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## Effect of Irrigation Periods and Organic Fertilization on Some Soil Properties and Lettuce Production

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### Abstract:

The study was conducted in Baghdad Governorate, Al-Mahmoudiya District, Al-Yusufiyah Sub-district (Al-Qasr Al-Awsat) during the 2021 growing season to evaluate the effects of irrigation intervals and organic fertilization on selected soil properties and lettuce production. The experiment included two factors: the first factor was irrigation intervals, consisting of watering the crop every 3, 5, and 7 days (denoted as I3, I5, and I7, respectively). The second factor was the application of organic fertilizer to the soil at rates of 0, 10, 20, and 30 kg ha<sup>-1</sup> (denoted as H0, H1, H2, and H3, respectively). The experiment was arranged in a randomized complete block design (RCBD) with three replicates, encompassing a total of 36 experimental units, each with an area of 3 m<sup>2</sup>. The results indicated that the I3 treatment (irrigating the crop every 3 days) resulted in the highest green yield productivity, reaching 205.775 µg ha<sup>-1</sup>. Conversely, the I7 treatment (irrigating the crop every 7 days) produced the best soil aggregate stability, achieving 59.590%. Regarding organic fertilization, the H3 treatment (30 kg h<sup>-1</sup> of organic fertilizer) demonstrated superiority across all studied characteristics. This treatment significantly reduced soil bulk density to 1.260 µg m<sup>-3</sup> compared to the control treatment (H0) at 1.362 µg m<sup>-3</sup>. Furthermore, total soil porosity increased to 52.633% under H3 compared to 48.793% for the control. The H3 treatment also resulted in the highest soil aggregate stability, reaching 56.593%, compared to 48.177% in the control treatment. Additionally, H3 achieved the highest vegetative yield of lettuce plants, at 165.727 megagrams ha<sup>-1</sup>, compared to 119.780 megagrams ha<sup>-1</sup> in the control.

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### تأثير مدد الري والتسميد العضوي في بعض صفات التربة ونتاج الخس

هديل عامر جبار

كلية علوم الهندسة الزراعية/ جامعة بغداد

### الخلاصه:

تم إجراء الدراسة في محافظة بغداد، قضاء المحمودية، ناحية اليوسفية (قصر الأوسط) خلال موسم النمو لعام 2021 لتقييم تأثير فترات الري والتسميد العضوي على بعض خصائص التربة وإنتاجية الخس. تضمنت التجربة عاملين: العامل الأول هو فترات الري، والتي شملت ري المحصول كل 3، 5، و7 أيام) تم ترميزها بـ I3، I5، و I7 على التوالي. (أما العامل الثاني فكان إضافة السماد العضوي للتربة بكميات بلغت 0، 10، 20، و30 كغم هكتار<sup>-1</sup>) تم ترميزها بـ H0، H1، H2، و H3 على الترتيب. تم تصميم التجربة باستخدام تصميم القطاعات العشوائية الكاملة (RCBD) بثلاث مكررات، وشملت 36 وحدة تجريبية، مساحة كل

وحدة منها 3 م<sup>2</sup>. أظهرت النتائج أن المعاملة I3 (ري المحصول كل 3 أيام) أدت إلى أعلى إنتاجية للكتلة الخضراء، حيث بلغت 205.775 ميكاغرام هكتار<sup>-1</sup> في المقابل، حققت المعاملة I7 (ري المحصول كل 7 أيام) أفضل استقرار لتجمعات التربة، حيث بلغت النسبة 59.590%. أما بالنسبة للتسميد العضوي، فقد أظهرت المعاملة H3 (30 كغم هكتار<sup>-1</sup> من السماد العضوي) تفوقاً في جميع الخصائص المدروسة. حيث انخفضت الكثافة الظاهرية للتربة إلى 1.260 ميكاغرام م<sup>3</sup> مقارنة بمعاملة السيطرة (H0) التي بلغت 1.362 ميكاغرام م<sup>3</sup>. كما زادت المسامية الكلية للتربة إلى 52.633% في المعاملة H3 مقارنة بـ 48.793% في معاملة السيطرة. وحققت المعاملة H3 أعلى نسبة استقرار لتجمعات التربة، حيث بلغت 56.593% مقارنة بـ 48.177% في معاملة السيطرة. بالإضافة إلى ذلك، سجلت المعاملة H3 أعلى إنتاجية نباتية لنباتات الخس، إذ بلغت 165.727 ميكاغرام هكتار<sup>-1</sup> مقارنة بـ 119.780 ميكاغرام هكتار<sup>-1</sup> في معاملة السيطرة.

## Introduction

Lettuce (*Lactuca sativa L.*), a member of the Asteraceae family, is a winter vegetable widely cultivated in Iraq and across the globe due to its high nutritional value. Globally, lettuce ranks 26th in nutritional value among vegetables and fruit crops. However, its relatively high consumption has elevated it to the 4th position in the United States after tomatoes, oranges, and potatoes in terms of consumption (Khamees *et al.*, 2023; Ati and Hamed, 2024). Lettuce holds significant importance in the global economy, with an annual production of 26 million tons (FAO, 2019). It is typically grown in soils rich in organic matter, which accelerates lettuce growth and reduces harvest duration.

Lettuce is classified as a leafy vegetable consumed fresh. It contains several essential vitamins, such as A, B, and C, as well as minerals including iron, calcium, magnesium, phosphorus, and potassium, along with dietary fibers (Abdal Rauf *et al.*, 2018; Kibar, 2018). Lettuce being a leafy vegetable, it needs large nitrogen fertilization. However, the misuse of chemical fertilizers not only leads to pollution of the soil but also brings about health problems for humans and animals. Chemical fertilizers are also one of the main sources of environmental pollution when used in large quantities (Elia and Serio, 1998). Thus, an alternative way to reduce such undesirable effects needs to be studied. An organic type of fertilizer is one of them. It will provide all the nutrients the soil needs and make the soil fertile, and it will help the plants grow well and increase yield. In addition, organic fertilizers reduce considerably the use of synthetic inputs and lower their negative impacts compared to chemical fertilizers (Scialabba, 2002). Among the major organic fertilizers is humic acid which comes from the decay of organic matter. Humic acid boosts plant growth and strengthens plant toughness against stress conditions; it also works as a regulator for plant hormones. Humic acid also has nutrient availability, enhances the absorption of potassium, calcium, magnesium, and phosphorus, and at the same time, it reduces the full effects of mineral fertilizers in the soil. All these improve the humic acid organic fertilizer by improving the physical characteristics of the soil. This makes the soil increase its volumetric water content and availability and gives the necessary nutrient content for the proper growth of plants.

Humic acid provides a varied array of physiological, physical, chemical, and biological benefits. It is not contaminated by any heavy metals and weed seeds. It decreases the water accumulation around the root zone and minimizes the chances of infections by fungi, bacteria, and nematodes (Ati *et al.*, 2017). Humic acids are highly active and possess a high cation exchange capacity for the development of soil structure (Al-Araji and Al-Hamdani, 2012). The impact of organic matter works through two pathways: it improves soil properties and acts as a nutrient source. The first pathway has a much greater effect because of the basic part organic matter plays in improving the physical properties of the soil, including soil porosity, permeability, movement of water and air in the soil, rooting, moisture content, and temperature in the soil.

Soil physical properties are inherently variable due to many influencing aspects, such as organic fertilization and management of irrigation water. These indicate effects on the bulk density, soil structure, aggregate stability, and porosity found in the development of pore spaces which further create massive variations in the properties of soils. Such variations need to be well understood for effective agriculture and management. The documentation of variability in soil properties becomes a reflection of that characteristic, thus serving as an important record. Water

scarcity is the major environmental constraint that affects plant production more than other environmental impacts. One strategy that has been proposed to address water scarcity is regulating the irrigation frequency during the growing season or reducing the irrigation events through water scheduling (Ti *et al.*, 2023). Therefore, water-saving in agriculture is among the strategies to fight against water scarcity now and in the future.

## Martials and Methods

### The Experimental Site and Pre-Planting Characteristics

The field experiment was conducted in Baghdad Governorate, Al-Mahmoudiya District, Al-Yusufiyah Sub-district (Al-Qasr Al-Awsat) during the 2021 agricultural season to study the effects of irrigation intervals and organic fertilization on some soil properties and lettuce production. The soil of the experimental site was classified as clay loam texture, falling under the *Typic Torrifuvent* suborder according to the classification of the Soil Survey Staff (2014).

Soil samples were collected from various locations within the field before the start of the experiment at a depth of 0-30 cm to measure certain physical and chemical properties (Tables 1 and 2). The land was prepared by plowing it with a moldboard plow in perpendicular directions, followed by leveling, grading, and smoothing operations. The field was divided into raised beds containing experimental units. Each experimental unit measured 4 m in length and 0.75 m in width, with an area of 3 m<sup>2</sup>. Lettuce seeds of the variety *Al-Fajr*, approved by the Iraqi Ministry of Agriculture, were sown in a nursery on September 3, 2021. After one month, the seedlings were transplanted into the field on October 5, 2021. The seedlings were planted on both sides of the ridges at 25–30 cm from the ridge's crest, with a spacing of 25 cm between plants.

**Table 1: Physical Properties of the Soil**

Property	Units	Soil Depth (0.0-0.30 m)
Sand	g kg <sup>-1</sup> soil	369
Silt		253
Clay		378
Soil Texture Class	Clay Loam	
Bulk Density	μg m <sup>-3</sup>	1.31
Particle Density		2.66
Porosity	%	50.56
Volumetric Water Content at 33 kPa	cm <sup>3</sup> cm <sup>-3</sup>	0.380
Volumetric Water Content at 1500 kPa		0.206
Available Water		0.174

The experimental field was fertilized with 200 kg ha<sup>-1</sup> of superphosphate fertilizer before transplanting during soil preparation. Additionally, 200 kg ha<sup>-1</sup> of urea fertilizer was applied in two splits: the first at a rate of 100 kg ha<sup>-1</sup> two weeks after transplanting, and the second at a rate of 100 kg ha<sup>-1</sup> when the heads began to form.

**Table 2: Chemical Properties of the Soil**

Property	Units	Soil Depth (0.0-0.30 m)
Electrical Conductivity (EC1:1)	dS m <sup>-1</sup>	2.16
pH	-	7.14
Organic Matter	g kg <sup>-1</sup> soil	7.41

Carbonate Minerals		226
HCO <sub>3</sub>	mmolc L <sup>-1</sup>	1.00
Ca <sup>++</sup>		9.40
Mg <sup>++</sup>		8.63
Na <sup>+</sup>		7.00
Ka <sup>+</sup>		0.83
Cl <sup>-</sup>		11.30
Available Nitrogen	mg kg <sup>-1</sup> soil	30.22
Available Potassium		119
Available Phosphorus		8.35
Cation Exchange Capacity	cmolc kg <sup>-1</sup> soil	23.31

### The Experimental Design and Treatment Factors

The experiment was designed using a Randomized Complete Block Design (RCBD) and included two factors:

#### 1. Irrigation intervals (irrigation frequency):

- Irrigation every three days (I3).
- Irrigation every five days (I5).
- Irrigation every seven days (I7).

#### 2. Addition of organic fertilizer (humic acid):

- No addition of humic acid to the soil.
- Addition of humic acid to the soil at a rate of 10 kg ha<sup>-1</sup>.
- Addition of humic acid to the soil at a rate of 20 kg ha<sup>-1</sup>.
- Addition of humic acid to the soil at a rate of 30 kg ha<sup>-1</sup>.

Number of experimental units = 3 (irrigation intervals) × 4 (humic acid treatments) × 3 (replicates) = 36 experimental units.

Soil samples were collected from the surface layer (0–30 cm) before the plant maturity stage.

The samples were dried, ground, sieved through a 2 mm sieve, and thoroughly mixed. The soil's physical properties were then measured, including bulk density, from which total porosity was calculated, saturated hydraulic conductivity, and soil aggregate stability.

Lettuce heads were manually harvested on December 30, 2021, and the total yield of the heads was calculated in tons per hectare.

## RESULTS AND DISCUSSION

### The Effect of Irrigation Intervals and Organic Fertilizer on Soil Bulk Density

The results in Table 3 indicate significant differences in the effect of irrigation intervals on soil bulk density. A decrease in bulk density was observed with an increase in the number of irrigations (shorter irrigation intervals). The I3 treatment (irrigation every three days) resulted in the lowest bulk density of 1.235 µg m<sup>-3</sup>, while the I7 treatment (irrigation every seven days) recorded the highest bulk density at 1.418 µg m<sup>-3</sup>. Regarding the addition of organic fertilizer, the bulk density value decreased as the amount of organic fertilizer increased. Bulk density decreased from 1.362 Mg m<sup>-3</sup> in the control treatment (H0, no fertilizer added) to 1.260 µg m<sup>-3</sup> in the H3 treatment, which had the highest organic fertilizer content.

As for the interaction between irrigation intervals and organic fertilizer, the I3H3 treatment (irrigation every three days with the highest organic fertilizer content) recorded the lowest mean bulk density of 1.173 µg m<sup>-3</sup>, whereas the I7H0 treatment (irrigation every seven days with no fertilizer added) recorded the highest mean bulk density of 1.450 µg m<sup>-3</sup>. This decrease in bulk density is attributed to the critical role of organic fertilizer in increasing soil organic carbon,

which promotes root growth and distribution, reduces the C/N ratio, and enhances microbial activity. Moreover, organic fertilizer improves the soil's physical properties by enhancing soil particle aggregation (Sahaf and Atee, 2007a; Dawod *et al.*, 2024).

**Table 3: The Effect of Irrigation Interval and Organic Fertilizer on Soil Bulk Density**

Bulk Density					
Organic Fertilizer	Irrigation Intervals (Days) (I)			Organic Fertilizer Average	
	I3	I5	I7		
No Addition (H0)	1.333	1.303	1.450	1.362	
Addition of 10 kg ha <sup>-1</sup> to the Soil (H1)	1.210	1.273	1.420	1.301	
Addition of 20 kg ha <sup>-1</sup> to the Soil (H2)	1.223	1.247	1.420	1.297	
Addition of 30 kg ha <sup>-1</sup> to the Soil (H3)	1.173	1.223	1.383	1.260	
LSD 5% (I x H)	0.038**			LSD 5%	0.022**
Average Irrigation Interval	1.235	1.262	1.418		
LSD 5% (I)	0.019**				

**Total Porosity as Affected by Irrigation Intervals and Organic Fertilizer**

Table 4 presents the results achieved in imposing different irrigation intervals and organic fertilizer treatments on the total porosity of the soil. The results achieved by the I3 treatment indicate that this treatment is favorable for enhancing total porosity, as it achieved the highest value, 53.573%. On the other hand, the I7 irrigation interval proved least favorable as it dually recorded the least total porosity, 46.683%. Observing the different organic fertilizer treatments, the results indicate that the H3 treatment promises the best total porosity at 52.633%. The corresponding values under the H0, H1, and H2 treatments were 48.793%, 51.087%, and 51.257%, respectively. In the interaction between irrigation intervals and organic fertilizer, results revealed significant variations among treatments.

**Table 4: The Effect of Irrigation Interval and Organic Fertilizer on Total Soil Porosity**

Total Porosity					
Organic Fertilizer	Irrigation Intervals (Days) (I)			Organic Fertilizer Average	
	I3	I5	I7		
No Addition (H0)	49.880	51.010	45.490	48.793	
Addition of 10 kg ha <sup>-1</sup> to the Soil (H1)	54.510	52.130	46.620	51.087	
Addition of 20 kg ha <sup>-1</sup> to the Soil (H2)	54.010	53.140	46.620	51.257	
Addition of 30 kg ha <sup>-1</sup> to the Soil (H3)	55.890	54.010	48.000	52.633	
LSD 5% (I x H)	NS			LSD 5% (H)	1.572**
Average Irrigation Interval	53.573	52.573	46.683		
LSD 5% (I)	1.361**				

The I3H3 treatment realized the maximum total porosity, which was at 55.890%. On the other hand, the lowest total porosity value was noted in the I7H0 treatment, at 45.490%. The increase in total porosity is principally derived from the increased organic matter content within the soil, which caused the fall in bulk density. This, in turn, causes an improvement of the structure of the soil and redistributes the pore sizes, resulting in an increase in total porosity.

**The Effect of Irrigation Intervals and Organic Fertilizer on Saturated Hydraulic Conductivity**

The results in Table 5 show the effect of irrigation intervals and organic fertilizer on the values of saturated hydraulic conductivity. The highest average hydraulic conductivity was recorded for the I3 treatment, reaching 3.530 cm h<sup>-1</sup>, while the I7 treatment recorded the lowest average value at 2.294 cm h<sup>-1</sup>. Regarding the effect of organic fertilizer, the H1 treatment achieved the highest average hydraulic conductivity of 2.938 cm h<sup>-1</sup>, whereas the H0 treatment recorded the lowest average value at 2.668 cm h<sup>-1</sup>.

In terms of the interaction between irrigation intervals and organic fertilizer, the I3H3 treatment recorded the highest hydraulic conductivity at 3.940 cm h<sup>-1</sup>, while the lowest value was recorded for the I7H0 treatment at 1.967 cm h<sup>-1</sup>. The increase in saturated hydraulic conductivity at higher levels of organic fertilizer is attributed to the increase in total porosity, the reduction in soil bulk density, the increase in organic carbon content, and the improvement in soil structure (Akoul, 2013). Adding organic fertilizers to the soil improves its various properties, provides essential nutrients for plants, and enhances its water retention capacity, which increases water availability in the soil and reduces water deficits (Shariatmadari *et al.*, 2006; Ati and Dawod, 2024).

**Table 5: The Effect of Irrigation Interval and Organic Fertilizer on Saturated Hydraulic Conductivity**

Saturated Hydraulic Conductivity				
Organic Fertilizer	Irrigation Intervals (Days) (I)			Organic Fertilizer Average
	I3	I5	I7	
No Addition (H0)	3.110	2.927	1.967	2.668
Addition of 10 kg ha <sup>-1</sup> to the Soil (H1)	3.547	2.787	2.480	2.938
Addition of 20 kg ha <sup>-1</sup> to the Soil (H2)	3.523	2.720	2.460	2.901
Addition of 30 kg ha <sup>-1</sup> to the Soil (H3)	3.940	2.563	2.270	2.924
LSD 5% <sub>(I x H)</sub>	0.284**			LSD 5% <sub>(H)</sub>   0.164**
Average Irrigation Interval	3.530	2.749	2.294	
LSD 5% <sub>(I)</sub>	0.142**			

**The Effect of Irrigation Intervals and Organic Fertilizer on Soil Aggregate Stability**

Results in Table 6 show major differences in the impact of irrigation intervals on soil aggregate stability. As seen in the table, aggregate stability rose with longer irrigation intervals; average stability values were 45.895%, 52.170%, and 59.590% for treatments I3, I5, and I7, respectively. With respect to the organic manure effect on aggregate stability, stability significantly improved as the amount of organic manure increased. The average values of stability were 48.177%, 51.277%, 54.160%, and 56.593% for the treatments H0, H1, H2, and H3, respectively.

For the interaction effect between irrigation intervals and organic fertilizer, the I7H3 treatment gave the best average aggregate stability with 60.820%, in an extreme contrast with the lowest average stability recorded for the I3H0 treatment, which was 41.110%.

An increase in the use of organic fertilizer relates positively to improving soil aggregate stability since organic matter helps to enhance the physical properties of the soil, for instance, bulk density and total porosity (Jabbar and Al-Sheikhly, 2013; Akoul, 2017). More importantly, organic manures significantly improved binding materials and organic acids released into the system; these improve soil aggregate stability by encouraging the aggregation of soil particles (Abdul Hamza, 2010; Jabbar and Al-Sheikhly, 2013; Majchrzak *et al.*, 2016).

**Table 6: The Effect of Irrigation Interval and Organic Fertilizer on Aggregate Stability**

Aggregate Stability				
Organic Fertilizer	Irrigation Intervals (Days) (I)			Organic Fertilizer Average
	I3	I5	I7	
No Addition (H0)	41.110	46.160	57.260	48.177
Addition of 10 kg ha <sup>-1</sup> to the Soil (H1)	43.420	50.240	60.170	51.277
Addition of 20 kg ha <sup>-1</sup> to the Soil (H2)	49.020	53.350	60.110	54.160
Addition of 30 kg ha <sup>-1</sup> to the Soil (H3)	50.030	58.930	60.820	56.593
LSD 5% <sub>(I x H)</sub> 3.756*				LSD% <sub>(H)</sub> 2.168**
Average Irrigation Interval	45.895	52.170	59.590	
LSD 5% <sub>(I)</sub>	<b>1.878**</b>			

**The Effect of Irrigation Intervals and Organic Fertilizer on Vegetative Yield**

The results in Table 7 indicate significant differences in the effect of irrigation intervals on the vegetative yield of lettuce plants. The highest average yield was recorded for the I3 treatment, reaching 205.775 µg ha<sup>-1</sup>, while the I7 treatment recorded the lowest average vegetative yield of 97.345 µg ha<sup>-1</sup>. Regarding the effect of organic fertilizer on vegetative yield, the results showed a significant increase in yield with higher amounts of organic fertilizer applied. The average vegetative yields were 119.780, 136.570, 151.990, and 165.727 µg ha<sup>-1</sup> for the treatments H0, H1, H2, and H3, respectively. The addition of organic fertilizer is highly important for increasing plant productivity by providing essential nutrients. Additionally, it improves soil properties by enhancing moisture retention, increasing aeration, and reducing soil bulk density (Atee and Al-Sahaf, 2007). The increase in yield can be attributed to the role of humic acid in improving the availability of key nutrients in the soil, which resulted in increased plant size and yield (Ati and Razin, 2021; Ati and Alwzzan, 2022; Al-Hamdani and Al-Hadithi, 2017; Alwazzan and Ati, 2024).

**Table 6: The Effect of Irrigation Interval and Organic Fertilizer on Vegetative Yield**

Vegetative Yield				
Organic Fertilizer	Irrigation Intervals (Days) (I)			Organic Fertilizer Average
	I3	I5	I7	

No Addition (H0)	163.430	113.970	81.940	119.780
Addition of 10 kg ha <sup>-1</sup> to the Soil (H1)	196.040	121.240	92.430	136.570
Addition of 20 kg ha <sup>-1</sup> to the Soil (H2)	217.150	135.190	103.630	151.990
Addition of 30 kg ha <sup>-1</sup> to the Soil (H3)	246.480	139.320	111.380	165.727
LSD 5% <sub>(I x H)</sub>	5.371**			LSD 5% <sub>(H)</sub> 3.101**
Average Irrigation Interval	205.775	127.430	97.345	
LSD 5% <sub>(I)</sub>	2.685**			

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