Available online at http://bjas.bajas.edu.iq
https://doi.org/10.37077/25200860.2024.38.1.24
College of Agriculture, University of Basrah

Basrah Journal of Agricultural Sciences

ISSN 1814 – 5868 Basrah J. Agric. Sci., 38(1), 312-323, 2025 E-ISSN: 2520-0860

The Impact of Biofertilizers, Organic Fertilizers, and Foliar Application of Boron on Yield Characteristics of Maize (*Zea mays* L.)

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Received 10th April 2025; Accepted 29th June 2025; Available online 30th June 2025

Abstract: This study took place under silty loam soil conditions at the Al-Musayyib project site (Babil Governorate, Iraq) from 15 July to 10 November 2024, to assess the interactive effects of biofertilizers, applied organic manure, and boron foliar application on yield attributes of maize (*Zea mays* L. Al-Maha). An experiment laid down in factorial arrangements in randomized complete block design (RCBD) consisted of three factors: an Azotobacter and Azospirillum seed inoculation (uninoculated, inoculated) and sheep manure in quantities of 0, 10, and 20 Mg ha^{-1} and boron (boric acid) applied as a foliar treatment at levels of 0, 75, and 150 mg L^{-1}. Biofertilization in combination with high rates of organic manure and foliar spraying of boron gave great responses in the major yield components of dry matter yield, grains per cob, and total grain yield. The three-way interaction between the applied treatments achieved a significant contribution in synergy for all measured yield attributes. The results point towards the opportunity for integrated nutrient management to improve maize productivity under silty loam conditions as a feasible alternative to conventional fertilization approaches

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

Introduction

Biofertilizers can be defined as a range of organisms or biological additives applied to soil or seed or both in order to address the nutritional requirements of plants. Their application has contributed towards crop productivity and, in certain cases, yield increase potential being over 40%, while costs of production are significantly reduced as compared to the use of chemical fertilizers. Of greater import is that biofertilizers improve nutrient content and energy compounds in crops, work excellently in improving nutrient availability, and stimulate growth in plants (García-Fraile *et al.*, 2015). At the top rank among microbial inoculants used in biofertilizer technology are Azospirillum spp. These also have the property of possessing the nitrogenase enzyme, which enables these bacteria to fix atmospheric nitrogen biologically through biological nitrogen fixation. Furthermore, Azospirillum spp. may possess drought tolerance and growth hormone activity while remaining in proximity to crop roots (Bhateria & Kumar, 2022). On the other hand, Azotobacter spp. are better nitrogen-fixing bacteria in agriculture due to their importance in soil, water, and sediments. They also produce plant growth-promoting substances, including phytohormones. Azotobacter inoculation enhances seed germination (Baral & Adhikari, 2013). Among agriculturists, it is commonplace to know that organic matter improves the physical, chemical, and fertility characteristics of soil. The improvement of soil energetics is urgently required, especially where soils have low organic matter content, particularly under the arid and semi-arid climatic regimes, including Iraqi soils. Organic matter helps to provide macro and micronutrients to crops while simultaneously improving soil's physical properties like permeability, water, and air movement, moisture-holding capacities, etc. (Wang *et al*., 2019).

Micronutrients, such as boron, which is essential for foliar fertilization in plants, are required by all plants in very minute quantities. Boron is crucial in the aspects of pollen growth, seed formation, and fertilization rates. It also contributes to sugar transport across cell membranes and cell wall formation, in addition to its role in amino acid biosynthesis. Boron, on the other hand, faces strict limitations in the soils of Iraq, because precipitation and fixation by calcium carbonate renders boron unavailable for the uptake of plants. Foliar application or soil application can efficiently mitigate this problem, wherein foliar nourishment suffices for high-quality crop production (Pandey &Verma, 2017). Yellow maize (*Zea mays*) ranks top among the most important field crops that are important in food production. The grains are enriched with starch, oil, minerals, vitamins, and especially vitamin A, of which concentrations are twenty times higher than in wheat grains. These grains are indispensable for making livestock feed and providing the necessary amino acids needed for the growth of animals (Huthily *et al*., 2020; Abdullah, 2023). On the basis of the Above, the Study Aimed to, Explore the outcome of biofertilizer, organic fertilizer, and foliar boron application on selected yield traits of yellow maize and to analyze the interaction effects among the studied factors on biofertilization, organic fertilization, and boron foliar application in yellow maize on yield traits.

Materials & Methods

The experiment was conducted in the Al-Musayyib project in Babil Governorate in Babylon Governorate, within the coordinates of 32°47'29.6"N latitude and 44°26'21.3"E longitude. The study was carried out on a silty loam soil for the cultivation of yellow corn (*Zea mays* L.), variety (Al-Maha), during the 2023 agricultural season. The objective was to investigate the effects of biofertilizers, organic fertilizers, and boron foliar application on some yield characteristics of yellow corn. Soil samples were collected randomly from different areas of the field at a depth of 0-30 cm before the experiment began. The samples were air-dried, thoroughly crushed using a hammer, and passed through a 2-mm sieve. Composite samples were then prepared and analyzed to determine certain chemical, physical, and biological properties of the soil before planting, as shown in Table (1)

The experiment included three factors: the first factor involved the application of bacterial biofertilizers (a mixture of Azotobacter and Azospirillum bacteria) at two levels (no application and application of biofertilizer). The second factor involved the application of organic fertilizer (fermented sheep manure) at three levels (0, 10, and 20 Mg ha^{-1}). The third factor involved foliar spraying of boron in the form of boric acid (H_3BO_3, 17.4% B) at three levels (0, 75, and 150 mg B L^{-1}). The experiment was laid out in a randomized complete block design (RCBD) with three replications

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

Attributes		Values	Units of measurement
Electrical conductivity (ECe)		3.0	ds m-1
Soil pH (pH)		7.67	
Organic matter		8.71	gm kg-1 soil
Gypsum		2.15	
Lime		211.0	
Cation exchange capacity (CEC)		19.72	cmol kg-1
Available nitrogen		27.84	mg kg-1 soil
Available phosphorus		11.34	
Available potassium		123.61	
Available boron		0.98	
Bulk density		1.31	Mg m-3
Porosity		50.57	
Azotobacter bacteria		0.57×10^6	Cfu gm-1 soil
Azospirillum bacteria		0.98×10^6	
Soil horizons	Sand	29.12	%
	Silt	48.02	
	Clay	22.86	
soil texture		Silty Loam	

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

The experiment was implemented on July 15, 2023, in silty clay loam soil. Yellow corn seeds of the Al-Maha variety, obtained from the Abu Ghraib Agricultural Rescobch Center, were manually planted at a rate of three seeds per hole. After one week of germination, the plants were thinned to one plant per hole. Weeds were manually removed as needed, and the corn stem borer (Sesamia cretica) was controlled using granular Diazinon at a concentration of 10% (5 kg ha^{-1}) in three applications: the first application 20 days after germination, the second application 10 days after the first, and the third application 25 days after the second, with three granules placed in the plant's hcobt.

Half the recommended doses of fertilizer were given for all treatments (Ali, 2012). For nitrogen, urea (46% N) was added at 60 kg N ha^{-1} in two splits, first at planting and the second 30 days after germination. Potassium (41.5% K) was added as potassium sulfate at 37.5 kg ha^{-1} and applied in two equal splits with nitrogen application, mixed into the soil. Phosphorus was applied as triple superphosphate (20% P) at 20 kg ha^{-1} before one-time application and mixing into the soil before planting.

Both Azotobacter and Azospirillum are among the bacterial strains of biofertilizers that were used in this study and are collected from Al-Zaafaraniya Agricultural Research Laboratories. The strains were selected for their well-advertised ability to fix atmospheric nitrogen, which is the basis of very significant improvement in soil fertility and plant growth. Known to fix nitrogen freely, Azotobacter is referred to as free-living nitrogen fixers in soils, whereas Azospirillum has been shown to enhance root development and nutrient uptake mainly nitrogen. The bacteria are also capable of producing growth promoters in terms of auxins and cytokinins, which stimulate root and shoot development thus enhancing yield performance.

Prior to field application, a laboratory germination test was conducted to evaluate the effectiveness of the selected bacterial isolates. The test confirmed their positive impact on seed germination and early seedling vigor, which justified their use in the field experiment.

The seeds were inoculated with the bacterial mixture in a sterilized plastic container for 30 minutes, with the addition of 8% Arabic gum (8 g gum dissolved in 100 ml distilled water) to ensure bacterial adhesion to the seeds. The inoculated seeds were then planted, following the protocol of Vincient (1970). The organic fertilizer (fermented sheep manure) was obtained from the Fadak Farm affiliated with the Al-Husseiniya Shrine and was applied before planting by mixing it into the soil. Irrigation was carried out as needed, and the yellow corn plants were harvested on November 10, 2024, at full maturity. The required measurements were then taken.

- Number of Grains per cob (grains. cob $^{-1}$):

Ten plants were randomly selected from each experimental unit, and the number of grains per cob was counted. This method was adopted from Al-Sahooki.(1990)

- Total Grain Yield (Mg ha^{-1}):

The total grain yield was calculated using the following formula:)Total Grain Yield = Grain Yield per Plant × Plant Density (, This method was based on the approach outlined by Al-Sahooki (1990).

- Biological Yield (Mg ha^{-1})

The plants were cut at soil level and dried at a temperature of 60–70°C until a constant weight was achieved. The dried samples were then weighed using a precision balance. The biological yield was calculated using the following formula: Biological Yield=

Vegetative Biomass Weight + Grain Yield (Ears Weight) by Al-Sahooki (1990).

Table (2): Chemical Properties of Organic Fertilizer (Sheep Manure)

Chemical Properties	Organic Fertilizer (Sheep Manure)
Ph	7.31
Electrical Conductivity (EC)	12.4 dS m^{-1}
Total Nitrogen (N%)	1.68
Total Phosphorus (P%)	0.62
Total Potassium (K%)	1.08
Organic Carbon	31.83
Organic Matter (%)	54.93
C/N Ratio	18.94

Results & Discussion

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

The results in Table (3) indicate the presence of significant differences in the effect of the studied factors on the number of grains per cob. The biofertilization treatment (Azotobacter + Azospirillum) showed a clear advantage, with the highest average of 531.10 grains cob^{-1}. The non-inoculated treatment performed poorly, recording an average of 462.40 grains cob^{-1}, with a significant increase of 14.86% .

Organic fertilization also showed a significant difference, as the 20 Mg ha^{1} treatment had the highest mean of 559.29 grains cob^{-1}, while the control (0 Mg ha ^{1}) treatment recorded the lowest mean of 437.17 grains cob^{-1} with a significant increase of 27.93% .

Boron foliar application at the rate of 150 mg L^{-1} increased the grains cob-1 over the untreated control (0 mg L^{-1}) with a significant increase of 10.62% by attaining a mean of 517.86 grains cob^{-1} .

The results further indicated that every one of the two-way interactions with biofertilization and organic amendments was significant for this trait. With an inoculation of 20 Mg ha^{-1}, the treatment gave the highest mean of 611.54 grains cob^{-1}, whereas the lowest means 426.46 grains cob^{-1} for treatment under non-inoculation with 0 Mg ha^{-1} represent a significant increase of 43.40 %. The highest mean 557.17 grains cob^{-1} was recorded in the treatment of inoculation + 150 mg B L^{-1}, while a non-inoculated + 0 mg B L^{-1} treatment had the lowest mean of 442.54 grains, with an increase of 25.90%. The means under treatment were 581.93 grains cob^{-1} (20 Mg ha^{-1} + 150 mg B L^{-1}) and 415.13 grains cob. -1 (0 Mg ha-^{1} + 0 mg B L-^{1}), thus signifying an increase of 40.18% .

Treatment (inoculation + 20 Mg ha – 1 + 150 mg B L – 1) had the highest mean of 630.52 grains cob – 1, while treatment (non-inoculated + 0 Mg ha – 1 + 0 mg B L – 1) had the lowest mean of 410.15 grains cob – 1 for the three-way interaction of biofertilization, organic fertilization, and application of boron, thus increasing mean grain cob – 1 by about 53.73%.

Total Grain Yield (Mg ha^{-1})

The data in Table (4) show that the effect of the monitored parameters on total plant yield varied with respect to the factors. The biofertilization treatment (Azotobacter + Azospirillum) yielded much better results than all other treatments. It achieved the best overall mean yield of 7.23 Mg ha^{-1}, while non-inoculated treatment had the lowest mean of 6.08 Mg ha^{-1}, which increased significantly by 18.91%.

Among the organic fertilization treatments, treatment with 20 Mg ha^{-1} was highly improved over control treatments with 0 Mg ha^{-1}. At 20 Mg ha^{-1}, it produced the highest mean value of 7.46 Mg ha^{-1}, while control treatment recorded the lowest mean value of 5.87 Mg ha^{-1}, amounting to an increase by about 27.08% .

Table (3): 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) 0	75	150	Average
Without inoculation	0	410.15	430.67	438.55	426.46
	10	443.63	453.70	463.77	453.70
	20	473.85	513.92	533.33	507.03
Inoculation (Azotobacter+ Azospirillum)	0	420.11	453.22	470.33	447.89
	10	480.44	550.55	570.66	533.88
	20	580.77	623.33	630.52	611.54
LSD0.05		4.97			2.87
		Biological x boron			Average
Without inoculation		442.54	466.10	478.55	462.40
Inoculation (Azotobacter + Azospirillum)		493.77	542.37	557.17	531.10
LSD0.05		2.87			1.66
		Organic x boron			Average
0		415.13	441.94	454.44	437.17
10		462.03	502.13	517.22	493.79
20		527.31	568.63	581.93	559.29
LSD0.05		3.52			2.03
Average of boron		468.16	504.23	517.86	
LSD0.05		2.03			

Compared to the various control treatments of untreated among which the lowest mean of 6.23 Mg ha⁻¹ was attained-which reflected an increase of 11.24% over control treatments-the treatment with boron foliar application at 150 mg L⁻¹ was significantly superior. The results also revealed that all two-way interactions between biofertilization and organic fertilization were indeed very significant for this trait. The (inoculated + 20 Mg ha⁻¹) treatment showed a higher expression of 49.36% compared to the lowest mean of 5.43 Mg ha⁻¹ non-inoculated control with 0 Mg ha⁻¹, which had a highest of 8.11 Mg ha⁻¹. In addition, the (inoculation + 150 mg B L⁻¹) treatment, with a mean of 7.56 Mg ha⁻¹, was highly distinguished from (non-inoculated + 0 mg B L⁻¹) treatment mean of 5.77 Mg ha⁻¹, representing an increase of 31.02%. Similarly, the (20 Mg ha⁻¹ + 150 mg B L⁻¹) treatment was the highest at 7.75 Mg ha⁻¹, while the (0 Mg ha⁻¹ + 0 mg B L⁻¹) treatment had the lowest average of 5.33 Mg ha⁻¹; thus, the increased mean of 45.40% was significant .

For the evaluation of the three-way interaction among biofertilization, organic fertilization, and boron application, the treatment (inoculation + 20 Mg ha⁻¹ + 150 mg B L⁻¹) obtained significant highest means of 8.43 Mg ha⁻¹ compared to (non-inoculated + 0 Mg ha⁻¹ + 0 mg B L⁻¹) treatment that attained the lowest mean of 5.07 Mg ha⁻¹; increment was significant at 66.27%

Table (4): Effect of Biofertilization, Organic Fertilization, and Boron Spraying and Their Interactions on Total Grain Yield (Mg ha⁻¹)

Biological fertilization	Organic fertilization (Mg ha-1)	Boron (mg L-1) 0	75	150	Average
Without inoculation	0	5.07	5.57	5.67	5.43
	10	5.77	6.07	6.17	6.00
	20	6.47	6.92	7.07	6.82
Inoculation (Azotobacter+ Azospirillum)	0	5.60	6.60	6.72	6.31
	10	6.90	7.40	7.52	7.27
	20	7.60	8.30	8.43	8.11
LSD0.05		0.076			0.044
		Biological x boron			Average
Without inoculation		5.77	6.18	6.30	6.08
Inoculation (Azotobacter + Azospirillum)		6.70	7.43	7.56	7.23
LSD0.05		0.044			0.025
		Organic x boron			Average
0		5.33	6.08	6.19	5.87
10		6.33	6.73	6.84	6.64
20		7.03	7.61	7.75	7.46
LSD0.05		0.054			0.031
Average of boron		6.23	6.81	6.93	
LSD0.05		0.031			

Biological Yield (Mg ha⁻¹)

The results in Table (5) indicate significant differences in the effect of the studied factors on biological yield. The biofertilization treatment (Azotobacter + Azospirillum) significantly outperformed, achieving the highest mean of 15.11 Mg ha^{-1}, while the non-inoculated treatment recorded the lowest mean of 12.88 Mg ha^{-1}, with a significant increase of 17.31%.

Regarding organic fertilization, the 20 Mg ha^{-1} treatment exhibited a significant advantage, producing the highest mean of 15.69 Mg ha^{-1}, compared to the control (0 Mg ha^{-1}) treatment, which resulted in the lowest mean of 12.40 Mg ha^{-1}, reflecting a significant increase of 26.53%.

For boron foliar application, the 150 mg L^{-1} treatment significantly outperformed, yielding the highest mean of 14.63 Mg ha^{-1}, compared to the untreated control (0 mg L^{-1}), which recorded the lowest mean of 13.23 Mg ha^{-1}.

Table (5): Effect of Biofertilization, Organic Fertilization, and Boron Spraying and Their Interactions on Biological Yield (Mg ha^{-1})

Biological fertilization	Organic fertilization (Mg ha-1)	Boron (mg L-1) 0	75	150	Average
Without inoculation	0	11.14	11.89	12.04	11.69
	10	12.20	12.55	12.96	12.57
	20	13.58	14.42	15.18	14.40
Inoculation (Azotobacter+ Azospirillum)	0	11.97	13.30	14.08	13.12
	10	14.59	15.40	15.70	15.23
	20	15.91	17.22	17.83	16.99
LSD0.05			0.315		0.182
			Biological x boron		Average
Without inoculation		12.31	12.95	13.39	12.88
Inoculation (Azotobacter + Azospirillum)		14.16	15.31	15.87	15.11
LSD0.05			0.182		0.105
			Organic x boron		Average
0		11.56	12.59	13.06	12.40
10		13.39	13.97	14.33	13.90
20		14.75	15.82	16.51	15.69
LSD0.05			0.223		0.129
Average of boron		13.23	14.13	14.63	
LSD0.05			0.129		

The results also demonstrated that all two-way interactions between biofertilization and organic fertilization were significant for this trait. The (inoculation + 20 Mg ha^{-1}) treatment yielded the highest mean of 16.99 Mg ha^{-1}, compared to the (non-inoculated + 0 Mg ha^{-1}) treatment, which recorded the lowest mean of 11.69 Mg ha^{-1}, reflecting a significant increase of 45.34%. Additionally, the (inoculation + 150 mg B L^{-1}) treatment showed the highest mean of 15.87 Mg ha^{-1}, compared to the (non-inoculated + 0 mg B L^{-1}) treatment, which recorded the lowest mean of 12.31 Mg ha^{-1}, with a significant increase of 28.92%. Similarly, the (20 Mg ha^{-1} + 150 mg B L^{-1}) treatment achieved the highest mean of 16.51 Mg ha^{-1}, compared to the (0 Mg ha^{-1} + 0 mg B L^{-1}) treatment, which yielded the lowest mean of 11.56 Mg ha^{-1}, with a significant increase of 42.82%.

For the three-way interaction between biofertilization, organic fertilization, and boron application, the (inoculation + 20 Mg ha^{-1} + 150 mg B L^{-1}) treatment significantly outperformed, achieving the highest mean of 17.83 Mg ha^{-1}, compared to the (non-inoculated + 0 Mg ha^{-1} + 0 mg B L^{-1}) treatment, which recorded the lowest mean of 11.14 Mg ha^{-1}, with a significant increase of 60.05%.

Discussion

The results presented in Tables (1, 2, and 3) indicate that seed inoculation with Azotobacter and Azospirillum bacteria led to a significant increase in certain yield traits, including the number of grains per year, total yield, and biological yield. This can be attributed to the role of microorganisms in decomposing organic matter, releasing both macronutrients and micronutrients in an available from within the root zone, allowing for their absorption by plants from the early growth stages. This process enhances vegetative growth, which in turn increases the production of photosynthetic assimilates from the source (leaves) to the reproductive stage, thereby supporting and enriching the grains with essential nutrients, leading to an increase in their number (Shamaa, 2014; Faqeera & Al-Shaabi, 2015; Ajeel & Al-Hakeim, 2024).

Additionally, the bacteria's ability to secrete organic acids, including mono-, di-, and tricarboxylic acids, plays a crucial role in modifying the pH of the rhizosphere, thereby increasing the availability of phosphorus, nitrogen, and potassium. Furthermore, the bacteria produce growth-promoting hormones that stimulate root development and enhance nutrient uptake, ultimately contributing to the overall biological yield. These findings are consistent with the results reported by (Ahmed, 2019; Sahan, 2019; Reddy *et al*., 2023; Sahib, 2024).

The results also demonstrated that the addition of organic fertilizer significantly enhanced the aforementioned yield traits. This improvement can be attributed to the increased availability of soil nutrients, which facilitates their absorption by plants, thereby positively influencing plant growth indicators such as plant height, leaf area, and grain yield. Organic fertilization plays a crucial role in improving soil chemical and physical properties, promoting root penetration, and increasing the population of beneficial soil microorganisms. Consequently, these factors contribute to the release and availability of essential nutrients, thereby fulfilling plant nutritional requirements, leading to enhanced dry matter accumulation. This, in turn, stimulates the development of secondary ears, allowing them to reach full maturity, ultimately reflecting positively on the total biological yield. These findings are in agreement with those reported by (Ahmed, 2019; Sahan, 2019; Hammoud, 2021; Ajeel & Al-Hakeim, 2024).

Furthermore, the results indicate that foliar application of boron in the form of boric acid significantly increased the studied yield traits. This effect is primarily due to boron's role in cell division and growth, leading to an increase in ear size and grain number per ear. Additionally, boron plays a vital role in the translocation of carbohydrates from the source to the sink, ensuring their availability at the appropriate time for growth centers. Another possible explanation is its role in enhancing pollen tube growth and fertilization, as well as promoting the elongation of silk cells at the ear tip during the period when pollen grains are ready for fertilization, ultimately leading to an increase in grain number (Abu-Dhahi &mohammed,2013; Khreibet *et al*., 2014).

Moreover, boron influences enzymatic activity, promoting root growth and enhancing the absorption of macronutrients and micronutrients from the soil, thereby increasing their concentration in plant tissues (leaves and grains). This increase in nutrient availability enhances plant growth and yield traits, ultimately improving total biological yield. However, it is important to note that excessive concentrations of boron can become toxic to plants, leading to leaf burn, chlorosis, and reduced growth, depending on plant species and soil conditions. These findings align with the results reported by Karbol & Al-Dulaimi (2017) and Jawad (2019).

Conclusions

Based on the results of this study, the following conclusions can be made:

1.Seed inoculation with a combination of Azotobacter and Azospirillum significantly improved all studied parameters, confirming the beneficial role of biofertilization in enhancing maize growth and productivity. However, the study did not evaluate reduced inoculation rates or potential efficiency plateaus, which should be addressed in future work.

2.The application of organic fertilizer in the form of sheep manure at 20 Mg ha^{-1} led to significant improvements in all traits. Despite this, the study did not test lower application rates to determine the minimum effective dose or assess the long-term impact of continuous use on soil properties.

3.Foliar application of boron at 150 mg L^{-1} resulted in a marked improvement in all measured traits. Yet, the potential toxicity effects at higher concentrations were not examined, leaving a knowledge gap regarding the optimal and safe range for boron application in maize.

4.The interaction between biofertilizers, organic manure, and boron application produced significant effects on all parameters, suggesting a synergistic relationship. Nevertheless, the absence of treatments with reduced or omitted inputs limits the ability to determine whether such interactions could compensate for lower individual application rates.

Acknowledgements

The authors would like to express their sincere thanks and appreciation to Mr. Hakim Al-Maamouri, the farm owner, for providing the research site and essential resources needed for the fieldwork, and for his ongoing support during the study period. Special gratitude is also extended to Prof. Dr. Hameed Kazem for his scientific supervision and valuable input that helped shape the direction of this research. The authors are also thankful to Asst. Prof. Mohammed Tarqan Abu Al-Mikh for his statistical analysis and his contribution to the accuracy and reliability of the results. Appreciation is extended to all individuals who provided technical or moral support throughout the research.

Contributions of authors

M.R.A: Collection of specimens, laboratory techniques, writing and revision of the manuscript.

M.M.H: Proposed the research idea, contributed to writing and revising the manuscript, and participated in field experiment setup.

I.R.A: Assisted in writing and reviewing the manuscript, and contributed to technical supervision and coordination.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval

All procedures involving plant care and field management complied with standard agricultural research ethics.

References

Aasfar, A., Kadmiri, I. M., Azaroual, S. E., Lemriss, S., El Mernissi, N., Bargaz, A., Zeroual, Y., & Hilali, A. (2024). Agronomic advantage of bacterial biological nitrogen fixation on wheat plant growth under contrasting nitrogen and phosphorus regimes. *Frontiers in Plant Science*, 15, 1388775. https://doi.org/10.3389/fpls.2024.1388775

Abdel-Mawgoud, A. M. R., El-Naggar, A. H., & El-Sayed, S. A. (2020). The integration of bio and organic fertilizers improve plant growth, grain yield, quality and metabolism of hybrid maize (*Zea mays* L.). *Agronomy*, 10(3), 319. https://doi.org/10.3390/agronomy10030319

Abdullah, D. F. (2023). Evaluation of the Agricultural Reality of the Industrial Yellow Corn Crop in the Iraqi Province of Kirkuk. *In IOP Conference Series: Earth and Environmental Science* (Vol. 1262, No. 10, p. 102012). IOP Publishing. https://doi.org/10.1088/1755-1315/1262/10/102012

Abu Dhahi, Y. M., & Mohammed, H. A. (2013). The role of foliar application of manganese and boron under water stress conditions on maize (*Zea mays* L.) yield traits and water use efficiency. *Diyala Journal of Agricultural Sciences*, 5(1), 239–250. https://iasj.rdd.edu.iq/journals/journal/issue/12902

AG, B., Rashwan, E., & El-Sharkawy, T. A. (2017). Effect of organic manure, antioxidant and proline on corn (*Zea mays* L.) grown under saline conditions. *Environment, Biodiversity and Soil Security*, 1(2017), 203-217. https://doi.org/10.21608/jenvbs.2018.2513.1021

Ajeel, M. R., & Al-Hakeim, M. S. (2024). The Influence of Biological and Organic Fertilization and Boron Spraying in Some Soil Characteristics. *In IOP Conference Series: Earth and Environmental Science* (Vol. 1371, No. 8, p. 082022). IOP Publishing. https://doi.org/10.1088/1755-1315/1371/8/082022

Baral, B. R., & Adhikari, P. (2013). Effect of Azotobacter on growth and yield of maize. *SAARC Journal of Agriculture*, 11(2), 141-147. https://doi.org/10.3329/sja.v11i2.18409

Bayar, J., Shah, S., Khan, W., Ali, S., Ahmad, M., & Khan, A. (2024). Boron foliar application improves growth, yield and grain quality of maize. *Polish Journal of Environmental Studies*, 33(3), 3079–3089. https://doi.org/10.15244/pjoes/177183

Bhateria, R., Rimmy, Yogita, & Kumar, S. (2022). Role of Plant–Microbe Interactions in Combating Salinity Stress. In Plant Stress Mitigators: Action and Application (pp. 259-280). Singapore*: Springer Nature Singapore*. https://doi.org/10.1007/978-981-16-7759-5_13

Fakirah, A. B., & Alshabi, G. (2015). Effect of Different Levels of Bio-fertilizer and Plant Population on the Grain Yield and Yield Components of Corn (*Zea mays*. L). *Jordan Journal of Agricultural Sciences*, 11(2). https://doi.org/10.12816/0030446

García-Fraile, P., Menéndez, E., and Rivas, R. (2015). Role of bacterial biofertilizers in agriculture and forestry. *Aims Bioengineering*, 2(3), 183-205. https://doi.org/10.3934/bioeng.2015.3.183

Gerdemann, J. W., & Nicolson, T. H. (1963). Spores of mycorrhizal Endogone species extracted from soil by wet sieving and decanting. *Transactions of the British Mycological Society*, 46(2), 235–244. https://doi.org/10.1016/S0007-1536(63)80079-0

Huthily, K. H., Al-Dogagy, K. A., & Kalaf, M. A. (2020). Effect of nitrogen fertilization and foliar application of zinc in growth and yield of maize (*Zea Mays* L.). *International Journal of Agricultural Stat. Science*, 16, 1375-1380. https://connectjournals.com/03899.2020.16.1375

Khan, K. S., Ali, M. M., Naveed, M., Rehmani, M. I. A., Shafique, M. W., Ali, H. M., Abdelsalam, N. R., Ghareeb, R. Y., & Feng, G. (2022). Co-application of organic amendments and inorganic P increase maize growth and soil carbon, phosphorus availability in calcareous soil. *Frontiers in Environmental Science*, 10, 949371. https://doi.org/10.3389/fenvs.2022.949371

Khreibet, H. K., Saleh, H. A., & Shalal, H. K. (2014). Boron spraying and its effect on grain yield and its components in sorghum. *Iraqi Journal of Agricultural Sciences*, 45(5), 470-478. https://www.iraqoaj.net/iasj/article/222318

Kumar, P. A., Mehera , B., & Kumar , P. (2023). Effect of Foliar Application of Boron and Silicon on Growth and Yield of Maize (*Zea mays* L.). *International Journal of Plant & Soil Science*, 35(14), 256–262. https://doi.org/10.9734/ijpss/2023/v35i143043

Pandey, A. N. and P. Verma.(2017). Boron deficiency and toxicity and their tolerance in plants: a review. *Journal of Global Biosciences.* 6(4): 4958-4965. https://jgb.uorajg.in/index.php/jgb/article/view/4958

Reddy, S. R. P. K., Debbarma, V., and Reddy, K. (2023). Influence of Biofertilizers and Organic Liquid Nutrients on Growth, Yield and Economics of Maize (*Zea mays L.*). *International Journal of Environment and Climate Chang*e, 13(7), 724-731. https://doi.org/10.9734/ijecc/2023/v13i71925

Sahib, M. R. A. A. M. (2024). The Influencer of Biological and Organic Fertilization and Boron Spraying in Some Growth and Yield Properties of Maize. *Euphrates Journal of Agricultural Science*, 16(1). https://iasj.rdd.edu.iq/journals/journal/issue/15234

Sahouki, M. M. (1990). Yellow maize: Its production and improvement .University of Baghdad, Ministry of Higher Education and Scientific Research, Iraq, p. 488.

Vincent, J. M. (1970). A manual for the practical study of root-nodule bacteria (IBP Handbook No. 15). Oxford: Blackwell Scientific Publications. https://archive.org/details/manualforpractic0000vinc

Wang, J., Sun, N., Xu, M., Wang, S., Zhang, J., Cai, Z., & Cheng, Y. (2019). The influence of long-term animal manure and crop residue application on abiotic and biotic N immobilization in an acidified agricultural soil. *Geoderma*, 337. 710-717. https://doi.org/10.1016/j.geoderma.2018.10.022

تأثير الأسمدة الحيوية والعضوية والرش الورقي بالبورون في بعض صفات الحاصل لنبات الذرة الصفراء (*Zea mays L.*)

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المستخلص: أُجريت هذه الدراسة تحت ظروف تربة مزيجية غرينية في موقع مشروع المسيب (محافظة بابل، العراق) خلال الفترة من 15 تموز إلى 10 تشرين الثاني 2024، بهدف تقييم التأثيرات التفاعلية للأسمدة الحيوية، والسماد العضوي المضاف، والرش الورقي بالبورون في بعض صفات حاصل الذرة الصفراء (Zea mays L. الصنف المها). نُفذَت التجربة باستخدام تصميم القطاعات العشوائية الكاملة (RCBD) وفق ترتيب عاملي بثلاثة عوامل: تلقيح البذور ببكتيريا Azotobacter وAzospirillum (غير ملقحة، ملقحة)، وإضافة سماد أغنام بمستويات 0، 10، و20 ميكاغرام هـ$^{-1}$، والرش الورقي بحمض البوريك كمصدر للبورون بتركيزات 0، 75، و150 ملغم لتر$^{-1}$. أظهر التلقيح الحيوي عند دمجه مع المستويات العالية من السماد العضوي والرش الورقي بالبورون استجابات كبيرة في أهم مكونات الحاصل مثل حاصل المادة الجافة، وعدد الحبوب في العرنوص، والحاصل الكلي من الحبوب. وسجل التفاعل الثلاثي بين المعاملات تأثيرًا معنويًا متداخلًا في جميع الصفات المدروسة للحاصل. وتشير النتائج إلى إمكانية اعتماد الإدارة المتكاملة للعناصر الغذائية لتحسين إنتاجية الذرة الصفراء تحت ظروف التربة الغرينية المزيجية، كخيار بديل عملي عن الأساليب التقليدية في التسميد.

الكلمات المفتاحية: سماد حيوي، سماد عضوي، رش ورقي، حمض البوريك، الذرة الصفراء.