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Impact of Irrigation and Tillage Systems Under Different Levels of Boron Fertilizer on the Growth and Productivity of Broccoli

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The experiment was carried out in the research field of the College of Agriculture and Forestry / University of Mosul / Tourist Forest Area, during growing season (2023-2024). The experiment included a study the effect of three factors. The first and second factors were studied for their effects on mechanical traits, and the third factor was added to it to study horticultural traits. The first factor included: tillage systems (surface tillage and deep tillage) and the second factor included irrigation systems (drip irrigation system and surface irrigation system). The third factor was spraying with boron fertilizer at three concentrations (0, 75, and 100 mg L-1). Spraying was done during three stages of plant growth. The first one month after transplanting, the second spraying 15 days after the first spray, and the third spray 15 days after the second spray in terms of growth characteristics vegetative and yield of broccoli plants and study of mechanical and economic characteristics. Thus, the experiment for mechanical traits 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, while the experiment on horticultural traits included 12 treatments (2×2×3), the study was carried out in the field using a split-split plot system within a completely randomized block design (RCBD), where tillage systems were placed in the main plots. The irrigation systems in the sub plots and the sub-sub plots included boron concentrations, and each treatment was repeated three times. The results were analyzed statistically according to the design used, and the means were compared according to Duncan's multinomial test at the probability level of 0.05. The results can be summarized as follows:- The characteristics represented by irrigation time, human effort, number of irrigation times and the amount of wasted water were affected by the tillage systems factor, as the surface tillage system showed a significant superiority in all characteristics over the deep tillage system. The drip irrigation system showed significant superiority in of irrigation time, human effort, and number of irrigation times per season. The plants of the surface tillage system showed significant superiority in the yield characteristics that included (Weight of secondary heads, plant yield of secondary heads, and yield of secondary heads) compared to plants of the deep tillage system. Plants treated with boron showed significant superiority in all yield characteristics.

Keywords: surface tillage, irrigation system, Yield, boron.

1. 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, and has been known for about 27 centuries in the Mediterranean region and many regions of the Asian continent. Broccoli heads (flower inflorescences) are considered the plant's nutritional source. Broccoli is unique in its high nutritional value, as it contains a large amount of nutrients, proteins, and vitamins, in addition to its great importance from a medical standpoint, as it is considered an antibiotic for many diseases. Broccoli has an economic importance no less than its health importance, as the two researchers showed that broccoli is one of the crops that has great economic benefit in all parts of the country. [1-3]. Population growth around the world and insufficient fresh water 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 fresh water. In addition to climate change, which poses an additional threat to limited freshwater supplies, especially in arid and semi-arid areas. [4] The use of contemporary irrigation systems in conjunction with appropriate irrigation scheduling in areas with little water can achieve the best possible effect of increasing farm income. The natural properties of the soil play a major role in determining the quality of the soil and its suitability from its unsuitability for agriculture, the hardness of the soil, drainage, and the soil's moisture storage capacity, aeration, root penetration, and the ability to retain plant nutrients are all factors directly related to soil conditions, which change with tillage operations. Tillage systems are among the most prominent methods in modern agricultural mechanization because of their major role in improving soil properties, which is reflected in agricultural production. [5,6,7]. Boron has an important role in agricultural operations, as it contributes greatly to increasing the growth and productivity of the plant, due to its great importance in the composition of the cell wall and the formation and transport of complex sugars, in addition to its role in the formation of pollen. The plant absorbs boron fertilizer in the form of boric acid H3BO3, where the boron fertilizer is ready for absorption by plants in dry and semi-arid areas, which have a low content of ready-made boron due to the high pH in these areas. [8].

2. Materials and methods

The experiment was conducted in the vegetable field of the Department of Horticulture and Landscape Design/College of Agriculture and Forestry/University of Mosul, during the fall growing season 2023-2024. The land was divided into two parts: the first part: surface tillage, and the second part: deep tillage. Then the leveling process was completed, after which the field was determined, and the tillage direction was from north to south. The experimental unit included two lines 4.2 m long and 1.5 m wide for the experimental unit. Thus, the area of the experimental unit was 6.3 square meters, and the number of plants in the experimental unit was 24 plants (12 plants for each line), .The MATSURI variety produced by TOKITA (Japanese origin) was used in the experiment. Broccoli seeds were purchased from local markets and planted in beds on 8/15/2023 inside plastic trays and with special soil (peat moos),

where the beds were shaded to reduce the falling sunlight, then seedlings were transferred broccoli from the midwives to the field on 9/19/2023 and planted manually.

Statistical analysis

Thus, the experiment for mechanical traits 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.

While the experiment on horticultural traits included 12 treatments (2×2×3), the study was carried out in the field using a split-split plot system within a completely randomized block design (RCBD), where tillage systems were placed in the main plots, irrigation systems in the Sub plots and the Sub-Sub plots included boron concentrations of boron fertilizer, and each treatment was repeated three times. The results were analyzed statistically according to the design used, and the means were compared according to Duncan's multinomial test at the probability level of 0.05. [9]

Studied Traits

- Irrigation time (one hour/ha/one irrigation)
- Human effort (MJ/ha/season
- Number of irrigation times per season (irrigation/ha/season)
- Main head weight (g. plant-1)
- Yield of main heads (tons. ha-1)
- Plant yield from secondary heads (g. plant-1)
- Yield of secondary heads (tons. ha-1)

3. Results and discussion

1-Irrigation time (one hour/ha/once irrigation)

In Table (1), the data presented in the averages of the tillage systems indicate that there is a significant difference between the tillage systems (surface tillage and deep tillage), where the deep tillage system outperformed the surface tillage system by significantly reducing irrigation time with a value of 15.39 hours/ha/irrigation, while Irrigation time with the surface tillage system is 17.57 hours/ha/irrigation.As for the effect of the results on the averages of irrigation systems, the data presented in the table showed that there were significant differences between irrigation systems (drip irrigation and surface irrigation) in irrigation time, as the drip irrigation system achieved a difference in a significant decrease in irrigation time with a value of 10.94 hours/ha/water in comparison, with the surface irrigation system, the irrigation time reached the highest rate of 22.02 hours/ha/irrigation. As for the results of the dual interaction between the irrigation systems (drip irrigation system and the irrigation system) and the tillage systems (superficial tillage and deep tillage), the results showed significant differences in irrigation time, as the lowest value with a significant decrease was achieved when the deep tillage system

was overlapped with the drip irrigation system for this characteristic to be the best interaction treatment out of all the treatments, with a value of 7.33 hours/ha/irrigation, while the interaction between the deep tillage system and the surface irrigation system gave the highest time period for irrigating the crop, amounting to 23.45 hours/ha/one irrigation, This is in agreement with [10], where the result of the superiority of the deep tillage system with the drip irrigation system is explained according to what [11] concluded, as the porosity of the soil leads to a decrease in the bulk density of the soil, thus resulting in an increase in the number of channels and waterways that contribute to the speed of draining water into the soil, which reduces the time required for irrigation compared to surface plowing.

Table (1) Effect of tillage and irrigation systems and their bilateral interaction on irrigation time (h/ha/one irrigation)

Irrigation systems	Tillage systems		Average effect of irrigation systems
	Surface tillage	deep tillage	
Drip irrigation	c 14.55	d 7.33	b 10.94
Surface irrigation	b 20.59	a 23.45	a 22.02
Average effect of tillage systems	a 17.57	b 15.39	

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

* Lower values are better.

2-Human effort (MJ/ha/season)

It is noted from Table (2) that there are clear significant differences between the averages of the tillage systems (surface tillage and deep tillage) for the human effort expended in plowing operations, with the deep plowing system being significantly superior to the least human effort of 2205.57 MJ/ha/season, while the human effort for the plowing system increased surface level reached 2254.18 MJ/ha/season.As for the average effect of irrigation systems (drip irrigation and surface irrigation), the results show that there are significant differences between the averages of irrigation systems for the human effort expended in irrigation operations, as the surface irrigation system achieved superiority with a significant decrease over the drip irrigation system with human effort amounting to 2126.58 MJ/ha/season, while the human effort of the drip irrigation system reached 2333.17 MJ/ha/season.As for the results of the bilateral interactions between irrigation systems (drip irrigation and surface irrigation) and tillage systems (surface tillage and deep tillage), the results indicate that there are significant differences in 75% of the coefficients of this interaction for human effort, as this treatment (the surface irrigation system overlapping with the tillage system) outperformed the deep tillage) affected most of the treatments for this interaction for this trait with the least human effort amounting to 2108.35 MJ/ha/season, while the comparison treatment (drip irrigation system overlapping with the surface tillage system) gave the highest human effort in this interaction amounting to 2363.54 MJ/ha/season. , This result is explained only by the small number of irrigation times, which led to a reduction in human effort in irrigation, this is consistent with [12] who found that irrigation is the third largest energy consumer in agricultural operations.

Table (2) The effect of tillage and irrigation systems and their bilateral interaction on human effort (MJ/ha/season)

Irrigation systems	Tillage systems		Average effect of irrigation systems
	Surface tillage	deep tillage	
Drip irrigation	a 2363.54	b 2302.79	a 2333.17
Surface irrigation	c 2144.81	c 2108.35	b 2126.58
Average effect of tillage systems	a 2254.18	b 2205.57	

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

* Lower values are better.

3- Number of irrigation times per season (irrigation/ha/season)

The results shown in Table (3) showed that there were significant differences in the number of irrigation times per season for the average tillage systems (surface tillage and deep tillage). The results showed that there was a significant superiority for the deep tillage system in reducing the number of irrigation times during the season, which recorded 32.0 irrigations/ha/ season, while the number of irrigation times with the surface tillage system reached 36.0 irrigations/ha/season.As for the averages of irrigation systems (drip irrigation and surface irrigation), the surface irrigation system significantly outperformed the lowest number of irrigation times per season, reaching 25.5 irrigations/ha/season, while the number of irrigation times increased nearly double in the drip irrigation system, reaching 42.5 irrigations/ha/season.

Table (3) The effect of tillage and irrigation systems and their bilateral interaction on the number of irrigation times per season (irrigation/ha/season)

Irrigation systems	Tillage systems		Average effect of irrigation systems
	Surface tillage	deep tillage	
Drip irrigation	a 45.0	b 40.0	a 42.5
Surface irrigation	c 27.0	d 24.0	b 25.5
Average effect of tillage systems	a 36.0	b 32.0	

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

* Lower values are better.

As for the results of the dual interaction between tillage systems (surface tillage and deep tillage) and irrigation systems (drip irrigation and surface irrigation), the results presented in the table show that there is a significant superiority of this treatment (the surface irrigation system mixed with the deep tillage system) over all the treatments in this overlap in the number of irrigation times per season, as the value of this treatment was recorded at 24.0 irrigations/ha/season, while the comparative treatment in terms of the number of irrigation times per season when the drip irrigation system was overlapped with the surface tillage system increased by nearly double to reach 45.0 irrigations/ha/season, This result is explained according to the amount of water consumed in the irrigation system and the porosity of the soil in the deep tillage system, which contribute to increasing soil moisture for longer periods, which is reflected in the number of irrigation times per season, and this was confirmed by

[13,14] .

4- Main head weight (g. plant-1)

The results of Table (4) indicate that the average effect of tillage systems on the weight of the main head did not cause significant differences between the deep tillage system and the surface tillage system. As for the effect of irrigation systems on the weight of the main head, the surface irrigation system was significantly superior to the drip irrigation system with a value of 770.73. g.plant-1 for the superior system and 681.35 g.plant-1 for the drip irrigation system. As for the effect of boron spraying, the two concentrations of 75 and 100 mg l-1 gave a significant superiority in the weight of the main head by 802.78 g.plant-1 for the high concentration and 774.25 g.plant-1 for the concentration of 75 mg L-1 compared to the non-spraying treatment (0 mg L-1).In the bilateral interaction between tillage systems and irrigation systems, the results indicate that there are significant differences in some of the parameters of this interaction in the weight of the main head of the plant. highest significant value for the weight of the main head recorded when the deep tillage system was overlapped with the surfaceirrigation system was 819.41 g. plant-1, and the lowest value was 546.52 g. plant-1 in the deep tillage system, overlapping with the drip irrigation system in the weight of the main head.As for the effect of the dual interaction between tillage systems and boron fertilizer concentrations, it is clear from the results that the surface tillage system combined with a high concentration (100 mg l-1) of boron fertilizer gave the highest significant value, reaching 846.84 g. plant-1 in the weight of the main head, to excel. On several parameters of this interaction, the interaction of the deep tillage system with no spraying with concentrations of boron fertilizer resulted in the lowest value of 580.73 g. plant-1 for this trait.In the bilateral interaction between irrigation systems and boron fertilizer, the results indicate that the surface irrigation system combined with a concentration of 100 mg L-1 of boron solution significantly outperformed most of the coefficients of this interaction for the weight of the main head, where the interaction of the surface irrigation system with a high concentration of boron gave the highest value. Significance reached 855.84 g.plant-1 for this trait, and the lowest value reached 565.89 g. plant-1 when interfering with the drip irrigation system and not spraying with boron fertilizer (0 mg L-1) in the weight of the main head.In the results of the triple interaction between tillage systems, irrigation systems, and spraying with boron fertilizer, the data presented for this interaction indicate that there are significant differences between more than half of the coefficients of this interaction in the weight of the main head, as it gave the highest significant value in the weight of the main head when the surface tillage system was overlapped with the drip irrigation system and spraying with boron fertilizer at medium concentration (75 mg L-1) it reached 900.00 g. plant-1, while the lowest value in the weight of the main head was 441.00 g. plant-1 in the deep tillage system overlapping with the drip irrigation system and not spraying with boron fertilizer.

Table (4). Effect of tillage, irrigation systems and boron spraying systems and their interaction on the weight of the main head (g. plant-1)

Average effect of tillage systems	Tillage systems × Irrigation system	Boron concentrations (mg. l^{-1})			Irrigation system	Tillage systems
		100	75	0		
682.97 a	546.52 c	641.67 d	556.89 e	441.00 f	Drip	Deep tillage
	819.41 a	875.78 a	862.00 ab	720.45 cd	Surface	
769.11 a	816.19 a	857.78 ab	900.00 a	690.78 d	Drip	Surface tillage
	722.04 b	835.89 ab	778.12 bc	552.11 e	Surface	
	Average effect of Irrigation systems	758.72 b	709.45 b	580.73 c	Deep tillage	Tillage system × Boron
		846.84 a	839.06 a	621.45 c	Surface tillage	
	681.35 b	749.72 b	728.45 b	565.89 d	Drip	Irrigation system × Boron
	770.73 a	855.84 a	820.06 a	636.28 c	Surface	
		802.78 a	774.25 a	601.09 b	Average effect of Boron	

*Means that share the same alphabet according to the overlap factor do not differ significantly later according to Duncan's multinomial test at the probability level ($0.05 \geq p$).

5-Yield of main heads (tons. ha-1)

The results in Table (5) indicate that there were no significant differences between the tillage systems in the yield of main heads. As for the effect of irrigation systems, the surface irrigation system was significantly superior to the drip irrigation system with a value of 29.3610 tons. ha-1 for the superior system in this characteristic, and the value with the drip irrigation system, it reached 25.9563 tons. ha-1 for the yield of the main heads, while the results of the effect of boron show that both concentrations of 75 mg L-1 and 100 mg L-1 did not create significant differences between them and were significantly superior to not spraying with boron fertilizer (0 mg L-1) In the sum of the main vertices.In the bilateral interaction between tillage systems and irrigation systems for main head yield, the data resulting from this interaction indicate that the deep tillage system combined with the surface irrigation system gave the highest significant value amounting to 31.216 tons. ha-1, exceeding 50% of the coefficients of this interaction in this characteristic, while the lowest value when the deep tillage system was combined with the drip irrigation system was 20,820 tons. ha-1 for the yield of the main heads.As for the bilateral interaction between tillage systems and spraying with boron, it was shown through the results of this interaction that there are significant differences in this interaction for the main heads yield, as the results gave the highest significant value for the main heads yield amounting to 32,260 tons. ha-1 for the surface tillage system overlapping with the high concentration (100 (mg. l-1) of boron fertilizer, and the lowest value resulted when the deep tillage system was combined with not spraying with boron fertilizer (0 mg. l-1) for the yield of the main heads, which amounted to 22.123 tons. ha-1.As for the effect of

the bilateral interaction between irrigation systems and boron fertilizer concentrations, these interactions resulted in significant differences in their results in most of the main head yield parameters, as the surface irrigation system interacting with the high concentration of boron significantly outperformed most of the parameters of this interaction with a value amounting to 32.603 tons. ha-1 for the yield of the main heads, and the lowest value when the drip irrigation system was combined with no boron spraying was 21.558 tons ha-1 for this trait.As for the triple interaction between tillage systems, irrigation systems, and spraying with boron concentrations (0, 75, and 100 mg L-1), this interaction gave a significant superiority to the surface tillage treatment with drip irrigation and the use of the medium concentration (75 mg L-1) of boron fertilizer, with a value amounting to 34.286 tons ha-1, which exceeded many of the coefficients of this interaction for the yield of the main heads, while the lowest value recorded in this interaction for the yield of the main heads in the deep tillage system with drip irrigation and not spraying with boron fertilizer amounted to 16,800 tons ha-1.

Table (5). Effect of tillage, irrigation systems and boron spraying systems and their interaction on the yield of main heads (tons ha-1)

Average effect of tillage systems	Tillage systems × Irrigation system	Boron concentrations (mg. l^{-1})			Irrigation system	Tillage systems
		100	75	0		
26.018 a	20.820 c	24.444 d	21.215 e	16.800 f	Drip	Deep tillage
	31.216 a	33.363 a	32.838 ab	27.446 cd	Surface	
29.300 a	31.093 a	32.677 ab	34.286 a	26.315 d	Drip	Surface tillage
	27.506 b	31.844 ab	29.643 bc	21.033 e	Surface	
	Average effect of Irrigation systems	28.904 b	27.027 b	22.123 c	Deep tillage	Tillage system × Boron
		32.260 a	31.964 a	23.674 c	Surface tillage	
	25.9563 b	28.561 b	27.750 b	21.558 d	Drip	Irrigation system × Boron
	29.3610 a	32.603 a	31.240 a	24.239 c	Surface	
		30.5821 a	29.4954 a	22.8985 b	Average effect of Boron	

*Means that share the same alphabet according to the overlap factor do not differ significantly later according to Duncan's multinomial test at the probability level ($0.05 \geq p$).

6-Plant yield from secondary heads (g. plant-1)

The results of Table (6) show that the tillage systems in plant yield from secondary heads resulted in significant differences, as the value of this trait in the significantly superior system (the surface tillage system) reached 831.87 g. plant-1, and the value of the trait in the non-superior system (the deep tillage system). It amounted to 523.26 g. plant-1. As for the effect of irrigation systems on plant yield from secondary heads, the results show that there are no significant differences between the drip irrigation system and the surface irrigation system in

this characteristic. As for the effect of boron, it gave the concentration (75 mg L-1) and the high concentration (100 mg L-1) was significantly superior compared to plants not treated with boron in the plant yield of secondary heads, as the value of this trait in the concentration treatment reached 854.34 gm plant-1 and the high concentration treatment reached 832.74 g. plant-1 for this trait.Regarding the effect of the dual interaction between tillage systems and irrigation systems on plant yield from secondary heads, it is clear from the results of this interaction that all the binary interaction treatments were significantly superior in this respect to the interaction treatment between the deep tillage system and drip irrigation. The highest significant value in plant yield resulted from the secondary yields of this interaction in the surface tillage system overlapping with drip irrigation amounted to 862.53 g. plant-1, and the lowest value in this interaction for this trait reached 361.45 g. plant-1 when the deep tillage system was overlapping with the drip irrigation system.As for the effect of the dual interaction between tillage systems and spraying with boron fertilizer on plant yield from secondary heads, the surface tillage system combined with a concentration of 75 mg L-1 of boron fertilizer gave the highest significant value for this trait, amounting to 1137.94 g. plant-1, to be significantly superior to all treatments in this overlap for plant yield from secondary heads, while the deep tillage system combined with plants not treated with boron gave the lowest value of 264.42 g. plant-1 for the plant yield from secondary heads.Regarding the effect of the interaction between irrigation systems and boron fertilizer concentrations on the yield of secondary heads, it is clear from the results presented for this interaction that there are significant differences in the coefficients of this interaction between irrigation and boron systems for this characteristic, so that the highest significant value in this characteristic is with the surface irrigation system overlapping with the concentration of 100 mg L-1of boron with a value of 993.37 g. plant-1 in the plant yield of secondary heads, with a significant superiority over all treatments for this interaction, and the lowest value amounted to 286.95 g. plant-1 in the drip irrigation system overlapping with a concentration of 0 mg L-1 for this trait.The results of the triple interaction between the studied factors (tillage systems, irrigation systems, and boron fertilizer) for plant yield from secondary heads indicate that the interaction treatment between the surface tillage system and the drip irrigation system with the use of a concentration of 75 mg L-1 of boron fertilizer was significantly superior to all of this interaction treatments for this trait, the value of the trait in the superior interaction reached 1300.62 g.plant-1, while the lowest value reached 178.03 g.plant-1 for plant yield from secondary heads when treating the interaction between the deep tillage system and the drip irrigation system with no use of boron (0 mg L-1).

Table (6). Effect of tillage, irrigation systems and boron spraying systems and their interaction on plant yield from secondary heads (g. plant-1).

Average effect of tillage systems	Tillage systems × Irrigation system	Boron concentrations (mg. l^{-1})			Irrigation system	Tillage systems
		100	75	0		
523.26 b	361.45 b	453.15 d	453.18 d	178.03 e	Drip	Deep tillage
	685.08 a	1016.13 b	688.29 c	350.81 d	Surface	
831.87 a	862.53 a	891.09 b	1300.62 a	395.87 d	Drip	Surface tillage

	801.20 a	**970.60 b**	**975.25 b**	**457.76 d**	**Surface**	
	Average effect of Irrigation systems	**734.64 c**	**570.74 d**	**264.42 f**	**Deep tillage**	**Tillage system × Boron**
		930.85 b	**1137.94 a**	**426.82 e**	**Surface tillage**	
	611.99 a	**672.12 c**	**876.90 b**	**286.95 e**	**Drip**	**Irrigation system × Boron**
	743.14 a	**993.37 a**	**831.77 b**	**404.28 d**	**Surface**	
		832.74 a	**854.34 a**	**345.62 b**	**Average effect of Boron**	

*Means that share the same alphabet according to the overlap factor do not differ significantly later according to Duncan's multinomial test at the probability level ($0.05 \geq p$).

7-Yield of secondary heads (tons. ha-1)

The results presented in Table (7) indicate that the effect of tillage systems resulted in significant differences in plant yield from secondary heads, as the surface tillage system was significantly superior to the deep tillage system in this trait, with a value amounting to 31,690 tons. ha-1, while the value of this trait was in the system deep tillage 19.934 tons ha-1. As for the effect of irrigation systems on plant yield from secondary heads (tons ha-1), it did not give significant differences between the drip irrigation system and the surface irrigation system, while the effect of boron concentrations (0, 75, and 100 mg L-1 It gave significant differences between spraying with boron (75 and 100 mg L-1) and not spraying (0 mg.L-1), where the values of the significantly superior concentrations reached 32,546 and 31,724 tons.ha-1, while the lowest value reached 13,166 tons ha-1 at a concentration of 0 mg. L-1 for this trait.Through the results of the bilateral interaction between tillage systems and irrigation systems, it is clear from the data presented that the highest yield of secondary heads, amounting to 32.858 tons. ha-1, was found when the surface tillage system was overlapped with the drip irrigation system ,accordingly, this treatment differed significantly only with the treatment of the deep tillage system overlapped with the drip irrigation system gave the lowest value in the secondary yield of 13,770 tons.ha-1.The results of the bilateral interaction between tillage systems and boron fertilizer indicate that there are significant differences in all the treatments of this interaction for the plant's yield from secondary heads, as the treatment (surface tillage system combined with a concentration of 75 mg.L-1 of boron fertilizer) significantly outperformed all treatments in this interaction. With a value of 43,350 tons.ha-1 for this trait, the lowest value recorded when treated with a deep tillage system combined with no boron spraying (0 mg. L-1) amounted to 10,073 tons ha-1 for this trait.As for the effect of the dual interaction between irrigation systems (drip irrigation system and irrigation system) and between boron concentrations (0, 75, and 100 mg.L-1), the results indicate that the treatment of the surface irrigation system overlapping with a high concentration of boron (100 mg.L-1) gave the highest significant value in this characteristic and was significantly superior to all treatments in this interaction for plant yield from secondary heads, amounting to 37.843 tons.ha-1, while the lowest value was 10.931 tons.ha-1 when treated with a drip irrigation system overlapping with no spraying with boron (0 mg.L-1) for this trait.The results of the triple interaction between the studied factors show that the highest value in plant yield from secondary heads,

amounting to 49.547 tons.ha-1, was found when the surface tillage system was overlapped with the drip irrigation system and the use of a concentration of 75 mg.L-1 of boron, and thus this treatment was significantly superior to all the coefficients in this overlap, while the lowest value recorded in this characteristic was 6.782 tons.ha-1 in the deep tillage system overlapping with the drip irrigation system and not using boron spraying (0 mg.L-1).

Table (7). Effect of tillage, irrigation systems and boron spraying systems and their interaction on the yield of secondary crops (tons.ha-1).

Average effect of tillage systems	Tillage systems × Irrigation system	Boron concentrations (mg. l-1)			Irrigation system	Tillage systems
		100	75	0		
19.934 b	13.770 b	17.263 d	17.264 d	6.782 e	Drip	Deep tillage
	26.098 a	38.710 b	26.221 c	13.364 d	Surface	
31.690 a	32.858 a	33.946 b	49.547 a	15.081 d	Drip	Surface tillage
	30.522 a	36.975 b	37.152 b	17.439 d	Surface	
	Average effect of Irrigation systems	27.986 c	21.742 d	10.073 f	Deep tillage	Tillage system × Boron
		35.461 b	43.350 a	16.260 e	Surface tillage	
	23.314 a	25.605 c	33.406 b	10.931 e	Drip	Irrigation system × Boron
	28.310 a	37.843 a	31.686 b	15.401 d	Surface	
		31.724 a	32.546 a	13.166 b	Average effect of Boron	

*Means that share the same alphabet according to the overlap factor do not differ significantly later according to Duncan's multinomial test at the probability level ($0.05 \geq p$)

4. Conclusions

our study showed the significant superiority of the surface tillage system overlapping with the drip irrigation system at a concentration of 75 mg L-1 in most vegetative growth traits and total yield compared to the comparison treatment when not sprayed with boron fertilizer, for both irrigation and tillage systems. This study recommended adopting a concentration of 75 mg L-1 of boric acid while conducting future studies. As for tillage systems and irrigation systems, this study recommends using the surface tillage system and the drip irrigation system when growing the broccoli crop.

References

1. Omar, S. J, Salam. M. S, Luqman. G. K, Bakhtiyar. A. Q, & Qayyum. A. K. A. M. (2013). The effect of some plant growth regulators on the growth and yield of broccoli (Corvet-F1) variety. Koya University Journal. Issue (26): 261-276.

2. Omar, S. J. (2010). Effects of Planting dates, apical removal, IAA application, boron fertilizer and growing condition on the growth and yield of some culivars of Broccoli (Brassica oleraceae Var. Italica) in Sulaimani governorate. Ph. D. Dissertation, College of Agriculture, University of Sulaimani .
3. Aknan, A. M. A. (2021). The effect of seed planting time and spraying with neutral nanofertilizer on the growth and yield of two hybrids of broccoli. Master's thesis, College of Agriculture and Forestry, University of Mosul, Ministry of Higher Education and Scientific Research, Republic of Iraq.
4. Mostafa, H., & Farag, A. (2021). Effects of Irrigation systems and water strees with low water and soil quality on quinoa yield in arid conditoins. Misr Journal of Agricultural Engineering, 38(1), 15-26.
5. Rashad, M. A., Zedan, A. M., Salman, M. S., & Khedr, A. F. (2023). Assessment of Low Head Irrigation Systems and Soil Mulching to Save Water for maize Cultivation. Misr Journal of Agricultural Engineering, 40(3), 161-172.
6. Mb Darwish, W., A El-Howeity, M., & A Atia, A. (2022). Assessing the impacts of irrigation systems and various rates of mineral and bio-fertilizers on yield and water use efficiency of potatoes. Misr Journal of Agricultural Engineering, 39(2), 185-204.
7. Melad, A. (2021). The role of basic tillage methods and growth regulators in some productive traits of peanut crops in the Homs region. Al-Baath University Journal - Agricultural Sciences and Biotechnology Series, 43(23).
8. Al-Saadon, A. S. S., & Muhawish, N. M. (2021). Effect of Boron and Nitrogen Level under Different Plant Spacings on some Growth and Yield Parameters of Broccoli (Brassica oleracea var. italica Plenck) in a gypsiferous soil. College Of Basic Education Research Journal, 17(2), 1387-1418.
9. SAS(2017). Statistical Analysis System. SAS Institute. Inc. 27511,USA.
10. Shalal, J. K. (1980). Study of the origin and characteristics of the solid layer in some sedimentary soils of central Iraq. Master Thesis. faculty of Agriculture. Baghdad University.
11. Al-Khafaji, I. J. (2009). The effect of plowing depth with a subsoil plow on the efficiency of hardpan removal and yellow corn yield. Kufa Journal of Agricultural Sciences.-1(2):21-29.
12. Lawston, P. M., Santanello Jr, J. A., & Kumar, S. V. (2017). Irrigation signals detected from SMAP soil moisture retrievals. Geophysical Research Letters, 44(23), 11-860.
13. Mahdi, N. T., & Mohammed, H. A. (2013). Assesment of water consumptive use and crop factor for cabbage brassica oleracea. L under different irrigation systems. Diyala Agricultural Sciences Journal, 5(1), 204-216.
14. Al-Khafaji, I. J. (2001). Study of some operational indicators of the Massey Ferixon MF-399 tractor with subsoil plow and its efficiency in improving some physical properties of the soil. Master Thesis. Department of mechanization. faculty of Agriculture. Baghdad University.