Sustainability of Onion Farming Using Organic Amendments and Modern Cultivation Methods Under a Surface Drip Irrigation System

Marwan Musa Nasr1 Alaa Salih Ati2 Hanan Salah Mahdee 3
1Dept. of Desertification Combat-College of Agricultural Eng. Sci./ University of Baghdad/ Iraq
2Dept. of Soil Sciences and Water Resources-College of Agricultural Eng. Sci./ University of Baghdad/ Iraq
3Dept. of Soil Sciences and Water Resources-College of Agriculture / Kirkuk University / Iraq
*Corresponding author's email: alaa.salih@coagri.uobaghdad.edu.iq
Email addresses of coauthors: marwan.m@coagri.uobaghdad.edu.iq, hanansalah@uokirkuk.edu.iq

Abstract

To investigate the effects of organic soil amendments and varying irrigation levels on the sustainability of both irrigation water and onion, a field experiment was undertaken at the College of Agriculture, Kirkuk University, during the 2023 agricultural season. The study was structured as two separate experiments, each employing different cultivation methods, and was designed as a factorial experiment within Randomized Complete (RCBD) with Split – Plot design. The experiment included the following treatments: First, cultivation method: surface drip irrigation, one drip line/plant line (C1), and surface drip irrigation, one drip line/two plant lines (C2). Second, irrigation levels: irrigation when 35% of the ready water was depleted (comparison treatment) (I1), irrigation 75% of the comparison treatment (I2), and irrigation 50% of the comparison treatment (I3). Third, soil amendments: quail waste (10 µg h-1) (A1) and poultry waste (10 µg h-1) (A2) without addition (comparison: chemical fertilization) (A3). The factors of water consumption, yield, and productivity of irrigation water for onions were measured in order to determine the sustainability of the onion crop with its production and the water used necessary for onion growth during the onion growing season. The highest yield of onion was obtained for irrigation levels treatment with I1, soil amendments treatment with A2 and interaction treatments was with I1A2. The highest irrigation water productivity of onion was obtained for irrigation levels treatment with I2, soil amendments treatment was with A2 and the interaction treatment with I2A2. The C2 cultivation method recorded the highest results. Minimizing water consumption, incorporating organic soil amendments, and optimizing land use through maximum plant density (while avoiding any reduction in yield) can significantly enhance the sustainability of both water resources and onion production.

Keywords: Water Sustainability, Sustainable Agriculture, Water productivity.

Introduction

The onion (Allium cepa L.), derived from the Latin word 'cepa,' meaning "onion," is the most extensively cultivated species within the Allium genus and is recognized for its significant role as a vegetable worldwide. For 7,000 years, people have grown onions and selectively bred them. Even though it is technically a biannual plant, it is usually grown every year. These days, modern varieties usually grow to be between 15 and 45 cm height. The leaves are spread out in a flat, fan-shaped pattern and range in color from yellowish to bluish-green. The thick, hollow, cylinder-shaped leaves of this plant

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have one side that is bowed. Out of the top countries, China made the most, contributing 19% to the world's output and becoming the leading provider. After China, Mali, Japan, and South Korea became important intermediate suppliers [13]. Most types of onions are mostly water (89%) with only a small amount of protein (1%), carbs (4% sugar and 2% dietary fiber), and negligible fat. Onions have 166 kJ (40 kilocalories) of energy per 100 g (3.5 oz) dose, but they don't have many important nutrients. Globally, onions have garnered the attention of researchers due to their strategic and economic significance [1,2,29] . It is recommended to implement measures aimed at safeguarding and enhancing local agricultural products, specifically onion and other vegetable yields. This can be achieved through the formulation of targeted agricultural strategies designed to mitigate the competitive effects of imports, particularly concerning product variety and pricing [21]. The productivity variable significantly impacts marketing efficiency [18]. Winter vegetables, such as onions, possess particular nutritional and climatic needs. They generally get sufficient resources, with the exception of water, owing to inadequate precipitation. Irrigation procedures are essential to meet the water requirements of each crop and to offset the shortfall in rainfall [19.[

Water resources are essential for maintaining the ecosystems of arid and semi-arid areas. In recent decades, Iraq's water resources have faced significant challenges. The second part of the twentieth century saw a significant decline in water supply, primarily because of the implementation of irrigation projects in adjacent countries like Syria, Turkey, and Iran, resulting in widespread desiccation. Furthermore, desertification has become a significant issue, intensifying the decrease in agricultural output and the diminishment of cultivable land in dry and semi-arid climates. This phenomenon significantly threatens Iraq's food security, as shown by reduced arable land production from soil salinization, waterlogging, plant cover degradation, advancing shifting dunes, and heightened dust storm occurrences. Climate forecasts predict an increase in intensity, frequency, and length of drought conditions, exacerbating these issues [3, 22]. The worldwide surface temperature over the first two decades of the 21st century (2001–2020) was 0.99 [0.84 to 1.10] °C elevated compared to 1850-1900. Moreover, the global surface temperature has risen more rapidly since 1970 than during any previous 50-year interval in the last 2000 years [15.[

Irrigation is essential for enhancing agricultural output, particularly in areas with little natural rainfall, and maintaining plant health at economically viable levels. As competition for water resources escalates in urban, industrial, and agricultural sectors, there is a pressing need to enhance water usage efficiency. This requires enhancing irrigation methods, including the precise scheduling, timing, and management of water distribution throughout the crop development cycle. [4,7,25]. However, developing an effective watering plan poses significant difficulties. The obstacles arise from several factors, including meteorological conditions, differing crop needs, irrigation infrastructure specifications, and integrating modern soil and water sensor technology to improve water management practices. Moreover, precisely evaluating evapotranspiration rates and identifying necessary water inputs are essential for formulating a thorough irrigation plan [5,14 .[

A major difficulty in agriculture is the scarcity of water supplies [8]. Multiple studies have shown a link between Soil Organic Matter (SOM) and essential hydrological parameters, including water infiltration, soil water-holding capacity, and total water content [20]. Organic matter enhances soil aggregation, enabling pore development and improving water retention [32]. The impact of organic matter on soil's water retention capacity has been extensively studied, with diverse findings [6, 26]. [24] showed a slight rise in soil moisture along with higher organic carbon levels. They argued that the speed of storing organic carbon and the expected increase in water supply should be equal and were seen as unimportant. Other studies have shown that organic matter significantly affects water absorption [6, 26]. Studies show that organic matter helps hold water better in soils that have less clay [6, 10]. Studies have shown that adding organic matter to soil greatly improves its ability to hold onto water. The natural qualities of organic matter can greatly improve the water hold capacity [34.[

In summary, recent developments in Iraq underscore the urgent need a critical shortage of irrigation water and diminished onion productivity. To address these challenges, it is imperative to adopt measures that enhance the sustainability of irrigation water. We must implement irrigation systems that have been proven to improve water sustainability, leading to an increase in both irrigation water and onion productivity. In light of these challenges, this study aims to: ① Study of water productivity and crop productivity using surface drip irrigation with one line per plant row versus one line per two plant rows. ② Knowing the effect of irrigation level on the amount of water used, water productivity and crop productivity. ③ Comparison of the effect of adding quail waste and poultry waste versus chemical fertilizer on water consumption, water productivity and onion yield. ④ Study of synergistic effects to determine the best interaction of factors to achieve the highest water and crop productivity while reducing water consumption .

Material and Methods

In the 2023 agricultural season, a field experiment took place at the College of Agriculture, University of Kirkuk, situated at coordinates 44°20'32" E and 35°23'21" N. The field soil underwent a morphological description, followed by classification according to the American soil classification system. It was categorized within the great group of Typic Torrifluvent in accordance with the classification provided by [30]. Preliminary measurements and analyses of the field soil were conducted by collecting soil samples from depths of 0.00-0.30 m. To examine the physical and chemical properties of the soil, as outlined in Table 1, following the methodologies described by [9]. The experiment included the following treatments:

.1 Cultivation method (C:(

a. C1: Surface drip irrigation 1 drip line : 1 plant line.

b. C2: Surface drip irrigation 1 drip line : 2 plant lines.

.2 Irrigation levels (I:(

a. I1: Irrigation when 35% of the available water is depleted (control .(

b. I2: Irrigation is 75% of the control.

c. I3: Irrigation is 50% of the control.

.3 Soil amendments (A:(

a. A1: Without application (control: only chemical fertilization.(

b. A2: Quail waste (10 tons ha-1.(

c. A3: Poultry waste (10 tons ha-1.(

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The experiment was conducted on an area measuring 2000 m2. Initially, the land underwent vertical tillage using a moldboard plow to a depth of 0.25 m. Following this, the soil surface was refined with disc harrows and subjected to both initial and final leveling processes. Two distinct experiments incorporating two cultivation methods were conducted. Each method was applied within a factorial experiment framework set in Randomized Complete (RCBD) with Split – Plot design. In this design, irrigation levels were allocated across three main plots. Subsequently, each main plot was segmented into three replicates, within which soil amendments (considered secondary plots) were randomly assigned. This structure resulted in a total of 27 experimental units for each cultivation method, calculated as (3 irrigation levels × 3 soil amendments × 3 replicates). Statistical analysis included comparing means using the Least Significant Difference (LSD) test at a significance level of 0.05. The data analysis was performed using SAS software, version 2018. To prepare animal manure from poultry and quail (Table 2), a "manure" was constructed in the soil with dimensions of 1m x 2m x 2m. This pit was initially lined with nylon material. Following this, sawdust was incorporated into the waste to facilitate a homogeneous mix, after which the mixture was evenly sprayed with water until its humidity level was maintained between 40-60% .

Table 1. Physical and chemical characteristics of field soil before planting

Property	Unit	Value
sand	gm kg^{-1}	633
silt		60
clay		307
Sandy Clay Loam		
Bulk Density	μg m^{-3}	1.43
Particle Density		2.65
Porosity	%	47
Volumetric Moisture Content At 33 Kpa	cm^3 cm^{-3}	0.249
Volumetric Moisture Content At 1500 Kpa		0.151
Available Water		0.150
Electrical Conductivity	ds m^{-1}	3.26
pH		7.22
Organic Matter	gm kg^{-1}	10.0
Carbonate Minerals		290

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Table 2. Chemical composition of decomposed animal waste

Sample type	C/N	Total nitrogen	Total phosphorus	Total potassium	Organic carbon	EC	pH
		(g kg^{-1})				(dS m^{-1})	
Poultry waste	6.81	42.0	13.1	19.4	286	7.81	5.66
Quail waste	2.30	100	8.15	18.40	230.0	5.22	6.13

Following the planting of the bulbs, irrigation schedules were precisely calculated. The initial irrigation reached a depth of 0.30 meters, ensuring the soil moisture reached field capacity, facilitated by a surface drip irrigation system. Subsequent irrigations were administered whenever 35% of the available water had depleted, again replenishing the soil moisture to field capacity. For measurement of soil moisture content, soil samples obtained from the field were dried using a Microwave Oven. This process was guided by a calibration method proposed by [17] to estimate the moisture content accurately. The application of irrigation-level treatments was executed on October 20, 2023. The bulbs were planted on September 1, 2023, on drip irrigation lines. The distance between one line and another was 0.50 m, with one line and two lines, and the distance between one plant and another was 0.1 m. One experimental unit included three lines of 50 m length. Agriculture services continued, including manual irrigation, and weeding whenever necessary, and at the "Maturation" stage, the bulbs were harvested from all experimental units on December 24, 2023.

Results and Discussion

Water consumption factors

The data from Tables 3 and 4 shows that the longest stage of plant growth was the vegetative stage, lasting 40 days with treatments I1A1, I1A2, and I1A3, and with both cultivation methods (C1 and C2) achieving the same duration. The highest number of irrigations occurred during the vegetative growth stage, with 9 irrigations for treatments I1A1, I1A2, and I1A3, and with both cultivation methods (C1 and C2) achieving the same number of irrigations. It's important to note that there was an increase of one irrigation during the seedling and maturity stages with treatment A1. During the vegetative growth stage, the highest interim water consumption (mm stage-1) was observed. The I1A1 treatment had the greatest depth of interim water consumption, with 165.7 mm stage-1 for C1 and 177.7 mm stage-1 for C2. On the other hand, the lowest stage water consumption occurred during the maturity stage with the I2A2 treatment, at a depth of 22.3 mm stage-1 for C1 and 25.4 mm stage-1 for C2. The difference in water consumption between the two treatments (I1A1 and I2A2) is mainly due to the duration of the plant's growth stages. The vegetative growth stage lasts 40 days, while the maturity stage lasts 25 days, explaining the variation in water consumption.

The irrigation treatment also has a role in this, as using half the depth of the irrigation water used with the comparison treatment led to a decrease in water consumption. Moreover, the soil improver has a role in this, as the quail waste worked to increase the moisture content in the soil and thus worked to create good moisture conditions for plant growth. It prevents the plant from being exposed to water

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stress, which increases the depth of irrigation water consumed by the plant. It is worth noting that the maturity stage does not require a great depth of irrigation compared to the rest of the stages because, during the maturity stage, the plant has grown. Its structures have developed significantly, and the roots, leaves, and stems have become more effective in absorbing water and nutrients. Therefore, the plant is more able to use water efficiently. This is called “structural adaptation.” In terms of “growth control,” in the maturity stage, plant growth is better regulated, and the plant controls the consumption of water and nutrients based on its actual needs. This helps reduce water waste and improve irrigation water productivity. On the other hand, “sustainability” is important, as mature plants preserve their resources more sustainably and can survive for long periods without the need for large amounts of water, and this contributes to the sustainability of the plant and its continuity in the environment. In short, the maturity stage represents a period of adaptation and improvement for the plant, making it more efficient in using water and other resources.

During the seedling stage, the root begins to grow and develop. The roots need water for absorption and nutrition, and developing strong roots helps the plant to stabilize and grow well. This is in terms of root growth. In terms of the formation of leaves and stems, the seedling begins to form leaves and stems, and these parts need water for growth and tissue development. The plant needs water to produce chlorophyll and carry out photosynthesis. It is worth noting that during the seedling stage, the plant is more sensitive to environmental conditions and needs water to adapt to the soil and changing temperatures. Therefore, the seedling stage is considered a critical period in the life of the plant as it needs water in larger quantities to ensure its growth and stability in the environment. It must be noted that it is very important that the total amount of irrigation water during the seedling stage of onion growth is greater than the bulb formation stage and the maturity stage. However, this stage is short. Compared with the vegetative growth stage, the longer duration of the vegetative growth stage leads to its superiority in water consumption over the seedling stage. However, the irrigation interval is the shortest during the seedling stage. To verify this matter, the number of irrigations during the growth period of a given stage can give us the period between one irrigation and another. Daily water consumption is an indicator of the importance of the seedling growth stage (critical stage) and the role of both irrigation levels and soil amendments in reducing water consumption. The duration of irrigation is necessary between one irrigation and another during the seedling stage. It was the shortest period, and this led to an increase in the number of irrigations per unit of time (in proportion and ratio), especially in the establishment stages of the plant, as the highest coefficient of irrigation duration was (Period of growth stage (day))/(Number of irrigations) with I1A1, I2A1, and I3A1 treated for three days with C1 and C2 respectively. At the same time, the rest of all treatments during the seedling stage gave a similar irrigation period of 4.3 days. Regarding the longest irrigation period during all growth stages, it was during the maturity stage with treatments I1A1 I1A2, I2A1, I2A2, I3A1, and I3A2 have a duration of 8.3 days with C1 and C2, respectively.

Quail waste and poultry waste (A2 and A3) improve the soil's water retention property, which is reflected in the duration of irrigation

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with these two treatments. Soils amended with poultry manure have better water-holding capacity, and the increased water retention benefits plant growth during dry periods [12]. To know the role of all irrigation levels and soil amendments in reducing water consumption, daily water consumption must be observed during the seedling growth stage and all growth stages. The highest daily water consumption was during the seedling stage, a separate stage from the rest of the stages with the I1A1 treatment at a depth of 5 mm day-1 with C1 and C2, respectively (which is the highest water consumption during all stages of growth and all treatments of the experiment). The lowest daily water consumption was during the seedling stage only (separate stage) with the I2A2 and I2A3 treatments at a depth of 2.4 mm day-1 with C1 and C2, respectively. The lowest daily water consumption was during the maturity stage with I2A2 treatment at a depth of 0.9 and 1 mm day-1 with C1 and C2, respectively, for the same reasons mentioned previously. Therefore, it can be said, “The depth of water consumption according to the stage of the plant (staged water consumption) is determined by two main determinants: the length of the stage and the depth of the irrigation water used during that stage. Two or more growth stages can be equal during the plant’s growth season in terms of the length of the stage but differ from the water requirement at that stage depends on the physiological composition of the plant at that stage, and the growth requirements (water demand) and specifically the depth of irrigation water (water requirement) differ at that stage.

The length of the growing season was 114 days with all experimental treatments, and the mean number of irrigations was 25 with I1A1, I2A1, and I3A1 and 23 with I2A1, I2A1, I2A1, I3A1, I3A1 and I3A1 with C1 and C2 respectively. It can be noted that the contribution of soil amendments (A2 and A3) in improving the irrigation interval, i.e., increasing the period between one irrigation and another, is due to increasing the soil's water retention. This results in an increase or decrease in the number of irrigations per unit of time, and here, the role of amendments in reducing the number of irrigations becomes clear .

Table 3. Effect of irrigation level on water consumption factors of onions with surface drip irrigation system: Drip line/plant line

		Seedling stage			Vegetative growth stage			Bulb growth stage			Maturity stage			Total		
Irrigation levels	Water consumption factors	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3
I1	Period of growth stage (day)	24	24	24	40	40	40	25	25	25	25	25	25	114	114	114
	Number of irrigations	8	7	7	9	9	9	4	4	4	4	3	3	25	23	23
	Interim water consumption (mm stage $^{-1}$)	120.90	115.60	115.60	177.70	160.40	165.50	95.80	73.50	77.80	63.30	50.80	52.90	457.60	400.30	411.70
	Daily water consumption (mm day $^{-1}$)	5.04	4.82	4.82	4.44	4.01	4.14	3.83	2.94	3.11	2.53	2.03	2.12	4.01	3.51	3.61
	Number of irrigations	8	7	7	9	9	9	4	4	4	4	3	3	25	23	23
	Interim water consumption (mm stage $^{-1}$)	60.40	57.80	57.80	88.80	80.20	82.70	47.90	36.80	38.90	31.60	25.40	26.40	228.80	200.10	205.80

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	Daily water consumption (mm day $^{-1}$)	2.52	2.41	2.41	2.22	2.01	2.07	1.92	1.47	1.56	1.26	1.02	1.06	2.01	1.76	1.81
	Number of irrigations	8	7	7	9	9	9	4	4	4	4	3	3	25	23	23
	Interim water consumption (mm stage $^{-1}$)	90.60	86.70	86.70	133.20	120.30	124.10	71.80	55.20	58.30	47.50	38.10	39.70	343.20	300.20	308.70
	Daily water consumption (mm day $^{-1}$)	3.78	3.61	3.61	3.33	3.01	3.10	2.87	2.21	2.33	1.90	1.52	1.59	3.01	2.63	2.71

Table 4. Effect of irrigation level on water consumption factors of onions with surface drip irrigation system: Drip line/2plant line

		Seedling stage			Vegetative growth stage			Bulb growth stage			Maturity stage			Total		
Irrigation levels	Water consumption factors	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3
I1	Period of growth stage (day)	24	24	24	40	40	40	25	25	25	25	25	25	114	114	114
	Number of irrigations	8	7	7	9	9	9	4	4	4	4	3	3	25	23	23
	Interim water consumption (mm stage $^{-1}$)	120.90	115.60	115.60	177.70	160.40	165.50	95.80	73.50	77.80	63.30	50.80	52.90	457.60	400.30	411.70
	Daily water consumption (mm day $^{-1}$)	5.04	4.82	4.82	4.44	4.01	4.14	3.83	2.94	3.11	2.53	2.03	2.12	4.01	3.51	3.61
	Number of irrigations	8	7	7	9	9	9	4	4	4	4	3	3	25	23	23
	Interim water consumption (mm stage $^{-1}$)	60.40	57.80	57.80	88.80	80.20	82.70	47.90	36.80	38.90	31.60	25.40	26.40	228.80	200.10	205.80
	Daily water consumption (mm day $^{-1}$)	2.52	2.41	2.41	2.22	2.01	2.07	1.92	1.47	1.56	1.26	1.02	1.06	2.01	1.76	1.81
	Number of irrigations	8	7	7	9	9	9	4	4	4	4	3	3	25	23	23
	Interim water consumption (mm stage $^{-1}$)	90.60	86.70	86.70	133.20	120.30	124.10	71.80	55.20	58.30	47.50	38.10	39.70	343.20	300.20	308.70
	Daily water consumption (mm day $^{-1}$)	3.78	3.61	3.61	3.33	3.01	3.10	2.87	2.21	2.33	1.90	1.52	1.59	3.01	2.63	2.71

Yield

The tables (Tables 5 and 6) indicate that the highest yield of the onion crop was achieved with the I1 irrigation level treatment, producing 52.06 µg ha-1 with C1 and 62.77 µg ha-1 with C2. In contrast, the lowest yield was observed with I2, yielding 48.36 Mg ha-1 with C1 and 54.63 µg ha-1 with C2. The highest yield observed in the soil amendments treatment was achieved using A2, with yields of 53.29 and 62.86 µg ha-1 for C1 and C2, respectively. Conversely, the lowest yield was recorded for A1, with yields of 46.28 and 53.74 µg ha-1 for C1 and C2, respectively. The highest yield of the interaction treatment was with I1A2, with a weight of 54.67 and 67.66 Mg ha-1 with C1 and C2, respectively. The lowest yield was with I2A1, with a weight of 43.66 and 49.67 µg ha-1 with C1 and C2, respectively.

The highest yield was achieved with full irrigation without exposing the crop to water stress, as [16, 27] stated that the full use of irrigation water from the crop's irrigation needs (water consumption)

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Table 5. The effect of irrigation level and soil amendments on yield of onions with a surface drip irrigation Table 6. The effect of irrigation level and soil amendments on yield of onions with a surface drip irrigation

Treatments	Yield (Mg ha^{-1})			
	A1	A2	A3	Mean of A (L.S.D. = 2.45)
I1	48.88	54.67	52.62	52.06
I2	43.66	51.67	49.76	48.36
I3	46.29	53.54	51.44	50.42
Mean of I (L.S.D. = 1.89)	46.28	53.29	51.27	(L.S.D. A * I = 3.22)

Treatments	Yield (Mg ha^{-1})			
	A1	A2	A3	Mean of A (L.S.D. = 3.11)
I1	56.21	67.66	64.45	62.77
I2	49.67	57.67	56.55	54.63
I3	55.33	63.25	61.77	60.12
Mean of I (L.S.D. = 2.23)	53.74	62.86	60.92	(L.S.D. A * I = 4.31)

led to the highest yield of 38.09 tons/ha, while the lowest yield of 22.23 tons/ha was recorded at the lowest irrigation water application level (40% of water consumption). Irrigating onions at a rate of up to 40% of the crop's water consumption leads to a 30% reduction in onion productivity. When using 60% of the crop's water consumption, the production decrease is about 19%. However, if onions are irrigated at a rate of up to 80% of the crop's water consumption, the production decrease is less than 4% [28]. Water stress at certain stages can negatively affect quality, leading to a reduction in size and multiple bulbs, which leads to a low yield. The use of organic amendments improves soil health and provides crops with nutrients, leading to increased growth and production. These amendments can increase the organic carbon content in the soil, enhancing soil health and crop productivity [23]. Their use also leads to improved physical properties of the soil, which in turn positively impacts crop yield.

Irrigation water productivity and irrigation water used

It is clear from Figure 1 and 2 that the highest irrigation water productivity for onion for the irrigation levels treatment was with I2, with a productivity of 23.98 and 26.00 kg m-3, and the lowest volume of irrigation water used was 2033 and 2116 m3 with C1 and C2, respectively. The lowest productivity was with I1, with productivity of 12.89 and 14.95 kg m-3, and the highest volume of irrigation water used was 4066 and 4232 m3 with C1 and C2, respectively. The highest irrigation water productivity for the soil amendments treatment was with A2, with productivity of 20.27 and

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22.26 kg m-3, and the lowest irrigation water volume used was 2858 and 3002 m3 with C1 and C2, respectively. The lowest productivity was with A1, with a productivity of 14.91 and 16.70 kg m-3, and the highest irrigation water volume used was 3317 and 3432 m3 with C1 and C2, respectively .

The highest irrigation water productivity for the interaction treatment was with I2A2, with productivity of 27.12 and 28.82 Mg m-3, and the lowest irrigation water volume used was 1905 and 2001 m3 with C1 and C2, respectively. The lowest productivity was with I1A1, with a productivity of 11.05 and Mg m-3 12.28, and the highest volume of irrigation water used was 4423 and 4576 m3 with C1 and C2, respectively. Soil moisture is a crucial factor in plant growth and productivity. Different levels of soil moisture can have a significant impact on crop water and yield productivity. [31] conducted a study on the effect of various soil moisture levels (30% soil moisture depletion, 50% soil moisture depletion, and 70% soil moisture depletion) on sunflower productivity and water use efficiency (WUE). The total water used for the crop decreased as soil moisture depletion increased (30% < 50% < 70%). Crop yield was highest under 70% moisture depletion (14.3 t/ha), followed by 30% (13.2 t/ha) and 50% (12.150 t/ha). Water use efficiency (WUE) was also highest under 70% moisture depletion. Poultry manure improves soil properties and improves water and crop productivity. [11] showed the role of poultry manure and water treatment waste (WTR) in improving the physical and chemical properties of soil. The combination of both moisture depletion and poultry manure increases crop yield. Irrigation with 40% and 60% of ready water (AWD) with the use of water treatment waste and poultry manure led to increased grain and straw productivity, improved crop components (such as plant height and ear height), higher protein content, and increased concentration of Nutrients (N P K), these treatments also act as soil conditioners for clayey soil. The productivity of irrigation water increases with the increase in the productivity of the crops and with the decrease in the irrigation water used. It is noted that the productivity of irrigation water increases with the irrigation water level at a depletion rate of 75% (I2), that this level of irrigation level treatment used the least amount of irrigation water on the one hand, and that the use of quail waste (A2) increased the yield of the onion crop and that the combination of both treatment levels reduced the irrigation water used on the one hand and increased the crop yield on the other hand, so the best treatment in terms of irrigation water productivity and the decrease in irrigation water used was level (I2A2.(

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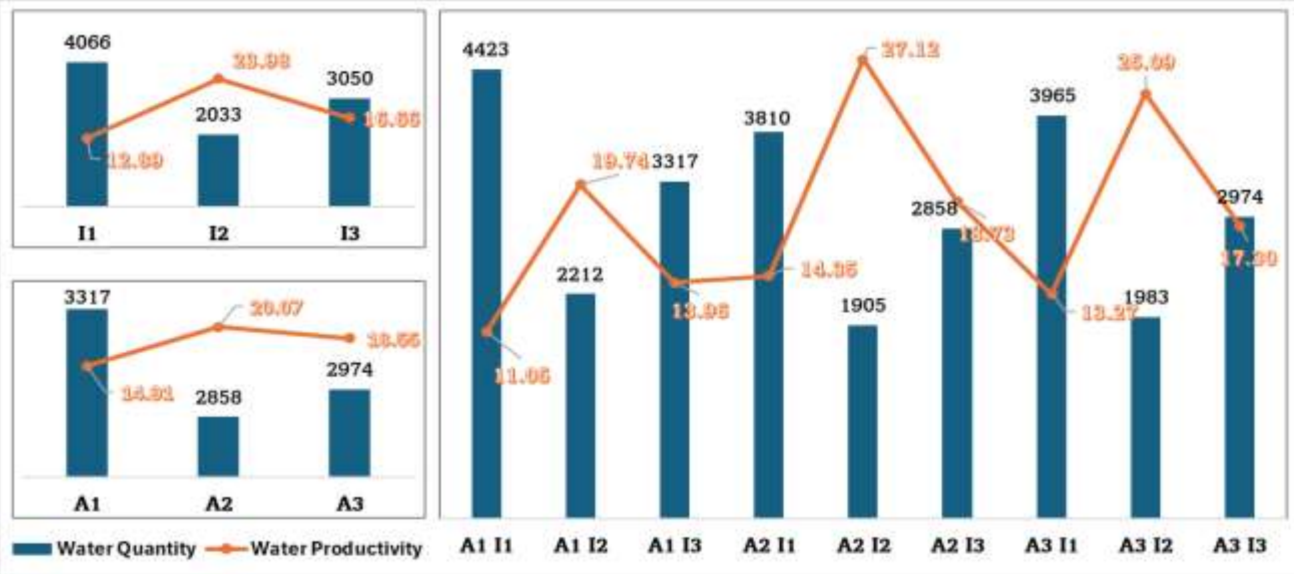

Figure 1. The effect of irrigation level and soil amendments on water quantity and water productivity with a surface drip irrigation system: Drip line/plant line.

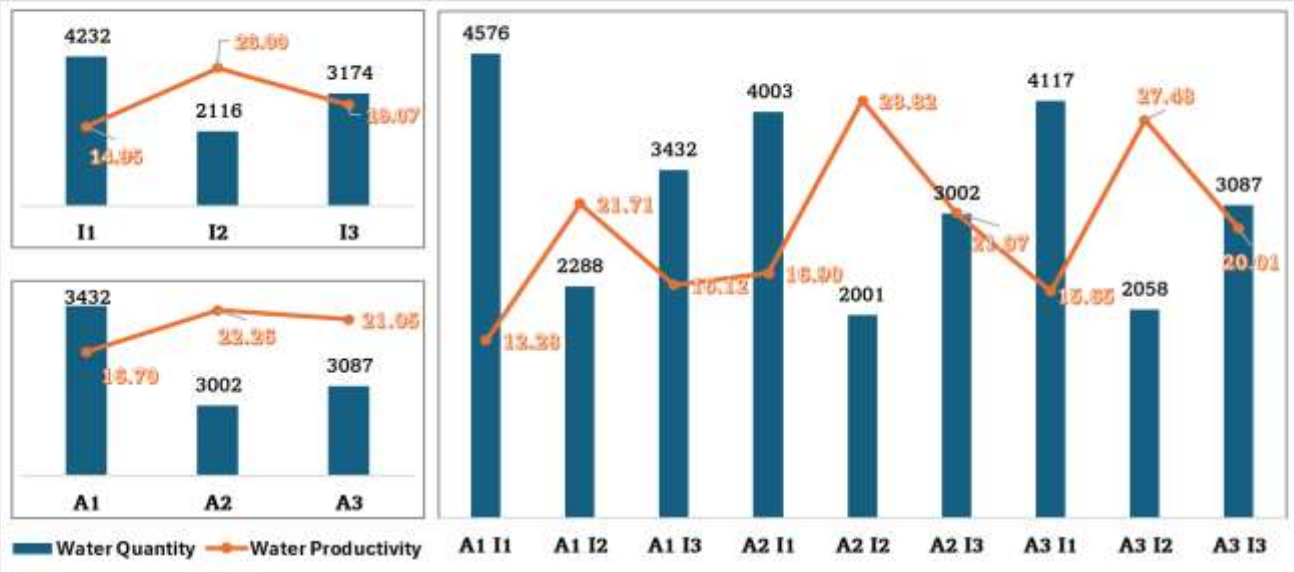

Figure 2. The effect of irrigation level and soil amendments on water quantity and water productivity with a surface drip irrigation system: Drip line/2plant line.

CONCLUSIONS

.1

Effect of irrigation levels: The highest onion crop productivity was obtained at irrigation level I1 (irrigation when 35% of available water is depleted), reaching 52.06 and 62.77 µg ha-1 with cultivation methods C1 and C2, respectively. The highest irrigation water yield was achieved at irrigation level I2 (75% of the control), reaching 23.98 and 26.00 µg m-3), with the lowest water volume applied (2033 and 2116 m3) with C1 and C2, respectively.

.2 Effect of organic soil amendments: The highest onion yield was achieved using soil amendment A2 (poultry litter at 10 µg ha-1), reaching 53.29 and 62.86 µg ha-1 with C1 and C2, respectively. A2 also recorded the highest irrigation water productivity, at 20.27 and 22.57 µg m-3, with the lowest water volume applied (2858 and 3002 m3) with C1 and C2, respectively.

.3 Effect of the interaction between irrigation levels and organic amendments: The highest onion yield was achieved with the I1A2 interaction (irrigation at 35% of the control with poultry waste), reaching 54.67 and 67.66 µg ha-1 with C1 and C2, respectively. The highest irrigation water productivity was achieved with the I2A2 reaction (75% of the standard with poultry waste), reaching 27.12 and 28.82 µg m-3, with the lowest water volume applied (1905 and 2001 m^3) with C1 and C2, respectively.

.4 Sustainability and Water Use Efficiency: The study showed that using drip irrigation with the addition of organic amendments (especially poultry waste) enhances the sustainability of onion crops by increasing yields and reducing water consumption. The C2 method (one drip line per two plant rows) showed better results compared to C1 in most cases, indicating greater resource use efficiency.

.5 irrigation at 75% of the control (I2) with the addition of poultry waste (A2) and cultivation in the C2 method (one drip line per two plant rows) represents the optimal option for achieving the highest irrigation water productivity and reducing water consumption, while irrigation at 35% of the available water (I1) with the same organic amendment (A2) and same cultivation method (C2) achieves the highest onion yields. These results support the goal of sustainable agriculture that uses resources efficiently without harming the environment.

REFERENCES

[1]Ali, N. S. and Albayati, D. H. (2018). The role of broad bean and onion intercropping on productivity of both crops and nitrogen budget in soil. The Iraqi Journal of Agricultural Science. 49 (1): 21-26. google scholar.

[2]Al-Khafaji, A. M. (2019). Stimulation Growth, Yield, and Accumulation of Antioxidant Compounds of Onion Hybrids by Colored Shades of Polyethylene Covers. Iraqi Journal of Agricultural Sciences. 50 (6): 1580-1587. google scholar.

[3]Al-Lami, A. A. A. A., Al-Rawi, S. S., and Ati, A. S. (2023a). Evaluation of the AquaCrop model performance and the impact of future climate changes on potato production under different soil management systems. Iraqi Journal of Agricultural Sciences. 54 (1): 253-267. google scholar.

[4]Al-Lami, A., Ati, A. and Al-Rawi, S. (2023b). Determination of Water Consumption of Potato Under Irrigation Systems and Irrigation Intervals by Using Polymers and Bio-Fertilizers in Desert Soils. Iraqi Journal of Agricultural Sciences. 54 (5): 1351-1363. google scholar.

[5]Al-Salihi, Z. K., and Salim, S. B. (2023). Effect of Length and depth of the drip tape on Wetting Front Advance in the Root Zone of Sunflower Using HYDRUS 2D/3D Program. Iraqi Journal of Agricultural Sciences. 54 (3): 768-776. google scholar.

[6]Ankenbauer, K. J. and Loheide, S. P. (2017). The effects of soil organic matter on soil water retention and plant water use in a meadow of the Sierra Nevada, CA. Hydrological Processes. 31(4): 891-901. google scholar.

ISSN 2072-3857

[7]Ati, A. S., and Razin, H. A. (2021). The Effect Irrigation Scheduling and Potassium Fertilization on Water Consumption of Potato (Solanum tuberosum L.) Under Modern Irrigation Systems. In IOP Conference Series: Earth and Environmental Science (Vol. 904, No. 1, p. 012008). IOP Publishing. google scholar.

[8]Ati, A. S., Wahaib, H. A., and Hassan, A. H. (2020). Effect of irrigation management and fertilization on N, P and K concentration of two wheat varieties. Diyala Agricultural Sciences Journal. 12 (special Issue): 402-417. google scholar.

[9]Black, C. A., Evans, D. D., and Ensminger, L. E. (1965). Methods of soil analysis. Agronomy, 9 Amer. Soc. Agron. Inc. Publisher, Madison, Wisconsin. USA. google scholar.

[10]Dawod, S.S., Ati, A.S. and Abdu Jabbar, I.A. (2024). Management of using saline irrigation water and tillage systems on the soil mechanical and hydraulic properties. Iraqi Journal of Agricultural Sciences, 55(6), pp.2050–2059. https://doi.org/10.36103/5b2srn23

[11]El-Gamal, B. A., Shahed, H. E., Shosha, A. A. and Aboyousef, H. (2021). Effects of water depletion and organic fertilization on soil properties and both productivity water and maize yield. Plant Cell Biotechnology and Molecular Biology. 22 (71-72): 610-628. google scholar.

[12]Eric H. (2021). The Surprising Power of Chicken Manure. Soil Science Society of America (SSSA). https://www.soils.org/news/science-news/surprising-power-chicken-manure./

[13]FAO. (2025)."Production of onions and shallots (green) in 2021: Crops/World Regions/Production Quantity from pick lists". United Nations Food and Agriculture Organization (FAO), Statistics Division (FAOSTAT). Last update in UNdata: 2024/01/22. Retrieved 26 January 2025.

[14]Hommadi, A. H. (2018). Evaluation Crop Evapotranspiration and Crop Coefficient of Squash (Zucchini) with Subsurface Water Retention Technology (SWRT) and without SWRT. Journal of Kerbala University. 14 (3): 47-57. google scholar.

[15]IPCC. (2023). Sections. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-9789291691647. PDF. google scholar.

[16]Jabbar, A. S., and Ati, A. S. (2025). Determining the water of groundnut under different irrigation systems and irrigation intervals Iraqi Journal of Agricultural Sciences, 56(2), 923-934. doi: https://doi.org/10.36103/ejmvxp19 .

[17]Jalilian, J., Moghaddam, S. S., and Tagizadeh, Y. (2017). Accelerating Soil Moisture Determination with Microwave Oven. J. of Chinese Soil and Water Conserv, 48 (2): 101-103. google scholar.

[18]Jassam, Q. T., Abd Al-majeed A. T. And Ali, E. H. (2022). An Economic Analysis of Some Factors Affecting in Marketing Efficiency of Dry Onion Crop Using the Tobit Regression Model. Iraqi Journal of Agricultural Sciences. 53 (1): 180-186. google scholar.

[19]Jwad, D. K. and Kadhim, D. H. (2021). Geographical Analysis of Climate Impact on Winter Vegetable Cultivation in Najaf Governorate. Journal of Tikrit University for the Humanities. 28 (3): 230-210. google scholar.

ISSN 2072-3857

[20]Jabbar, H. A., Ati, A. S., and Hassan, A. H. (2020). Furrow irrigation raised bed technology for improving water productivity in Iraq. Plant Archives, 20(2), 1017-1022.

[21]Kareem, G., k. and Salih, T., F. (2023). Measurement and analysis of the import demand function for some agricultural commodities in the Kurdistan Region - Iraq during the period (2005-2021). Tikrit Journal of Administration and Economics Sciences. 19 (62) part 2: 513-530. google scholar.

[22]Khamees, A. A. H., Ati, A. S., and Hussein, H. H. (2023). Effect of Surface and Subsurface Drip Irrigation and Furrows Irrigation System on Water Productivity, Growth and Yield of Lettuce (Lactuca Sativa L). In IOP Conference Series: Earth and Environmental Science (Vol. 1158, No. 2, p. 022009). IOP Publishing. google scholar.

[23]Matisic, M., Dugan, I. and Bogunovic, I. (2024). Challenges in Sustainable Agriculture-The Role of Organic Amendments. Agriculture. 14 (4): 643. google scholar.

[24]Minasny, B. and McBratney, A. B. (2018). Limited effect of organic matter on soil available water capacity. European journal of soil science. 69 (1): 39-47. google scholar.

[25]Nasr, M. M., and Wahib, H. A. (2024). Irrigation Performance Indicators to Measure Wasted Irrigation Water and Their Effect on Water Sustainability: Methodology. In IOP Conference Series: Earth and Environmental Science (Vol. 1371, No. 8, p. 082041). IOP Publishing. google scholar.

[26]Ni, J. J., Bordoloi, S., Shao, W., Garg, A., Xu, G. and Sarmah, A. K. (2020). Two-year evaluation of hydraulic properties of biochar-amended vegetated soil for application in landfill cover system. Science of the total environment. 712: 136486. google scholar.

[27]Ofga, L., Seyoum, T. and Ayana, M. (2022). Effect of Deficit Irrigation on Water Productivity and Yield of Onion (Allium cepa L) at Dire Dawa, Eastern Ethiopia. American Journal of Water Science and Engineering. 8 (3): 61-70. google scholar.

[28]Rop, D., Pyasi, S. K., Awasthi, M. K., Shrivastava, R. N. and Pandey, S. K. (2020). A Review of the Effect of Deficit Irrigation and Mulching on Yield and Water Productivity of Drip Irrigated Onion. International Journal of Science and Research. 9 (12): 1675-1681. google scholar.

[29]Roshdy, A. H. and Khadr, A. A. (2023). Potential Of Chitosan in Reducing Ga3 Doses and Their Effect on Growth, Yield, And Bulb Quality in" Giza Red" Onion. The Iraqi Journal of Agricultural Science. 54 (2): 563-571. google scholar.

[30]Soil Survey Staff.)2014(. Keys to Soil Taxonomy. 12th edition. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, D.C. google scholar.

[31]Soothar, R. K., Singha, A., Soomro, S. A., Chachar, A. U. D., Kalhoro, F. and Rahaman, M. A. (2021). Effect of different soil moisture regimes on plant growth and water use efficiency of Sunflower: experimental study and modeling. Bulletin of the National Research Centre. 45: 1-8. google scholar.

[32]Usowicz, B. and Lipiec, J. (2020). The effect of exogenous organic matter on the thermal properties of tilled soils in Poland and the Czech Republic. Journal of soils and sediments. 20: 365-379. google scholar.

[33]Xiao, T., Li, P., Fei, W. and Wang, J. (2024). Effects of vegetation roots on the structure and hydraulic properties of soils: A perspective review. Science of The Total Environment. 906: 167524. google scholar.

[34]Yang, F., Zhang, G. L., Yang, J. L., Li, D. C., Zhao, Y. G., Liu, F., ... and Yang, F. (2014). Organic matter controls of soil water

retention in an alpine grassland and its significance for hydrological processes. Journal of Hydrology. 519: 3086-3093. google scholar
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