

EFFECT OF IRRIGATION AND TILLAGE SYSTEMS ON THE AMOUNT OF WASTED WATER AND NET PROFIT OF BROCCOLI PLANTS

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ABSTRACT

The experiment was carried out in the research field of the College of Agriculture and Forestry / University of Mosul / Tourist Forest Area, during the growing season (2023-2024). The experiment included studying the effect of two factors, the first factor: tillage systems (surface plowing and deep plowing) and the second factor included irrigation systems (drip irrigation system and flood irrigation system). Thus, the experiment included 4 treatments (2 × 2). The study was carried out in the field using a split-plot system within a completely randomized block design (RCBD), where tillage systems were placed in the main plots, and irrigation systems were placed in the Sub plots. The results can be summarized as follows: - A- The characteristics represented by the amount of water per 30 cm and the amount of wasted water were affected by the factor of tillage systems, as the surface tillage system showed significant superiority in these characteristics over the deep tillage system. B- The characteristics represented by characteristics of vegetative growth were affected by the factor of deep plowing systems, as the deep tillage system showed lower costs compared to the surface tillage system, which gave better values in terms of net profit for the production process. The bilateral interaction treatment between the surface tillage system and the drip irrigation system showed the highest net profit for Characteristics of vegetative growth.

INTRODUCTION

Broccoli, scientific name: *Brassica oleracea* var. *Italica* is from the Brassicaceae family, which includes many winter vegetable crops. Broccoli is grown in the winter. It has been known for about 27 centuries in the Mediterranean region and many regions of Asia, and broccoli heads are considered the part from which the plant is eaten (Omar et al., 2013).

Broccoli has an economic importance no less than its health importance, as (Al-Kawaz, 2021) mentioned its economic value, and the researcher stated that broccoli is one of the crops that has great economic feasibility throughout the country due to its high prices, which significantly exceed the prices of the Lahana crop and the cauliflower crop, which dates back several years. The reasons for Maha's limited productivity inside Iraq, where 91% of it is obtained by importing from

neighboring countries, despite the ease of cultivation of this crop and the interest in it, may be due to the farmer's lack of experience with the requirements of growing broccoli and caring for it.

The natural properties of the soil play a major role in determining the quality of the soil and its suitability or its unsuitability for agriculture. Soil hardness, drainage, the soil's moisture storage capacity, aeration, root penetration, and the ability to retain plant nutrients are all factors that have a direct relationship to soil conditions, which change with tillage operations (Mild Al-Hassan 2021), and that Plowing the soil and preparing it for agriculture aims to increase the production of cultivated crops, and tillage systems are one of the most prominent methods in modern agricultural mechanization because of their major role in improving soil properties, which is reflected in agricultural production (Nicola, 2010).

Population growth around the world and insufficient freshwater resources have led many countries in the world to reach what is called water poverty or water scarcity, while the agricultural sector consumes about 70% of the world's freshwater (Mostafa and Farag, 2021), in addition to Climate change poses an additional threat to limited freshwater supplies, especially in arid and semi-arid areas (Rashad et al., 2023), so it was necessary to use the best irrigation system among the various irrigation systems, including irrigation and drip irrigation, in conjunction with appropriate irrigation scheduling in areas with water. Through which the best possible way to increase farm income can be achieved (Mb Darwish et al., 2022).

METHODOLOGY

The experiment was conducted in the research field of the College of Agriculture and Forestry/University of Mosul/Tourist Forest Area, during the growing season 2023-2024, where samples of the field soil were taken before planting from different areas of the field from the surface layer and at a depth of 0-30 cm to determine some of the physical and chemical characteristics of the soil. Then it was done dividing the land into two parts, the first part: plowing the land under the surface tillage system, and the second part: Under the deep plowing system, with a depth of 30-40 cm, the intersecting # was then carried out as primary plowing, followed by secondary plowing, and then the rest of the above treatments as well. The direction of the ridge was from north to south. The experimental unit included two ridges with a length of 4.2 m, and the distance between the ridge and the second plow was 0.75 m. Thus, the area of the ridge was from north to south. The experimental unit is 6.3 m², the number of plants in the experimental unit is 24 plants (12 plants for each ridge), as the number of plants in the experiment was 864 plants, and then the irrigation system was distributed over the experimental area, where the pipes of the drip irrigation system were extended, and the number of drippers in it reached 38092 One drip per hectare, and the distance between one pipe and another is 0.75 and between one drip and another is 0.35 meters, while the discharge of drippers per hectare reached 119988 liters/hour.

Agriculture operations

The MATSURI variety produced by TOKITA (Japanese origin) was used in the experiment. Broccoli seeds were purchased from local markets and planted on August 15, 2023 in plastic germination trays containing 50 cells using peat moss as a planting medium, after the seedlings reached the three-four stage. Real leaves, transplanted in the field in the morning on September 19, 2023, by hand with utmost care, keeping the peat moss around the roots during transplantation and maintaining soil moisture.

Service operations

Agricultural service operations were carried out identically for all experimental units, including irrigation, fertilization, weeding, and preventive control operations for diseases and insects. DAP fertilizer (18% nitrogen and 46% phosphorus) was added at a rate of 400 kg ha⁻¹, while urea

fertilizer (46% nitrogen) was added at a rate 200 kg ha⁻¹ is a supplement to the plant's need for nitrogen and potassium sulfate (50% potassium) at a rate of 100 kg ha⁻¹. Fertilizers were added to the soil at the rate of one batch of DAP fertilizer 20 days after transplanting and two batches of urea, the first 20 days after transplanting and the second at The beginning of the formation of pink discs and a single dose of potassium sulfate at the beginning of the formation of the pink discs (Matloub et al., 1989), The fungicide Terrazol was used at a concentration of 1 ml l⁻¹ sprayed on the soil as a preventive pesticide to combat soil fungi, and the insecticide Starfocus was used at a concentration of 1 ml l⁻¹ sprayed on the leaves to combat cutworms.

Experimental parameters and statistical design used:

The experiment included studying the effect of these factors:

The first factor: tillage systems:

This factor included two tillage systems:

A- Surface tillage system

B- Deep tillage system

The second factor is irrigation systems:

This factor included two irrigation systems:

A- Drip irrigation system

B- Surface irrigation system

The results were analyzed statistically according to the design followed using the split-split-plot system for all horticultural traits. As for mechanical traits, the split-plot system was used, and the program (SAS, 2017) was used to analyze the results using the Duncan multinomial test. At a probability level of 0.05 (Al-Rawi and Khalaf Allah, 2000).

Design of experimental parameters for mechanical attributes: - As a result of the interaction between the levels of the studied factors, the number of parameters is 4 (2 x 2). With three replicates, the experimental unit included two gardens with a length of 4.2 m, the distance between one ridge and the second was 0.75 m for each ridge, and the distance between one plant and another was 35 cm, with a rate of 12 plants/experimental unit (24 plants/treatment). The research was carried out in the field using a split plot system within a completely randomized block design (RCBD), where tillage systems were placed in the main plots and irrigation systems in the Sub plots.

Harvest:

Harvesting began on November 22, 2023 (99 days after planting) and ended on January 16, 2024.

Studied attributes:

The amount of water needed to reach a depth of 30 cm (liters/ha/irrigation)

The amount of water needed to reach a depth of 30 cm for the two irrigation systems (drip and stream irrigation) was calculated through the following equation:

$$QW = T \times Q$$

QW = Quantity of water for 30 cm depth (liters/ha/irrigation)

T= Irrigation time (h/ha/irrigation)

Q= Pump discharge (L/h)

The amount of water was calculated for a depth of 30 cm by using a soil moisture measuring device at this depth, which was equivalent to the amount of field capacity that was measured in the laboratory for that treatment.

The amount of wasted water (liters/ha/irrigation)

The amount of wasted water was calculated by subtracting the amount of water needed to reach a depth of 30 cm for all treatments from the drip irrigation system treatment with deep tillage, as it achieved the least amount of water to reach an irrigation depth of 30 cm in the shortest time.

$$WQ=WQ1-WQ2$$

WQ=amount of wasted water (liters/ha/irrigation)

WQ1 = The amount of water needed for each treatment to reach 30 cm irrigation depth (liters/ha/irrigation)

WQ2= The amount of water needed to reach a depth of 30 cm when treated with drip irrigation and deep plowing (liters/ha/irrigation).

Costs of the production process (\$/h/season)

The costs of the production process were calculated through the following equation:

$$C=CW+CP$$

C = costs of the production process

CW= Operating costs (\$/ha/season)

CP= Production costs (\$/ha/season)

Net profit of the production process (dollars/ha/season)

The net profit was calculated by multiplying the total yield with the price of one ton (500,000 dinars/ton) divided by the price of the dollar during the experiment period (1,550 dinars/dollar), minus the costs of the production process.

$$N=c-(500000 \times y)/1550$$

N = net profit

y = total yield (tons/ha)

C= Costs of the production process (\$/h/season).

Plant height (cm plant-1):

Plant length was measured from the area of contact with the soil to the highest leaf of the plant with a tape measure.

Number of leaves (leaf-1):

The number of leaves of each plant was calculated by counting all but the very smallest leaves.

Plant leaves area (cm² plant-1):

Five leaves were taken from each plant after harvesting, then five discs with an area of 1 cm² were taken from them, using a cork drill with a known measurement of 1 cm², the fresh weight of the discs and the fresh weight of the leaves from which the discs were cut were taken, and with the known area of the discs, the leaves area/plant was calculated using the ratio method and proportionality, according to the following equation:

Leaf area (cm² plant-1) = area of disc x fresh weight of leaves/fresh weight of disc then it was divided by 5 to extract the leaf area of one leaf, and then the result was multiplied by the total number of leaves of the plant to extract the leaves area of the entire plant.

RESULTS AND DISCUSSION

Quantity of water for 30 cm depth (liters/ha/irrigation)

In Table (4), the data presented in the averages of the tillage systems indicate that there are significant differences between the surface tillage system and the deep tillage system, where the deep tillage system outperforms by decreasing significantly, so that the amount of water consumed to reach a depth of 30 cm reaches 277,044 liters/ha/ irrigation, while in the tillage system On the surface, the amount of water reached 316,299 liters/ha/ irrigation to reach a depth of 30 cm. The presented results indicate that there are significant differences between the averages of irrigation systems in the amount of water consumed to reach a depth of 30 cm. The results showed that the drip irrigation system was significantly superior to the irrigation system in the amount of water consumed to reach a depth of 30 cm, with a value amounting to 196,983 liters/ha irrigation. When the amount of water in the irrigation system to reach a depth of 30 cm reached 396,360 liters/ha/ irrigation.

As for the bilateral interaction between the averages of the irrigation systems (drip irrigation system and the irrigation system) and the averages of the tillage systems (surface tillage and deep tillage), the data presented for this interaction in the amount of water consumed to reach a depth of 30 cm show that there are significant differences between the coefficients of this interaction, with the treatment superior to The interaction between the drip irrigation system and the deep tillage system in all the parameters of this interaction by reducing the amount of water to 30 cm depth, with a value amounting to 131,989 liters/ha/ irrigation, while the amount of water consumed to reach a depth of 30 cm reached the largest amount in the treatments of this interaction, amounting to 422,100 liters/ha/ irrigation. when the irrigation system overlaps with the deep tillage system for this trait.

This is consistent with the findings of Odeh et al. (2016) and Okasha et al. (2022). The explanation for the superiority of the deep plowing system overlapping with the drip irrigation system is that the physical properties of the soil in the deep plowing system have changed, as the porosity rate has increased, which consequently increases the speed of water drainage. Reaching the required depth (30 cm) without water losses compared to the surface tillage system, and this is consistent with what was found by Al-Khafaji (2001) and Al-Taie (1999).

Table (1) The effect of tillage and irrigation systems and their bilateral interaction on the amount of water for 30 cm depth (liters/ha/irrigation)

Irrigation systems	Tillage systems		Average effect of irrigation systems
	Surface tillage	deep tillage	
Drip irrigation	261978 c	131989 d	196983 b
Surface irrigation	370620 b	a 422100	396360 a
Average effect of tillage systems	316299 a	277044 b	

- Means with different letters have significant differences according to Duncan's multiple range test at the probability level (5%).

* Lower values are better.

Quantity of wasted water (liters/ha/irrigation)

In Table (8), the results indicate that there are significant differences between the average effect of the tillage systems (the surface tillage system and the deep tillage system), so that the deep tillage system is significantly superior to the lowest amount of wasted water, which amounted to 145,055 liters/ha/ irrigation, while the amount of wasted water in Surface tillage system: 184,310 liters/ha/ irrigation.

As for the average effect of irrigation systems (drip irrigation system and irrigation system) on the amount of wasted water, the drip irrigation system outperformed the irrigation system with a significant reduction in the lowest amount of wasted water amounting to 64,994 liters/ha/ irrigation, while the amount of wasted water was Tourism irrigation system: 264,371 liters/ha/ irrigation.

In the bilateral interaction between tillage systems and irrigation systems, the results gave significant differences in all parameters in this interaction for the amount of wasted water, as the interaction of the drip irrigation system with the deep tillage system in this characteristic resulted in the best value with a significant decrease of 0 liters/ha/ irrigation, as it did not produce This treatment resulted in no waste of water, while the treatment (the irrigation system overlapping with the deep plowing system) gave the highest amount of water wasted in this interaction, amounting to 290,111 liters/ha/ irrigation.

This is consistent with Mohammed Mahdi (2013) and Khalf (2015), as this result is explained based on what Al-Khafaji (2001) and Al-Taie (1999) indicated that deep plowing changes the physical properties of the soil, resulting in this change increasing the porosity rate of the soil. It increases the amount of water wasted in the irrigation system. Here, it must be pointed out that the treatment of the deep tillage system with the drip irrigation system, although it resulted in 0 liters/ha/irrigation of wasted water and the lowest operating costs in this experiment, nevertheless it gave the lowest overall yield and the lowest net profit.

Table (2) The effect of tillage and irrigation systems and their bilateral interaction on the amount of wasted water (liters/ha/irrigation)

Irrigation systems	Tillage systems		Average effect of irrigation systems
	Surface tillage	deep tillage	
Drip irrigation	129989 c	0 d	64994 b
Surface irrigation	238631 b	a 290111	264371 a
Average effect of tillage systems	184310 a	145055 b	

- Means with different letters have significant differences according to Duncan's multiple range test at the probability level (5%).

* Lower values are better.

Production process costs (\$/h/season)

The results in Table (11) indicate that there is a slight discrepancy between the averages of tillage systems in the production process costs, reaching \$10,242.02/ha/season for the deep tillage system, while the production process costs for the surface tillage system amounted to \$10,509.54/h/season.

As for the averages of irrigation systems in the costs of the production process, the data presented shows the superiority of the irrigation system over the drip irrigation system with the lowest costs

of the production process among the averages of irrigation systems amounting to 9976.47 dollars/ha/season, while the costs reached 10775.09 dollars/ha/season for the irrigation system. Drip. As for the results of the bilateral interaction between the averages of tillage systems and the averages of irrigation systems, it is clear from the data in the table that there are slight differences in the costs of the production process in all the treatments in this interaction, as the lowest costs of the production process resulted when the irrigation system was overlapped with the deep plowing system amounting to 9904.36 dollars/ha/season, while the costs of the production process increased in the comparative transactions until they reached their peak when the drip irrigation system was interspersed with the surface tillage system, amounting to 10970.50 dollars/ha/season. From the results, we notice that there is a slight difference in the costs of the production process between the transactions, and the reason for this is the difference in human effort between one transaction and another, and this is what was confirmed by Usunoz (2008), in addition to the difference in the costs of operating irrigation systems Hamedani (2011).

Table (3): Tillage and irrigation systems and their bilateral interaction affect the costs of the production process (dollars/ha/season)

Irrigation systems	Tillage systems		Average effect of irrigation systems
	Surface tillage	deep tillage	
Drip irrigation	10970.50	10579.68	10775.09
Surface irrigation	10048.59	9904.36	9976.47
Average effect of tillage systems	10509.54	10242.02	

* Lower values are better.

Net profit of the production process (\$/h/season).

The results of Table (12) indicate that there are differences between the averages of tillage methods in terms of net profit in terms of the results obtained, as it achieved the highest net profit of \$9164.49/ha/season when using the surface tillage system, while it gave the lowest net profit when treating deep tillage, amounting to 4581.21. \$/e/season

As for the average effect of irrigation systems, it achieved the highest net profit of \$8627.08/ha/season with the surface irrigation system, while the lowest net profit was \$5118.62/ha/season with the drip irrigation system.

The results of the bilateral interaction of irrigation systems with tillage systems showed the highest net profit of \$9658.85/ha/season when using the surface tillage system with the drip irrigation system, while the lowest net profit was given when using the treatment (the deep tillage system combined with the drip irrigation system) amounting to \$578.39. /e/season, this agrees with Srichandan et al. (2015), and Brahma and Phookan (2006).

This result (the superiority of the drip irrigation system overlapping with surface tillage) is explained based on what Thorup-kristensen (1993) and Gutezeit (2004) indicated that the development of broccoli roots needs nitrogen mainly to increase the density of roots in the soil, so the deeply plowed soil will It contributes to the drainage of nutrients in the soil during irrigation to depths that the broccoli root system does not reach, which reduces plant productivity at the deep tillage level. This is confirmed by Pool et al. (2022).

Table (4). The effect of tillage and irrigation systems and their bilateral interaction on the net profit of the production process (dollars/ha/season)

Irrigation systems	Tillage systems		Average effect of irrigation systems
	Surface tillage	deep tillage	
Drip irrigation	9658.85	578.39	5118.62
Surface irrigation	8670.12	8584.03	8627.08

Average effect of tillage systems	9164.49	4581.21	
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* Lower values are better.

Plant height (cm. plant⁻¹)

The data presented in Table (1) indicate that the surface tillage system was significantly superior to the deep tillage system in terms of plant height, with a value of 72.5489 cm. plant⁻¹ in the superior system, while the plant height during deep tillage reached 68.6293 cm. plant⁻¹. The results also showed the effect of the systems Irrigation there are significant differences between the drip irrigation system and the surface irrigation system in plant height, as the surface irrigation system was significantly superior to the drip irrigation system in this characteristic with a value of 71.8608 cm. plant⁻¹ compared to the value of plant height in the drip irrigation system, which amounted to 69.3174 cm. plant⁻¹.

As for the effect of the dual interaction between tillage systems and irrigation systems, the results presented in this table indicate that all the dual interaction treatments were significantly superior in this respect to the interaction treatment when using the deep tillage and drip irrigation system, as this last interaction treatment gave the lowest value in plant height. It reached 65.6663 cm. plant⁻¹, while the best interaction treatment in this trait was recorded in the case of interfering the surface tillage system with the use of drip irrigation, as the plant height in this treatment reached 72.9686 cm. plant⁻¹.

Table 5. The effect of tillage, irrigation and their interaction on plant height (plant. cm⁻¹).

Irrigation systems	Tillage systems		Average effect of irrigation systems
	Surface tillage	deep tillage	
Drip irrigation	72.9686 a	65.6663 b	69.3174 b
Surface irrigation	71.5923 a	72.1292 a	71.8608 a
Average effect of tillage systems	72.5489 a	68.6293 b	

- Means with different letters have significant differences according to Duncan's multiple range test at the probability level (5%).

Number of leaves (leaf. plant⁻¹)

Table (6) shows through its results that there are no significant differences between the deep tillage system and the surface tillage system in the number of leaves per plant. As for the effect of irrigation systems, the drip irrigation system was significantly superior to the irrigation system in this characteristic, as the number of leaves on the plant reached 24.3799 and 23.5008 leaf. plant⁻¹, respectively, for each system.

The effect of the bilateral interaction between tillage systems and irrigation systems gave significant differences between all treatments, as the highest significant increase in the number of leaves per plant resulted from the interaction of the surface tillage system and the drip irrigation system, with a value amounting to 25.7062 leaf. plant⁻¹, with a significant superiority over all treatments of this interaction, while the lowest value for this trait is when the surface tillage system and the irrigation surface system are combined, if the number of leaves in this treatment reaches 22.3697 leaf. plant⁻¹.

Table 6. Effect of tillage, irrigation systems and their interaction on the number of leaves per plant (plant leaf-1).

Irrigation systems	Tillage systems		Average effect of irrigation systems
	Surface tillage	deep tillage	
Drip irrigation	25.7062 a	23.0537 c	24.3799 a
Surface irrigation	22.3697 c	24.6320 b	23.5008 b
Average effect of tillage systems	24.0379 a	23.8428 a	

- Means with different letters have significant differences according to Duncan's multiple range test at the probability level (5%).

Leaves area (cm². plant⁻¹)

Through the results of Table (7), it is noted that there are significant differences between the surface tillage system and the deep tillage system in the leaves area of the plant, as the surface tillage system was significantly superior to the deep tillage system in this characteristic, reaching 25338.3 cm² plant⁻¹ in the superior system, while the leaves area reached the foliage of the plant in the deep tillage system is 16488.6 cm² plant⁻¹. As for the effect of irrigation systems, it also resulted in significant differences between the surface irrigation system and the drip irrigation system in terms of the leaves area of the plant, as the plants growing under the conditions of surface irrigation were superior in the leaves area of the plant to the plants growing under drip irrigation conditions, leaves area of the plant in surface irrigation system reached 23203.4 cm² plants⁻¹, compared to the leaves area of the plant in the drip irrigation system, which amounted to 18623.4 cm² plants⁻¹.

The results of the bilateral interaction between tillage systems and irrigation systems indicate that there are significant differences in all of this interaction in the leaf area of the plant, as the highest significant superiority was recorded when the surface tillage system was overlapped with the drip irrigation system for the leaf area of the plant, which was recorded at a value of 25973.3 cm² plant⁻¹, with a significant superiority over all parameters of this interaction, and the lowest value recorded when the deep tillage system was combined with the drip irrigation system, amounted to 11273.6 cm² plant⁻¹ for this trait.

Table 7. Effect of Tillage, Irrigation Systems, and their Interaction on Plant leaves Area (cm² plant⁻¹)

Irrigation systems	Tillage systems		Average effect of irrigation systems
	Surface tillage	deep tillage	
Drip irrigation	25973.3 a	11273.6 d	18623.4 b
Surface irrigation	24703.2 b	21703.6 c	23203.4 a
Average effect of tillage systems	25338.3 a	16488.6 b	

- Means with different letters have significant differences according to Duncan's multiple range test at the probability level (5%).

CONCLUSION

The deep tillage system gave a significant superiority in the amount of water up to 30 cm depth and the amount of wasted water compared to the surface tillage system. The surface tillage system gave better values in the net profit of the production process compared to the deep plowing system. The surface irrigation system showed better values in the net profit of the production process.

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