to feed livestock. This aligns with the historical use of barley, which is known for its high protein content, reaching up to 25% in dry barley [2], [3]. The elevated protein levels in cultured barley provide suitable feed for cows and sheep, offering significant nutritional value worldwide, along with essential vitamins and minerals that contribute to animal health [4].

Barley cultivation is a viable alternative not only when feed prices increase but also as one of the solutions to the agricultural, economic, and environmental issues that threaten food security. One fundamental solution is the production of green fodder in environments different from its original habitat and at times other than the usual cultivation periods [5]. Additionally, it aids in digestion, enhances the fertility rates of animals, and boosts their immunity. This method is viewed as a scientific approach to address the rising global costs of cereals and the growing food demands due to population growth. According to Mohammed, the addition of nutrient solutions plays a significant role in supplying plants with the necessary nutrients and improving the quality of the cultivation. Abdul Wahed noted that water quality is crucial for enhancing the qualities of barley cultivation, while Al-Razzaq et al. indicated that seed quantities contribute to increasing yields [6], [7]. The purpose of this experiment is to determine the optimal sowing amount, water quality, and the quantity of nutrients added to the cultivated barley, and to identify which factors are most effective and significant in the characteristics being studied.

2. Materials and Methods

A laboratory experiment was carried out in the Hydroponics Laboratory of the Field Crops Department at the College of Agriculture / University of Basra during the winter season of 2020-2021 with the aim of studying the effect of seed quantity, water quality and the concentration of the added nutrient solution on the production of barley culture. The study included three factors, the first factor is the use of NPK plant nutrient with a concentration of 30% N, 12% P, 8% K Where three levels of the first feeder were used without adding and the second level is more than the recommendation and the third level is less than the recommendation and is symbolized by the symbols (w1, w2 andw3) respectively, while the second factor is the quantities of culture, which are (125, 150 and 175) g dish^{-1} and its symbol is S1, S2, S3, while the third factor includes two types of water (non-sterile water and sterile water) and its code is m1 and m2. Plastic trays with dimensions of 17×27 cm were used. The experiment was carried out using a complete random design CRD and two repeaters.

The room was sterilized for 48 hours to create the conditions for natural cultivation, then the room was illuminated with electric lighting in addition to natural lighting, and the data were analyzed by the statistical program spss and the averages were compared in a way L.S.D according to what came by and the following characteristics were calculated: the height of the culture, the wet and dry weight of the vegetative total, the wet and dry weight of the root system, the percentage of protein in the vegetative and root part, and the protein quotient.

3. Results and Discussion

Culture height (cm)

The results of Table 1 showed significant differences between the average quantities of culture if the amount of culture S2 gave the highest average height of the culture reached 22.94 cm, while S3 the lowest average height of 16.61 cm and the reason is due to the intensity of competition for light and nutrients and this is consistent with Abdul Wahed As for the levels of the nutrient solution, the level W3 gave the highest height of the culture, which did not differ significantly from the level W2 amounted to 20.57 and 20.54 cm respectively [8], [9].This is confirmed by that the different amount of nutrient solution added contributed greatly to the optimal absorption of nutrients and their optimal participation in vital activities within the tissue. Vegetarianism and thus the ability of cells to divide and expand and fill cells led to an increase in the height of the culture as well as consistent with.

The treatment (m2) is significantly superior by giving it the highest average height of the cultured barley of 20.28 cm on the treatment (m1) as it gave the lowest height of 19.07 cm, and the reason for the decrease in the height of the cultured barley may be due to the presence of a percentage of salinity being tap water in addition to the imbalance of nutrients in it Which leads to an increase in the osmotic voltage in plant cells, which results in a change in the components of the cellular juice as a result of the increased absorption of salt ions and decreases accordingly the absorption of water and consumes the plant a large energy to maintain its osmotic voltage may lead to the consumption of energy necessary for growth and physiological processes and this leads to a decrease in the growth rate [10], [11].

The overlap between the quantities of culture and nutrient levels and water quality was significant as the combination (W3×S2×M2) gave the highest average plant height of 25.10 cm, while the synthesis (W1×S3×M1) recorded the lowest average of 14.25 cm and the reason for this is due to the overlap of the three factors, while the overlap between the quality of the added water and the quantities of seeds did not show any significant effect in this characteristic [12].

Table 1. Effect of Nutrient Levels, Seed Quantities, and Water Quality on Average Plant Height (cm)

Nutrients	**Seed Quantities / water quality**	**S1**	**S2**	**S3**	**W×M**
W1	**M1**	**17.55**	**19.25**	**14.25**	**17.20**
	M2	**15.75**	**23.05**	**17.65**	**18.81**
W2	**M1**	**17.45**	**23.80**	**18.65**	**19.96**
	M2	**22.30**	**23.85**	**17.20**	**21.12**
W3	**M1**	**22.10**	**22.60**	**16.00**	**20.23**
	M2	**21.70**	**25.10**	**15.95**	**20.91**
Average Seed Quantities		**19.48**	**22.94**	**16.61**	**Average water quality**
LSD$_{.0.05}$**(S)=1.16** **LSD(M×W) =N.S** **LSD(M×W×S)=2.84**					
M×S	**M1**	**19.03**	**21.88**	**16.30**	**19.07**
	M2	**19.92**	**24.00**	**16.93**	**20.28**
LSD$_{.0.05}$**(M)=0.95** **LSD(M×S) =N.S**					**Average nutrients**
W×S	**W1**	**16.65**	**21.15**	**15.95**	**17.92**
	W2	**19.88**	**23.82**	**17.92**	**20.54**
	W3	**21.90**	**23.85**	**15.97**	**20.57**
LSD$_{.0.05}$**(W)= 1.16** **LSD(W×S)=2.01**					

Wet weight of the root system (g. Dish^{-1})

The results of Table 2 showed significant differences between the average quantities of culture if the amount of culture S2 gave the highest average wet weight of the root group, which did not differ significantly from S3, amounting to 459.01 and 438.53 g dish-1، while S1 recorded the lowest average of 356.08 g dish-1 The reason for this is that the increase in the quantities of culture leads to an increase in the root total and this is consistent with Abdul Razzaq et al. As for the level of nutrients and water quality, we note that there is no significant effect on the wet weight characteristic of the smallpox total [13].

While the overlap between culture quantities and nutrient levels and water quality was significant, as the combination (W3×S2×M1) recorded the highest average wet weight of 549.60 g dish-1، while the synthesis (W1×S1×M1) recorded the lowest average of 231.23 g dish-1 and the reason for this is the overlap of the three factors together, either the overlap between the levels of the feeder and the quality of water has a significant effect if the combination is recorded between (M2×W1) The highest average was 449.47 g dish$^{-1،}$ which did not differ from other combinations except for the combination (M1×W1) gave the lowest average of 364.01 g dish-1, and the overlap of water quality and culture quantities was significant if the combination M2×S2 gave the highest average wet weight for the smallpox total of 469.28 g dish-1، while the combination M1×S1 recorded the lowest average of 325.28 g dish^{1-} ^{The} reason for this is the purity of the water and the increase in the amount of seed, and this is consistent with. While the interaction between nutrient levels and culture quantities was also significant if the combination W2×S2 recorded a higher average of 499.20 g dish^{-1} and these results are consistent with Zubaidi et al.

Table 2. Effect of Nutrient Levels, Seed Quantities and Water Quality on Mean Wet Weight Trait of Root Total (g. dish $^{-1}$)

Nutrients	Seed Quantities / water quality	S1	S2	S3	W×M
W1	M1	231.23	415.20	445.60	364.01
	M2	447.20	518.40	382.80	449.47
W2	M1	310.42	381.22	463.20	384.94
	M2	374.40	448.81	394.40	405.87
W3	M1	434.41	549.60	468.80	484.27
	M2	338.80	440.81	476.40	418.67
Average Seed Quantities		356.08	459.01	438.53	Average water quality
$LSD_{0.05}$(S)= 37.84	LSD(M×W)= 53.52		LSD(M×W×S)=92.71		
M×S	M1	325.28	448.64	459.20	411.04
	M2	386.80	469.28	417.84	424.64
$LSD_{0.05}$(M)=N.S		LSD(M×S)= 53.52			Average nutrients
W×S	W1	339.20	466.80	414.16	406.72
	W2	342.40	499.20	428.80	423.47
	W3	386.56	410.96	472.56	423.36
$LSD_{0.05}$(W)=N.S		LSD(W×S)=65.55			

Dry weight of the root system (g. dish^{-1}).

Table 3 indicates the emergence of significant differences in the average quantities of culture, where the amount of culture S2 gave the highest dry weight of the root total of 62.80 g dish-1 and a significant difference from the amount of culture S1, which gave the lowest average of 54.10 g dish^{-1} and mentioned Al farjawi et al. (2023) that increasing the amount of culture led to an increase in the dry weight of the root system [14], [15]. The other factors were not significant in this capacity.

While the interference had significant effects between the three factors, the combination W3×S2×M1 recorded the highest average dry weight for the smallpox total of 75.20 g dish-1 and the reason for this is due to the increase in wet weight Table 2 in this combination, while the combination W1×S3×M2 gave the lowest average of 45.60 g dish-1, while the other interactions were not significant for this characteristic.

Table 3. Effect of Nutrient Levels, Seed Quantities and Water Quality on Mean Dry Weight of Root Total (g dish $^{-1}$)

Nutrients	Seed Quantities / water quality	S1	S2	S3	W×M
W1	M1	53.60	48.00	58.40	53.33
	M2	56.00	69.60	45.60	57.07
W2	M1	52.00	68.00	52.00	57.33
	M2	56.60	54.40	48.80	53.27
W3	M1	57.60	75.20	55.20	62.67
	M2	48.80	61.60	56.00	55.47
Average Seed Quantities		54.10	62.80	52.67	

LSD.0.05(S)= 6.56 LSD(M×W) =N.S LSD(M×W×S)=16.16					Average water quality
M×S	M1	54.40	63.73	55.20	57.78
	M2	53.80	61.87	50.13	55.27
LSD.0.05 (M)= N.S LSD(M×S) =N.S					Average nutrients
W×S	W1	54.80	58.80	52.00	55.20
	W2	54.30	61.20	50.40	55.30
	W3	53.20	68.40	55.60	59.07
LSD.0.05(W) =N.S LSD(W×S)= N.S					

Wet weight of the vegetative total (g.dish^{-1}).

Table 4 indicates the emergence of significant differences between the average quantities of culture if the amount of culture S2 gave the highest average of 240.60 g. Plate^{-1} for wet weight while S3 recorded the lowest average of 156.87 g Plate^{-1} The reason for this is that the increase in the quantities of culture leads to competition between plants for growth requirements and this is consistent with Zubaidi et al. (2014). As for the nutrient levels, we note the superiority of the level W2, which did not differ significantly from the level W3 As they recorded the highest averages of 215.67 and 207.40 g dish-1، and the reason for this is that the wet weight of the vegetative total is greatly affected by the amount of nutrients, and this is consistent with Grigas et al. as for the quality of water, we note that there are no significant differences for the wet weight characteristic of the vegetative total.

While the overlap between the quantities of culture and the levels of the nutrient and the quality of water was of significant differences, as the combination (W3×S2×M1) recorded the highest average wet weight of 372.00 g dish^{-1}, while the combination (W1×S3×M2) recorded the lowest average of 113.20 g dish^{-1} and the reason for this is the overlap of the three factors together, either the overlap between the levels of the feeder, water quality, water quality and the quantities of culture were not significant for the characteristic of wet weight.

Table 4. Effect of Nutrient Levels, Quantities of Seeding and Water Quality on the Mean Wet Weight of Vegetative Total (g. dish $^{-1}$).

Nutrients	Seed Quantities / water quality	S1	S2	S3	W×M
W1	M1	193.60	172.00	184.80	183.47
	M2	194.00	243.60	113.20	183.60
W2	M1	161.20	195.60	164.80	173.86
	M2	262.00	186.40	147.60	198.67
W3	M1	258.80	372.00	153.60	261.46
	M2	185.20	274.00	177.20	212.13
Average Seed Quantities		209.13	240.60	156.87	Average water quality
LSD.0.05 (S)= 24.56 LSD(M×W) =N.S LSD(M×W×S)=60.136					
M×S	M1	204.53	246.53	167.73	206.27
	M2	213.73	234.67	146.00	198.13
LSD.0.05 (M) = N.S LSD(M×S)=N.S					Average nutrients

W×S	**W1**	**193.80**	**207.80**	**149.00**	**183.53**
	W2	**211.60**	**279.20**	**156.20**	**215.67**
	W3	**222.00**	**234.80**	**165.40**	**207.40**
LSD.0.05 **(W)= 24.56**			**LSD(W×S)= N.S**		

Dry weight of the vegetative total (g .dish^{-1}).

The results of Table 5 show significant differences between the average quantities of culture if the quantity of culture S2 recorded the highest average dry weight for the vegetative total amounted to 41.07 g dish^{-1} while S1 recorded the lowest average of 30.27 g dish^{-1} and the reason for the increase is due to the increase in the wet weight of the vegetative part Table (4) and this is consistent with Abdul Razzaq et al. and Abdul Wahid. As for the nutrient levels, the results showed above the level of W2, which did not differ from the level W3, as they recorded the highest averages of 37.33 and 36.00 g dish^{-1}, due to the fact that vegetative weight is greatly affected by the amount of nutrients.

We also note the superiority of water quality M1 as dry weight, which is consistent with the findings of Al farjawi et al. The overlap between culture quantities, nutrient levels and water quality was significant, as the combination (W3×S2×M1) gave the highest average dry weight for the vegetative total of 53.60 g dish-1, while the combination (W1×S1×M2) recorded the lowest average of 21.60 The reason for this is the overlap of the three factors together, either the interaction between the nutrient levels and water quality, as well as the quantities of culture and water quality, were not significant for this characteristic, while the interaction between the nutrient levels and the quantities of culture recorded significant differences if the highest combination W2×S2 highest average 45.60 g Plate^{-1}.

Table 5. Effect of nutrient levels, quantities of seeds and water quality on the average dry weight characteristic of vegetative total (g. dish $^{-1}$).

Nutrients	**Seed Quantities / water quality**	**S1**	**S2**	**S3**	**W×M**
W1	**M1**	**25.60**	**36.80**	**40.10**	**34.17**
	M2	**21.60**	**37.60**	**28.00**	**29.07**
W2	**M1**	**28.00**	**40.80**	**37.60**	**35.46**
	M2	**43.20**	**37.60**	**24.00**	**34.93**
W3	**M1**	**36.00**	**53.60**	**32.80**	**40.80**
	M2	**27.20**	**40.00**	**39.20**	**35.47**
Average Seed Quantities		**30.27**	**41.07**	**33.62**	**Average water quality**
LSD.0.05**(S)= 3.60**	**LSD(M×W) =N.S**		**LSD(M×W×S)=8.80**		
M×S	**M1**	**29.87**	**43.73**	**36.83**	**36.81**
	M2	**30.67**	**38.40**	**30.40**	**33.16**
LSD.0.05**(M)=2.96**			**LSD(M×S) =N.S**		**Average nutrients**
W×S	**W1**	**23.60**	**37.20**	**34.05**	**31.62**
	W2	**35.60**	**45.60**	**30.80**	**37.33**
	W3	**31.60**	**40.40**	**36.00**	**36.00**
LSD.0.05 **(W)= 3.60**			**LSD(W×S)=6.24**		

The percentage of protein in the vegetative and root part and protein quotient .

The results in Table 6 showed that the level of the nutrient W2 gave the highest percentage of protein for the vegetative part amounted to 21.32% and the increase rate was about 25.6% from the level of the nutrient W1, which has the highest protein percentage of 16.98% and the difference may be due to the difference in the amount of nitrogen that converts it into proteins according to the level of nutrients added, while the root part has given the level of nutrients W3 The highest protein percentage of cultured barley reached 17.53%, which did not differ from W2, which recorded a protein content of 16.30%, and the increase rate was 38% from W1, which gave the lowest average protein percentage of 12.68%, and these results are consistent with.

The results also showed significant differences in the protein yield, as the level of the nutrient W2 gave the highest average protein yield, which did not differ from the level of the nutrient W3 amounted to 1.352 and 1.269 kg $m^{-1,}$ while the level of the feeder W1 recorded the lowest average protein yield 0.731 kg m^{-1} and the reason for the superiority of nutrient levels is due to the fact that they contain high amounts and proportions of nitrogen compared to other solutions.

Table 6. Percentage of protein in the vegetative and root part and protein yield

Nutrients	Percentage of protein in the vegetative %	Percentage of protein part root%	protein yield kg m^{-1}
W1	16.98	12.68	0.731
W2	21.32	16.30	1.352
W3	19.15	17.53	1.269
LSD.0.05	1.85	1.84	0.16

4. Conclusion

This study demonstrated that the application of a nutrient solution containing 30% N, 12% P, and 8% K is highly effective in enhancing the growth and productivity of barley culture (Hordeum vulgare L.) under hydroponic conditions. The findings confirmed that seed quantity plays a critical role in determining growth performance, with 150 g $dish^{-1}$ (S2) emerging as the optimal sowing density, providing sufficient resources for growth while minimizing competition among plants. Similarly, nutrient concentration had a significant impact, where the W2 level resulted in superior plant height, biomass accumulation, and protein content compared to other treatments, indicating that moderate nutrient supplementation supports optimal nutrient absorption and metabolic activity. Water quality was also shown to be a decisive factor, with sterile water treatments generally producing higher growth and protein outcomes compared to non-sterile water, likely due to the reduction of salinity stress and microbial contamination. Interactions between nutrient levels, culture quantities, and water quality were significant across most measured traits, highlighting that barley production in hydroponics requires a balanced combination of these factors rather than reliance on a single variable.

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