The Influencer of Biological and Organic Fertilization and Boron Spraying in Some Growth and Yield Properties of Maize

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Abstract:
The experiment was conducted in the Al-Azawiya area, affiliated with the Musayyib project in Babil Governorate, during the winter agricultural season of 2023. The study aimed to investigate the effect of bio and organic fertilization and foliar spraying with boron on the growth and yield of yellow maize (variety: Al-Maha). The experiment was conducted using a factorial experiment based on a Randomized Complete Block Design (RCBD) and with three replications randomly distributed within three sectors, totaling 18 treatments to make the number of experimental units 54, The experiment included three factors: the first factor was bio-fertilization (seed inoculation) with a mixture of Azotobacter and Azospirillum at two levels (without inoculation, inoculation), The second factor was organic fertilization (sheep manure) added to the soil at three levels (0, 10, 20) Mg ha^{-1}. The third factor was foliar spraying of boron as boric acid at three levels (0, 5, 10) mg L^{-1}. The mean values of the treatments were compared using the Least Significant Difference (LSD) test at a significance level of 0.05.

The results of the experiment showed that the addition of bio and organic fertilizers and foliar spraying with boron resulted in significant differences in all vegetative growth and yield Properties. Additionally, the results indicated significant interactions between the bio-fertilizer (seed inoculation) and organic fertilizer (20 Mg ha^{-1}) and between the bio-fertilizer (seed inoculation) and foliar spraying with boron (10 mg L^{-1}), as well as between the organic fertilizer (20 Mg ha^{-1}) and foliar spraying with boron (10 mg L^{-1}), resulting in significant differences in all growth and yield Properties. Similarly, significant interactions were observed between the bio-fertilizer (seed inoculation), organic fertilizer (20 Mg ha^{-1}), and foliar spraying with boron (10 mg L^{-1}), indicating significant differences in all growth and yield Properties.

Keywords: Biofertilizer, Organic fertilizer, Foliar spraying, Boric acid, maize.

Introduction:

maize (Zea mays) is considered one of the most important field crops, playing a significant role in the food industry. Its grains are characterized by a high content of starch and oil, in addition to salts, minerals, and vitamins, especially vitamin A, which is estimated to be twenty times higher than that found in wheat grains. These vitamins are essential in the production of livestock feed, and without them, there would be no such advancement in the industry, similar to the importance of soybeans in providing essential amino acids for animal growth [1].

Biofertilizers are defined as a group of microorganisms or organic substances of any biological origin added to soil, seeds, or both, with the aim of meeting the nutritional needs of plants. Biofertilizers help increase productivity and also enhance the nutrient content and energy compounds in crops. They are considered successful alternatives to improve nutrient availability and stimulate plant growth [2]. Azospirillum spp bacteria are among the most important bacterial inoculants used in biofertilizer technology. These bacteria contain the enzyme nitrogenase, which enables them to reduce atmospheric nitrogen through a process called biological nitrogen fixation. They also have the ability to tolerate drought conditions and act as growth regulators when present near agricultural crops by secreting some plant hormones such as gibberellins, auxins, ethylene, and cytokinins [3]. Similarly, Azotobacter spp bacteria are also important bacterial inoculants as they contribute to nitrogen fixation, which is agriculturally significant. They play important roles in various environments including soil, water, and sediments. Additionally, they produce substances that enhance plant growth such as growth regulators (auxins, gibberellins, ethylene, cytokinins) [4].

It is well known to agricultural practitioners the role of organic matter in improving the physical, chemical, and fertility properties of soil. Adding organic matter to soils in dry and semi-dry climates, including Iraqi soils, is necessary to increase their vitality as they constitute an important source of both major and minor nutrients. Organic matter also plays a role in improving the chemical and physical properties of soil, including permeability, water and air movement, and moisture retention [5].

Crop productivity relies heavily on crop management practices grounded in sound scientific principles, Among these practices, foliar fertilization with micronutrients, including boron albeit in very small quantities, garners attention. Boron is crucial for the development of pollen grains, flowers, seed formation, and enhancement of fertilization rates, Additionally, it plays a vital role in the conversion and transport of sugars as they traverse cell membranes and participate in the formation of plant cell walls. Furthermore, boron contributes to the synthesis of amino acids and acts as a catalyst in enzymatic reactions, Therefore, foliar feeding of this element can play a distinctive role and serve as a successful solution to supply plants with adequate amounts of boron [6].

Based on the provided information, this study aims to examine the impact of adding biological and organic fertilizers, along with foliar spraying of boron, on the growth and yield of maize plants. The study also seeks to explore the combined interactive effect of the study factors (biological and organic fertilization, and foliar spraying of boron) on the growth and yield of maize plants.

Materials and Methods:

The experiment was conducted in the Al-Azawiya area within the framework of the Musayyib project in Babil province, at coordinates longitude (44° 43' 89") north and latitude (32° 79' 20") east. The soil was a Silty Loam for cultivating the maize (Zea Mays L.) crop, Mahha variety, in the agricultural season of 2023. The land had previously been cultivated and was suitable for planting maize. The purpose was to study the Influencer of Biological and Organic Fertilization and Boron Spraying in Some Growth and Yield Properties of Maize, The experiment included three factors: the first factor included biological fertilizers in the form of bacterial fertilizers (a mixture of Azotobacter and Azospirillum) at two levels: (no addition, addition of biological fertilizer). The second factor involved the addition of organic fertilizer in the form of fermented sheep manure at three levels: (0 Mg ha^{-1}, 10 Mg ha^{-1}, 20 Mg ha^{-1}). The third factor

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included foliar spraying with boron as boric acid H_3BO_3 (17.4% B) at three levels: (0 mg B L^{-1}, 5 mg B L^{-1}, 10 mg B L^{-1}).

Table (1): Some Chemical and Physical Properties of the Studied Soil.

❈ **The analyses were conducted at the laboratory of the Directorate of Agriculture in Karbala, Iraq.**

Attributes		Values	Units of measurement
Electrical conductivity (ECe)		3.0	ds m^{-1}
Soil pH (pH)		7.67	
Organic matter		8.62	gm kg^{-1} soil
Gypsum		2.15	
Lime		211.0	
Cation exchange capacity (CEC)		19.71	cmol kg^{-1}
Available nitrogen		26.42	mg kg^{-1} soil
Available phosphorus		11.2	
Available potassium		123.83	
Available boron		1.01	
Bulk density		1.31	Mg m^{-3}
Porosity		50.57	
Soil horizons	Sand	29.12	%
	Silt	48.02	
	Clay	22.86	
soil texture		Silty Loam	

The experiment was conducted on July 15, 2023, in Silty Loam soil, maize seeds, variety "Al-Maha," obtained from the Agricultural Research Department in Abu Ghraib, were manually sown at a rate of 3 seeds per hill. After one week of germination, the number of plants per hill decreased to one, and any excess seedlings were manually thinned out as needed. Chemical fertilizers (NPK) were applied to all treatments at half the recommended rate [7], Nitrogen was applied as urea fertilizer (46% N) at a rate of 60 kg N ha^{-1} in two split applications: the first at planting and the second after 30 days of germination. Potassium was applied as potassium sulfate (41.5% K) at a rate of 37.5 kg ha^{-1} in two equal splits concurrently with nitrogen applications, with the second split after 30 days of germination. Phosphorus was applied as triple superphosphate calcium (20% P) at a rate of 20 kg ha^{-1} in a single pre-planting application mixed with the soil.

Biological (bacterial) fertilizers were obtained from the Agricultural Research Laboratories in Az-Zafaraniya, consisting of Azotobacter and Azospirillum bacteria. These were mixed with yellow maize seeds in a sterilized plastic container for half an hour, with the addition of arabic gum at a concentration of 8% (8 g gum dissolved in 100 ml distilled water) to ensure adhesion of the inoculant to the seeds. The seeds were then planted after inoculation.

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Boric acid was sprayed in three stages (15 days after planting, 30 days after planting, and 45 days after planting), representing the stages of complete leaf formation, initiation of tassel formation, and silk formation, respectively. Spraying was done using a manual sprayer with a capacity of 10 liters, and the concentration was diluted while adding a small amount of surfactant (Zahi) to ensure complete leaf wetting and enhance spray solution efficiency. Spraying was conducted in the early morning to avoid high temperatures. The control treatment received distilled water spray.

Irrigation was carried out as needed, then the maize plants were harvested on November 10, 2023, when they reached full maturity, and the following measurements were taken:

1. Average plant height (cm): measured at the end of the growing season from above the soil surface to the end of the male inflorescence.
2. Leaf area (cm^2): measured using the equation (leaf area = length × maximum width × 0.75) at the stage of full flowering.
3. Total chlorophyll content in leaves (SPAD): measured using a SPAD chlorophyll meter directly on the plant in the field, with three readings taken and averaged.
4. Number of grains per cob (grains cob^{-1}): determined by selecting ten plants from each experimental unit.
5. Weight of 500 grains (g): calculated as the average weight of 500 grains from ten plants from each experimental unit (calculated from the yield of used maize grains after correcting for moisture content to 15.5%).
6. Total grain yield (Mg ha^{-1}): calculated according to the following equation (total yield = plant yield × plant density).

Results and Discussion:

1.Plant Height (cm):

The results in Table (2) indicate significant differences in the effect of the studied factors on plant height. The biofertilization treatment (Azotobacter + Azospirillum) showed significant superiority, yielding the highest mean of 198.99 cm, while the untreated control gave the lowest mean of 178.90 cm. Regarding organic fertilization, the treatment with 20 Mg ha^{-1} significantly outperformed, yielding the highest mean of 195.44 cm compared to the control treatment (0 Mg ha^{-1}), which yielded the lowest mean of 183.38 cm. As for boron spraying, the treatment with 10 mg L^{-1} significantly outperformed, yielding the highest mean of 190.47 cm compared to the control treatment (0 mg L^{-1}), which yielded the lowest mean of 187.37 cm.

The results showed that all pairwise interactions between biofertilization, organic fertilization, and boron were significant in this trait. The treatment (biofertilization + 20 Mg ha^{-1}) yielded the highest mean of 204.86 cm compared to the control treatment (no biofertilization + 0 Mg ha^{-1}), which yielded the lowest mean of 173.04 cm. Additionally, the treatment (biofertilization + 10 mg L^{-1}) yielded the highest mean of 201.02 cm compared to the control treatment (no biofertilization + 0 mg L^{-1}), which yielded the lowest mean of 178.1 cm. As for the treatment (20 Mg ha^{-1} + 10mg L^{-1}), it yielded the highest mean of 196.85 cm compared to the control treatment (0 Mg ha^{-1} + 0 mg L^{-1}), which yielded the lowest mean of 180.70 cm. Regarding the triple interaction between biofertilization, organic fertilization, and boron, the treatment (biofertilization + 20 Mg ha^{-1} + 10 mg L^{-1}) significantly outperformed, yielding the highest mean of 206.61 cm compared to the control treatment (no biofertilization + 0 Mg ha^{-1} + 0 mg L^{-1}), which yielded the lowest mean of 172.15 cm.

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Table (2): The Effect of Biological and Organic Fertilization and Foliar Boron Spray and Their Interactions on plant height (cm).

Biological fertilization	Organic fertilization (Mg ha^{-1})	Boron (mg L^{-1})			Average
		0	5	10	
Without inoculation	0	172.15	172.89	174.06	173.04
	10	176.78	177.52	178.61	177.64
	20	185.10	185.89	187.09	186.03
Inoculation (Azotobacter+ Azospirillum)	0	189.24	195.11	196.84	193.73
	10	197.49	198.08	199.59	198.39
	20	203.43	204.53	206.61	204.86
$LSD_{0.05}$		1.76			1.01
		Biological x boron			Average
Without inoculation		178.01	178.77	179.92	178.90
Inoculation (Azotobacter + Azospirillum)		196.72	199.24	201.02	198.99
$LSD_{0.05}$		1.01			0.59
		Organic x boron			Average
0		180.70	184.00	185.45	183.38
10		187.13	187.80	189.10	188.01
20		194.27	195.21	196.85	195.44
$LSD_{0.05}$		1.24			0.72
Average of boron		187.37	189.00	190.47	
$LSD_{0.05}$		0.72			

2. The leaf area (cm^2):

The results in Table (3) indicate significant differences in the effect of the studied factors on leaf area. The biofertilization treatment (Azotobacter + Azospirillum) significantly outperformed, yielding the highest mean of 261.90 cm^2, while the untreated control gave the lowest mean of 227.21 cm^2. As for organic fertilization, the treatment with 20 Mg ha^{-1} significantly outperformed, yielding the highest mean of 255.72 cm^2, compared to the control treatment (0 Mg ha^{-1}), which yielded the lowest mean of 233.14 cm^2. Regarding boron spraying, the treatment with 10 mg L^{-1} significantly outperformed, yielding the highest mean of 248.32 cm^2 compared to the control treatment (0 mg L^{-1}), which yielded the lowest mean of 241.35 cm^2.

The results showed that all pairwise interactions between biofertilization, organic fertilization, and boron were significant in this trait. The treatment (biofertilization + 20 Mg ha^{-1}) yielded the highest mean of 273.33 cm^2 compared to the control treatment (no biofertilization + 0 Mg ha^{-1}), which yielded the lowest mean of 216.44 cm^2. Additionally, the treatment (biofertilization + 10 mg L^{-1}) yielded the highest mean of 265.42cm^2 compared to the control treatment (no biofertilization + 0 mg L^{-1}), which yielded the lowest mean of 224.03 cm^2. As for the treatment (20 Mg ha^{-1} + 10 mg L^{-1}), it yielded

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the highest mean of 259.10cm^2 compared to the control treatment (0 Mg ha^{-1} + 0 mg L^{-1}), which yielded the lowest mean of 229.93 cm^2. Regarding the triple interaction between biofertilization, organic fertilization, and boron, the treatment (biofertilization + 20 Mg ha^{-1} + 10 mg L^{-1}) significantly outperformed, yielding the highest mean of 276.00 cm^2 compared to the control treatment (no biofertilization + 0 Mg ha^{-1} + 0 mg L^{-1}), which yielded the lowest mean of 213.33 cm^2.

Table (3): The Effect of Biological and Organic Fertilization and Foliar Boron Spray and Their Interactions on leaf area (cm^2).

Biological fertilization	Organic fertilization (Mg ha^{-1})	Boron (mg L^{-1})			Average
		0	5	10	
Without inoculation	0	213.33	215.67	220.33	216.44
	10	223.83	226.27	231.10	227.07
	20	234.93	237.20	242.20	238.11
Inoculation (Azotobacter+ Azospirillum)	0	246.53	249.13	253.83	249.83
	10	259.13	262.00	266.43	262.52
	20	270.33	273.67	276.00	273.33
$LSD_{0.05}$		0.709			0.409
		Biological x boron			Average
Without inoculation		224.03	226.38	231.21	227.21
Inoculation (Azotobacter + Azospirillum)		258.67	261.60	265.42	261.90
$LSD_{0.05}$		0.409			0.236
		Organic x boron			Average
0		229.93	232.40	237.08	233.14
10		241.48	244.13	248.77	244.79
20		252.63	255.43	259.10	255.72
$LSD_{0.05}$		0.501			0.289
Average of boron		241.35	243.99	248.32	
$LSD_{0.05}$		0.289			

3. Leaf Chlorophyll Content (SPAD):

The results in Table (4) showed significant differences in the effect of the studied factors on the chlorophyll content, as the treatment with the addition of biofertilizer (Azotobacter + Azospirillum) significantly outperformed, giving the highest average reading of 55.36 SPAD units, while the treatment without inoculation yielded the lowest average reading of 47.14 SPAD units. Regarding organic fertilization, the treatment with 20 Mg ha^{-1} outperformed significantly, yielding the highest average reading of 54.29 SPAD units compared to the treatment without addition (0 Mg ha^{-1}), which gave the lowest average reading of 47.80 SPAD units. As for boron spraying, the treatment with 10 mg L^{-1} outperformed significantly, yielding the

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highest average reading of 53.44 SPAD units compared to the treatment without spraying (0 mg L^{-1}), which gave the lowest average reading of 49.52 SPAD units.

The results indicated that all pairwise interactions between biofertilization, organic fertilization, and boron were significant in this trait. The treatment with inoculation + 20 Mg ha^{-1} gave the highest average reading of 58.20 SPAD units compared to the treatment without inoculation + 0 Mg ha^{-1}, which gave the lowest average reading of 42.87 SPAD units. Similarly, the treatment with inoculation + 10 mg L^{-1} yielded the highest average reading of 56.54 SPAD units compared to the treatment without inoculation + 0 mg L^{-1}, which gave the lowest average reading of 45.00 SPAD units. Furthermore, the treatment with 20 Mg ha^{-1} + 10 mg L^{-1} gave the highest average reading of 57.36 SPAD units compared to the treatment without addition (0 Mg ha^{-1} + 0 mg L^{-1}), which gave the lowest average reading of 46.47 SPAD units.

Regarding the triple interaction between biofertilization, organic fertilization, and boron, the treatment with inoculation + 20 Mg ha^{-1} + 10 mg L^{-1} significantly outperformed, yielding the highest average reading of 60.46 SPAD units compared to the treatment without inoculation + 0 Mg ha^{-1} + 0 mg L^{-1}, which gave the lowest average reading of 40.65 SPAD units.

Table (4): The Effect of Biological and Organic Fertilization and Foliar Boron Spray and Their Interactions on Leaf Chlorophyll Content (SPAD).

Biological fertilization	Organic fertilization (Mg ha^{-1})	Boron (mg L^{-1})			Average
		0	5	10	
Without inoculation	0	40.65	41.68	46.27	42.87
	10	46.36	47.64	50.52	48.17
	20	47.99	48.86	54.25	50.37
Inoculation (Azotobacter+ Azospirillum)	0	52.30	53.60	52.33	52.74
	10	52.90	55.66	56.84	55.14
	20	56.92	57.23	60.46	58.20
$LSD_{0.05}$		1.73			1.00
		Biological x boron			Average
Without inoculation		45.00	46.06	50.35	47.14
Inoculation (Azotobacter + Azospirillum)		54.04	55.50	56.54	55.36
$LSD_{0.05}$		1.00			0.58
		Organic x boron			Average
0		46.47	47.64	49.30	47.80
10		49.63	51.65	53.68	51.65
20		52.46	53.05	57.36	954.2
$LSD_{0.05}$		1.22			0.71
Average of boron		49.52	50.78	53.44	
$LSD_{0.05}$		0.71			

4. Number of grains per cob (grains cob^{-1})

The results in table (5) indicate significant differences in the effect of the studied factors

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on the trait of grain number per cob. The treatment with the addition of biological fertilization (Azotobacter + Azospirillum) significantly outperformed and yielded the highest mean of 576.33 grains cob^{-1}, while the untreated control gave the lowest mean of 452.26 grains cob^{-1}. Regarding organic fertilization, the treatment with 20 Mg ha^{-1} significantly outperformed and yielded the highest mean of 555.48 grains cob^{-1}, compared to the untreated control which yielded the lowest mean of 471.50 grains cob^{-1}. As for foliar boron spray, the treatment with 10 mg L^{-1} significantly outperformed and yielded the highest mean of 523.01 grains cob^{-1}, compared to the untreated control which yielded the lowest mean of 499.61 grains cob^{-1}.

The results indicate that all pairwise interactions between biological fertilization, organic fertilization, and boron were significant in this trait. The treatment of biological fertilization combined with 20 Mg ha^{-1} gave the highest mean of 622.91 grains cob^{-1}, compared to the untreated control which gave the lowest mean of 413.22 grains cob^{-1}. Similarly, the treatment of biological fertilization combined with 10 mg L^{-1} gave the highest mean of 586.60 grains cob^{-1}, compared to the untreated control which gave the lowest mean of 438.91 grains cob^{-1}. The treatment with both 20 Mg ha^{-1} and 10 mg L^{-1} gave the highest mean of 563.93 grains cob^{-1}, compared to the untreated control which gave the lowest mean of 458.81 grains cob^{-1}.

Regarding the triple interaction between biological fertilization, organic fertilization, and boron, the treatment with biological fertilization combined with 20 Mg ha^{-1} and 10 mg L^{-1} gave the highest mean of 633.08 grains cob^{-1}, compared to the untreated control which gave the lowest mean of 401.11 grains cob^{-1}.

Table (5): The Effect of Biological and Organic Fertilization and Foliar Boron Spray and Their Interactions on Grain Number per Cob (Grains cob^{-1})

Biological fertilization	Organic fertilization (Mg ha^{-1})	Boron (mg L^{-1})			Average
		0	5	10	
Without inoculation	0	401.11	419.12	419.44	413.22
	10	438.91	463.57	464.01	455.50
	20	476.71	492.67	494.77	488.05
Inoculation (Azotobacter+ Azospirillum)	0	516.51	534.51	538.34	529.78
	10	560.31	580.14	588.39	576.28
	20	604.11	631.55	633.08	622.91
$LSD_{0.05}$		3.82			2.21
		Biological x boron			Average
Without inoculation		438.91	458.45	459.41	452.26
Inoculation (Azotobacter + Azospirillum)		560.31	582.07	586.60	576.32
$LSD_{0.05}$		2.21			1.27
		Organic x boron			Average
0		458.81	476.81	478.89	471.50
10		499.61	521.86	526.20	515.89
20		540.41	562.11	563.93	555.48
$LSD_{0.05}$		2.70			1.56

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Average of boron	499.61	520.26	523.01	
$LSD_{0.05}$	1.56			

5. weight of 500 grains(g):

The results in table (6) indicate significant differences in the effect of the studied factors on the trait of weight of 500 grains, The treatment with the addition of biofertilizer (Azotobacter + Azospirillum) significantly outperformed and gave the highest mean weight of 176.11 g, while the untreated treatment yielded the lowest mean weight of 161.99 g. Regarding organic fertilization, the treatment with 20 Mg ha^{-1} significantly outperformed and yielded the highest mean weight of 174.43 g, compared to the untreated treatment which yielded the lowest mean weight of 164.27 g. As for the foliar spray with boron, the treatment with 10 mg L^{-1} significantly outperformed and yielded the highest mean weight of 170.18 g compared to the treatment without spray, which yielded the lowest mean weight of 167.91 g.

The results indicate that all pairwise interactions between biofertilizer, organic fertilization, and boron were significant for this trait. The treatment with biofertilizer + 20 Mg ha^{-1} yielded the highest mean weight of 181.37 g compared to the untreated treatment, which yielded the lowest mean weight of 157.08 g. Similarly, the treatment with biofertilizer + 10 mg L^{-1} yielded the highest mean weight of 177.29g compared to the untreated treatment, which yielded the lowest mean weight of 160.77 g. The treatment with 20 Mg ha^{-1} + 10 mg L^{-1} also yielded the highest mean weight of 175.44 g compared to the untreated treatment, which yielded the lowest mean weight of 162.93 g.

As for the triple interaction between biofertilizer, organic fertilization, and boron, the treatment with biofertilizer + 20 Mg ha^{-1} + 10 mg L^{-1} significantly outperformed and yielded the highest mean weight of 182.48 g compared to the untreated treatment, which yielded the lowest mean weight of 155.43 g.

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Table (5): The Effect of Biological and Organic Fertilization and Foliar Boron Spray and Their Interactions on weight of 500 grains(g)

Biological fertilization	Organic fertilization (Mg ha^{-1})	Boron (mg L^{-1})			Average
		0	5	10	
Without inoculation	0	155.43	157.39	158.42	157.08
	10	160.43	161.37	162.39	161.40
	20	166.44	167.65	168.40	167.50
Inoculation (Azotobacter+ Azospirillum)	0	170.42	171.21	172.75	171.46
	10	174.39	175.41	176.65	175.48
	20	180.37	181.27	182.48	181.37
$LSD_{0.05}$		0.40			0.23
		Biological x boron			Average
Without inoculation		160.77	162.14	163.07	161.99
Inoculation (Azotobacter + Azospirillum)		175.06	175.96	177.29	176.11
$LSD_{0.05}$		0.23			1.34
		Organic x boron			Average
0		162.93	164.30	165.58	164.27
10		167.41	168.39	169.52	168.44
20		173.40	174.46	175.44	174.43
$LSD_{0.05}$		0.28			1.64
Average of boron		167.91	169.05	170.18	
$LSD_{0.05}$		0.164			

6. Grain yield (Mg ha^{-1}):

The results in table (7) indicate significant differences in the effect of the studied factors on the trait of "total plant yield". The treatment with the addition of biofertilizer (Azotobacter + Azospirillum) significantly outperformed and yielded the highest mean of 8.92Mg ha^{-1}, while the untreated treatment yielded the lowest mean of 5.12 Mg ha^{-1}. Regarding organic fertilization, the treatment with 20 Mg ha-1 significantly outperformed and yielded the highest mean of 8.12 Mg ha^{-1}, compared to the untreated treatment which yielded the lowest mean of 5.98 Mg ha^{-1}. As for the foliar spray with boron, the treatment with 10 mg L^{-1} significantly outperformed and yielded the highest mean of 7.50 Mg ha^{-1} compared to the treatment without spray, which yielded the lowest mean of 6.70 Mg ha^{-1}.

The results indicate that all pairwise interactions between biofertilizer, organic fertilization, and boron were significant for this trait. The treatment with biofertilizer + 20 Mg ha^{-1} yielded the highest mean of 9.82 Mg ha^{-1} compared to the untreated treatment, which yielded the lowest mean of 4.04 Mg ha^{-1}. Similarly, the treatment with biofertilizer + 5 mg L^{-1} yielded the highest mean of 9.23 Mg ha^{-1} compared to the untreated treatment, which yielded the lowest mean of 4.78 Mg ha^{-1}. The treatment with 20 Mg ha^{-1} + 5 mg L^{-1} also yielded the highest mean of 8.83 Mg ha^{-1}

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compared to the untreated treatment, which yielded the lowest mean of 5.87 Mgha^{-1}.

Regarding the triple interaction between biofertilizer, organic fertilization, and boron, the treatment with biofertilizer + 20 Mg ha^{-1} + 10 mg L^{-1} significantly outperformed and yielded the highest mean of 10.15 Mg ha^{-1} compared to the untreated treatment, which yielded the lowest mean of 4.00 Mg ha^{-1}.

Table (5): The Effect of Biological and Organic Fertilization and Foliar Boron Spray and Their Interactions on plant yield (Mg ha-1).

Biological fertilization	Organic fertilization (Mg ha^{-1})	Boron (mg L^{-1})			Average
		0	5	10	
Without inoculation	0	4.00	4.01	4.10	4.04
	10	4.47	4.49	5.70	4.88
	20	5.88	5.91	7.50	6.43
Inoculation (Azotobacter+ Azospirillum)	0	7.75	7.79	8.22	7.92
	10	8.50	9.20	9.33	9.01
	20	9.63	9.67	10.15	9.82
$LSD_{0.05}$		0.102			0.059
		Biological x boron			Average
Without inoculation		4.78	4.81	5.77	5.12
Inoculation (Azotobacter + Azospirillum)		8.63	8.89	9.23	8.92
$LSD_{0.05}$		0.059			0.034
		Organic x boron			Average
0		5.87	5.90	6.16	5.98
10		6.48	6.85	7.51	6.95
20		7.76	7.79	8.83	8.12
$LSD_{0.05}$		0.072			0.041
Average of boron		6.70	6.85	7.50	
$LSD_{0.05}$		0.041			

Discussion:

The results presented in tables (2, 3, 4) indicate that seed inoculation with Azotobacter and Azospirillum bacteria led to a significant increase in some vegetative growth traits (plant height, leaf area, chlorophyll content). This can be attributed to the role of biological fertilizers in improving vegetative growth and increasing the surface area of the root absorption zone, thereby enhancing water and nutrient uptake by the plants. Additionally, these fertilizers may stimulate the secretion of hormones and active substances in the rhizosphere area, such as gibberellins, cytokinin's, auxins, and certain organic acids, which influence pH values around the root zone, facilitating nutrient availability, particularly phosphorus, and promoting root and root hair proliferation. These findings are consistent with previous studies [8,9].

Furthermore, the results demonstrate that the addition of organic fertilizers resulted in a significant increase in the aforementioned vegetative growth traits. This may be attributed to the role of organic matter in

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improving soil physical and chemical properties, providing a continuous supply of major and minor nutrients like nitrogen, phosphorus, and potassium, enhancing plant nutrient uptake, and promoting efficient root system development. This, in turn, increases nutrient and water absorption by the plant, leading to increased leaf area, cell elongation, and ultimately, higher photosynthetic rates, contributing to increased plant productivity. These findings are consistent with previous research [10,11].

Moreover, the results indicate that foliar spraying with boron as boric acid led to a significant increase in the mentioned vegetative growth traits. This could be attributed to the role of boron in promoting cell division and elongation, stimulating apex growth, enhancing root growth, and increasing stem elongation. Boron also plays a crucial role in cell wall development and cell differentiation, promoting root elongation and shoot growth. Additionally, boron enhances enzyme activity, potentially affecting growth hormones, particularly cytokinins, which sustain chlorophyll, resulting in increased chlorophyll content and, consequently, increased photosynthetic efficiency and plant productivity. These findings align with previous studies [12,13].

Similarly, the results from tables (5, 6, 7) demonstrate that seed inoculation with Azotobacter and Azospirillum bacteria led to a significant increase in some yield traits (number of grains per ear, weight of 500 grains, total yield). This is attributed to the role of microorganisms in releasing organic matter from its sources and releasing sufficient major and minor nutrients from the root zone, promoting efficient nutrient uptake by the plants from the early stages of growth, and increasing vegetative growth, leading to enhanced reproductive stages. This supports and enhances grain development by providing all essential elements and increasing their number. Additionally, the secretion of growth-stimulating hormones by the microorganisms may promote root growth and enhance their nutrient absorption capacity, including gibberellins and cytokinins. These findings are consistent with previous studies [14,15].

The results also demonstrated that the addition of organic fertilizer led to a significant increase in the mentioned traits. This could be attributed to the enhancement of soil fertility and its readiness for nutrient uptake by the plants due to the addition of organic fertilizers. This positively reflects on plant growth indicators, including increased plant height, leaf area, and grain yield. This improvement in the root zone's nutritional status through the provision of nutrients and enhancement of soil chemical and physical properties aids in root penetration into the soil and increases beneficial soil microorganisms, Consequently, it enables plants to acquire a larger quantity of their nutritional requirements, resulting in increased plant dry matter, which in turn stimulates the growth of secondary roots, allowing them to reach full reproductive stages. These findings are consistent with previous studies [8,9,11].

The results also indicate that foliar spraying with boron as boric acid led to a significant increase in the mentioned yield traits. This could be attributed to the role of boron in promoting cell division and growth, resulting in increased ear size and consequently, an increase in the number of grains per ear. Additionally, boron plays an effective role in carbohydrate transportation from source to sink and ensures their timely provision to growth centers, Boron also influences certain enzymes that promote root growth, thereby

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enhancing the uptake of major and minor nutrients from the soil, leading to increased concentration in the plant (leaves and grains). Consequently, this enhances growth and yield Properties, these findings are consistent with previous studies [12,16].

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