Effect of adding biofertilizer, fulvic acid and spraying with silicon on the growth and yield of corn *Zea mays* L

Saif Salah Al-Madhee and Waleed F. Hassan

Faculty of Agriculture, University of Kufa. Department of Soil Science & Water, Kufa, Iraq.
Corresponding Author: saifs.almadhee@student.uokufa.edu.iq Co-Author:
waleed.almayahi@uokufa.edu.iq

Abstract

A field experiment was conducted in the Kufa region of Najaf province during the autumn season of 2025 on a sandy loam soil to study the effect of adding biofertilizer, fulvic acid, and silicon spray on some growth and yield characteristics of corn (*Zea mays* L).A factorial experiment was used, and the treatments were distributed according to a randomized complete block design (RCBD). The three factors included: the first factor was the addition of biofertilizer at two concentrations (no addition and addition), designated as (B_0 and B_1); the second factor was the addition of fulvic acid at three concentrations (0, 8, and 16 L ha^{-1}), designated as (F_0 , F_1 , and F_2); and the third factor was silicon spraying at three Concentrations (0, 0.4, and 0.8 L ha^{-1}), designated as (S_0 , S_1 , and S_2). The results showed the following:The treatment with biofertilizer significantly excelled on without biofertilizer treatment in plant height, leaf area, chlorophyll content, dry matter yield, number of rows per cob, number of grains per row, grain yield, and biological yield, with increases of 5.64%, 8.45%, 6.61%, 36.10%, 19.45%, 14.98%, 12.95%, and 25.04%, respectively.The results showed that adding fulvic acid at a concentration of 16 L ha^{-1} significantly affected most growth and yield traits, with increases of 9.09%, 8.23%, 11.90%, 41.50%, 30.54%, 15.89%, 19.32%, and 40.50% for plant height, leaf area, chlorophyll content, dry matter yield, number of rows per ear, number of grains per row, grain yield, and biological yield, respectively.The results showed that spraying with silica at a Concentration of 0.8 L ha^{-1} significantly affected most growth and yield traits.The interaction between biofertilizer, fulvic acid, and silica spray significantly affected most of the studied plant traits. The treatment (B2F2S2) achieved the best values for most growth and yield traits of corn under the conditions of the study area.

Key words: biofertilizer, fulvic acid , silicon, Zea mays

Introduction

Achieving food security and increasing agricultural production has become one of the most significant challenges facing the world, given the continuous population growth and declining efficiency of natural resources. This necessitates the adoption of modern agricultural technologies that contribute to increased crop productivity while preserving soil fertility and mitigating negative environmental impacts. This has led to a shift towards adopting integrated nutrient management programs that combine production efficiency with the preservation of natural resource sustainability [5].Biofertilizers are among the most important modern agricultural technologies that have garnered increasing attention due to their crucial role in improving soil fertility and increasing the availability of nutrients to plants. They contain beneficial microorganisms such as the bacteria Chroococcum (Azotobacter) and Azospirillum (Brasilense), which are capable of fixing atmospheric nitrogen, solubilizing phosphorus,

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and secreting plant growth regulators. This stimulates root growth and increases the efficiency of water and nutrient absorption. These microorganisms contribute to stimulating biological activity in the rhizosphere, improving soil structure, and increasing organic matter content. This positively impacts plant growth and yield, in addition to reducing reliance on chemical fertilizers and achieving sustainable agriculture (Kumar et al., 2024).Fulvic acid is a major component of humic substances. Its low molecular weight and high water solubility give it a strong ability to form complexes with nutrients and maintain them in a form readily available for plant uptake. It improves the chemical and biological properties of the soil by increasing microbial activity, enhancing root growth, and increasing nutrient uptake. Furthermore, it activates physiological processes within the plant, improves photosynthetic efficiency, and increases dry matter accumulation, ultimately leading to improved growth, yield, and crop quality [13].Silicon is a beneficial element for plants, playing a vital role in enhancing growth and productivity by increasing the efficiency of photosynthesis, strengthening cell walls, and improving nutrient absorption and utilization. It also contributes to improved water balance within the plant and enhances its tolerance to adverse environmental conditions. Silicon spraying activates physiological processes and reduces damage caused by various stresses, positively impacting vegetative growth, dry matter accumulation, and yield composition. Studies have shown that using silicon compounds improves the growth and productivity of corn under different environmental conditions, highlighting the importance of incorporating it into integrated nutrient management programs [10] .corn (Zea mays L.) is one of the world's most important cereal crops due to its significant nutritional and economic value. It is used in human and animal feed, as well as in various food industries, and in the production of animal feed, starch, oils, and biofuels. It is characterized by its high productivity and clear responsiveness to modern fertilization and agricultural management programs. (Al-Omar et al., 2023).This study aims to determine the effect of adding biofertilizer, fulvic acid, and silicon spraying on the growth and yield of corn.

Materials and Methods

Experimental Location and Field Soil Description

A field experiment was conducted to study the effect of biofertilizer, fulvic acid, and silicon spraying on the growth and yield of corn. The experiment was carried out in Najaf province, specifically in Kufa, near the Ministry of Trade, Najaf Branch/Kufa Silo, during the autumn season of 2025. The location is at longitude (44.406191) and latitude (32.049402), in a sandy loam soil classified, according to the modern American classification, as below the maximum aggregate concentration (Torrifluvent) according to the international classification [18].

Experimental Design

The Study was conducted as a factorial experiment (2×3×3) using a randomized complete block design (RCBD). It included 18 treatments with three replicates (2×3×3×3), resulting in a total of 54 experimental units

Experimental Factors:

The experiment included three main factors:

factor 1:Isolation of a group of Azospirillum brasilence bacteria at a concentration of (7.86×10^9) cells/ml and of Azotobacter chroccocum bacteria at a concentration of 13.12×10^9 cells/ml. Two concentrations of application were carried out (no application and application), represented as (B0 and B1).

Factor 2:Fulvic acid was added to the soil along with the irrigation water at concentrations of (0, 8, and 16) L ha^{-1}, designated (0F, F1, and 2F), and its traits are listed in Table (2).

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Factor 3:Spraying the plants with silicon at Concentrations of (0, 0.4, and 0.8) L ha^{-1}, designated (S0, S1, and S2), and its traits are listed in Table (3).

Table (1) Some chemical and physical properties of the soil before the study.

units	values	traits
-	7.14	Soil pH
$DS.m^{-1}$	2.5	Electrical conductivity EC (1:1)
% meq of 100g $soil^{-1}$	12.0	Cationic ion exchange capacity CEC
%	3.2	Organic matter SOM
	0.55	Gypsum
	26.5	Carbonate minerals
available nutrient content		
$mg.kg^{-1}$	23.2	Nitrogen
	40.5	Phosphorus
	190.3	Potassium
dissolved ions		
mmol L^{-1}	1.75	Calcium
	2.39	Magnesium
	7.93	Potassium
	2.00	Sodium
	0.00	Carbonate
	16.72	Bicarbonate
	1.54	Sulfate
	1.97	Chloride
Soil separators		
%	4.23	Clay
	33.69	Silt
	62.07	Sand
Sandy Clay loam		texture
$Mg.m^{-2}$	1.15	Apparent density
$g.k^{-1}$	185.0	Field capacity
CFU × 10^4 g soil	110	Total number of organisms

Table (2) Some properties of fulvic acid

O.M %	K2O %	Total humic acid and folic acid	Organic carbon %	N %	K %
45-58.5	4-5.2	32-41.6	26	2.3-3.0	3.32-4.316

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Table (3) Some Properties of Silicon

Main Active Ingredient	Total Concentration of Active Ingredient	Soluble Potassium Oxide (K_2O)	Silicon Dioxide (SiO_2)	Specific Gravity / Density
Potassium Silicate)	35%	12%	19%	1.28 - 1.32 $g.cm^3$

Soil Preparation

The soil was plowed with a moldboard plow and harrowed using disc harrows. The field was divided into 2 x 3 m plots for each experimental unit, with 2.5 m spacing between plots to prevent fertilizer runoff and control water movement between plots. Random soil samples were taken from the 0-30 cm topsoil layer. After removing plant debris, the soil was air-dried, ground with a wooden mallet, passed through a 2 mm sieve, and thoroughly mixed to homogenize it. Homogenized samples were taken for chemical and physical analyses, the results of which are shown in Table 1.

cultivation

Maha cultivar, supplied by the Agricultural Division in Baghdad on July 25, 2025, were sown in rows within the plots with space between each one 75 cm and 25 cm between one plant and another at a rate of four rows per experimental unit. Two to three seeds were placed in each planting hole, and the plants were thinned to one plant per hole two weeks after emergence. The experimental unit had 32 plants, resulting in a plant density of 53.333 plants . ha^{-1}. Granular diazinon at a concentration of 10% (5 kg ha^{-1}) was used to control the corn stem borer (Sesamin cretica) twice: the first application 20 days after germination and the second 15 days after the first application, applied in the center of the third and fourth leaves . Nitrogen fertilizer was applied at a rate of 250 kg N ha^{-1} in the form of urea (46% N), phosphate fertilizer at a rate of 100 kg P ha^{-1} in the form of triple superphosphate, and potassium fertilizer at a rate of 100 kg K ha^{-1} in the form of potassium sulfate (41% K), according to the Ministry of Agriculture's recommendations.

studied traits

.Plant Height (cm) ,Leaf Area (m^2 $plant^{-1}$) ,Chlorophyll Measurement (mg.g plant), Biological Yield (Mg ha^{-1}), Number of Rows per cob (rows $.cob^{-1}$),Number of grains per row (grain . row^{-1}),Grain Yield (Mg ha^{-1}),Harvest Index %:

Statistical Analysis:

The results of the experiment were statistically analyzed according to the method of analysis of variance (ANOVA), and the significant differences between the means of the treatments were calculated using the least significant difference test at the concentration of 0.05 [3] using the SAS program in the statistical analysis.

Results and discussion

Plant Height (cm)

The results in Table (4) show that adding biofertilizer significantly increased plant height. Treatment (B1), which recorded an average height of 153.22 cm, excelled on the treatment (B0), which recorded 145.04 cm, representing a 5.64% increase.The results also showed that adding fulvic acid significantly increased plant height. The application concentration of 16 L ha^1 recorded the highest average height of 155.40 cm, while the average heights were 149.54 cm and 142.45 cm at the application concentrations of 8 L ha^{-1} and no application, respectively. The percentage increase at the 16 L ha^1

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concentration compared to the no application concentration and the 8 L ha^{-1} concentration was approximately 9.09% and 3.92%, respectively. Regarding the effect of silicon spraying, it was found that the 0.8 L ha¹ treatment significantly excelled the 0 and 0.4 L ha¹ concentrations, with results of (132.80, 155.96, and 158.63) cm³ at spray concentrations S0, S1, and S2, respectively. This represents an increase of 19.45% and 1.71% for the 0.8 L ha¹ concentration compared to concentrations 0 and 0.4 L ha¹, respectively.Significant differences were observed in the interaction between the biofertilizer and fulvic acid. Treatment B1F2 recorded the highest average at 160.30 cm³, while treatment B0F0 recorded the lowest average at 140.83 cm³, representing a 13.83% increase for excelled on treatment compared to the lowest treatment. The interaction between fulvic acid and silicon spraying showed significant differences, with treatment F2S2 achieving the highest average height of 168.95 cm, while treatment F0S0 recorded the lowest average height of 124.30 cm, representing an increase of 35.92%.The interaction between biofertilizer and silicon spraying also showed significant differences, with treatment B1S2 recording the highest average height of 165.50 cm, while treatment B1S0 recorded the lowest average height of 131.40 cm, representing an increase of 25.95%.The triple interaction between the studied factors also showed clear significant differences, with treatment B1F2S2 recording the highest value of 175.60 cm, while treatment B0F0S0 gave the lowest value of 123.00 cm, representing an increase of 42.76%.

Table (4) effect of biofertilizer, fulvic acid, silicon spraying, and their interactions on plant height (cm).

Average interaction of biofertilizer and fulvic acid	silicon spraying			fulvic acid	Biofertilizer
	S2	S1	S0	F	B
140.83	150.00	149.50	123.00	F0	
143.78	143.00	138.33	150.00	F1	
150.50	162.30	159.60	129.60	F2	B0
144.07	151.60	155.00	125.60	F0	
155.30	169.30	163.00	133.60	F1	
160.30	175.60	170.30	135.00	F2	B1
2.464	4.268			LSD	
Average biofertilizer	silicon spraying			interaction with silicon-based biofertilizer spraying	
	S2	S1	S0		
145.04	151.77	149.14	134.20	B0	
153.22	165.50	162.77	131.40	B1	
1.423	2.464			LSD	

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average fulvic acid	silicon spraying			eraction of fulvic acid and silicone spraying
	S2	S1	S0	
142.45	150.80	152.25	124.30	F0
149.54	156.15	150.67	141.80	F1
155.40	168.95	164.95	132.30	F2
1.742	3.018			LSD
	.158.63	155.96	132.80	average silicon spraying
	1.742			LSD

Leaf Area (m^2 $plant^{-1}$)

The results in Table (5) show that adding biofertilizer significantly increased the leaf area per plant. Treatment (B1), which recorded an average of 0.44 m^2 plant-1, was excelled on treatment (B0), which recorded 0.41 m^2 $plant^{-1}$, representing an increase of 8.45%.The results also showed that adding fulvic acid significantly increased the leaf area. The application concentration of 16 L ha-¹ recorded the highest average of 0.44 m^2 $plant^{-1}$, while the averages were recorded 0.43 and 0.413 m^2 $plant^{-1}$ at the application concentrations of 8 L ha¹ and no application, respectively. The increase at the 16 L ha^{-1} concentration, compared to the no-adding and the 8 L ha^{-1} concentration, was approximately 8.23% and 2.76%, respectively. Silicon spraying had a significant effect on increasing the plant's leaf area. The 0.8 L ha^{-1} spray concentration achieved the highest average of 0.47 m^2 $plant^{-1}$, followed by the 0.4 L ha^{-1} concentration, which recorded 0.43 m^2 $plant^{-1}$. The no-spray treatment recorded the lowest average of 0.38 m^2 $plant^{-1}$. The 0.8 L ha^{-1} concentration excelled on the no-spray and 0.4 L ha^{-1} treatments by 24.22% and 9.66%, respectively. The interaction between biofertilizer and silicon spraying showed significant differences, with treatment B1S2 recording the highest average at 0.48 m^2.plant¹, while treatment B0S0 recorded the lowest average at 0.35 m^2.plant¹, representing an increase of 37.11%.Similarly, triple interaction between the studied factors showed clear significant differences, with treatment B1F2S2 recording the highest value at 0.50 m^2/plant¹, while treatment B0F0S0 recorded the lowest value at 0.29 m^2.plant¹, representing an increase of 75.52%.

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Table (5) Effect of Biofertilizer, Fulvic Acid, Silicon Spraying, and their Interactions on the Leaf Area of Corn (m^2.plant^1)

Average interaction of biofertilizer and fulvic acid	silicon spraying			fulvic acid	Biofertilizer
	S2	S1	S0	F	B
0.39	0.46	0.42	0.29	F0	B0
0.42	0.46	0.42	0.37	F1	
0.43	0.47	0.42	0.39	F2	
0.43	0.45	0.43	0.41	F0	B1
0.44	0.48	0.45	0.40	F1	
0.46	0.50	0.46	0.41	F2	
N.S	0.0239			LSD	
Average biofertilizer	silicon spraying			The interaction of bio-fertilizer and silicone spraying	
	S2	S1	S0		
0.41	0.46	0.42	0.35	B0	
0.44	0.48	0.44	0.41	B1	
0.0079	0.0138			LSD	
average fulvic acid	silicon spraying			eraction of fulvic acid and silicone spraying	
	S2	S1	S0		
0.41	0.46	0.42	0.35	F0	
0.43	0.47	0.43	0.39	F1	
0.44	0.49	0.44	0.40	F2	
0.0097	N.S			LSD	
	0.47	0.43	0.38	average silicon spraying	
	0.0097			LSD	

Total Chlorophyll Concentration (mg/g plant):

The results in Table (6) show that the addition of biofertilizer led to a significant increase in

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total chlorophyll concentration in the leaves. Treatment (B1), which recorded an average of 1.48 mg/g, was excelled on treatment (B0), which recorded 1.39 mg/g, representing an increase of 6.61%.The results also showed a significant effect of fulvic acid in increasing total chlorophyll concentration in the leaves. Concentration F2 recorded the highest average of 1.49 mg.g, compared to concentrations F1 and F0, which recorded 1.48 and 1.33 mg/g, respectively. The percentage increase for concentration F2 was approximately 11.90% and 1.01%, compared to concentrations F0 and F1, respectively. Regarding the effect of silicon spraying, it was found that the 0.8 L/ha treatment significantly excelled the 0 and 0.4 L/ha concentrations, with values of 1.39, 1.44, and 1.47 mg.g at spray concentrations S0, S1, and S2, respectively. This represents an increase of 5.67% and 1.94% for the 0.8 L/ha concentration compared to concentrations 0 and 0.4 L/ha, respectively.Significant differences were observed in the interaction between the biofertilizer and fulvic acid. Treatment B1F2 recorded the highest average at 1.51 mg/g, while treatment B0F0 recorded the lowest average at 1.24 mg.g, representing a 22.50% increase for excelled on treatment compared to lowest treatment. The interaction between fulvic acid and silicon spraying showed significant differences, with treatment F2S2 achieving the highest average at 1.56 $mg.g^{1}$, while treatment F0S2 recorded the lowest average at 1.32 $mg.g^{1}$, representing an increase of 17.56%.The interaction between biofertilizer and silicon spraying also showed significant differences, with treatment B1S2 recording the highest average at 1.54 $mg.g^{1}$, while treatment B0S0 recorded the lowest average at 1.37 $mg.g^{1}$, representing an increase of 12.27%.Similarly, triple interaction between the studied factors showed clear significant differences, with treatment B1F2S2 recording the highest value at 1.59 $mg.g^{1}$, while treatment B0F0S2 gave the lowest value at 1.18 $mg.g^{1}$, representing an increase of 35.05%.

Table (6) Effect of biofertilizer, fulvic acid, and silicon spraying and their interactions on chlorophyll content in leaves (mg/g^{-1} plant)

Average interaction of biofertilizer and fulvic acid	silicon spraying			fulvic acid F	Biofertilizer B
	S2	S1	S0		
1.240	1.184	1.232	1.306	F0	
1.461	1.496	1.474	1.414	F1	
1.472	1.520	1.483	1.413	F2	B0
1.431	1.471	1.472	1.350	F0	
1.499	1.566	1.492	1.438	F1	
1.519	1.599	1.516	1.442	F2	B1
0.047	0.082			LSD	
Average biofertilizer	silicon spraying			The interaction of bio-fertilizer and silicone spraying	
	S2	S1	S0		
1.391	1.400	1.396	1.377	B0	
1.483	1.546	1.493	1.410	B1	
0.027	0.047			LSD	
average fulvic acid	silicon spraying			Interaction of fulvic acid and silicone spraying	
	S2	S1	S0		
1.336	1.327	1.352	1.328	F0	
1.480	1.531	1.483	1.426	F1	
1.495	1.560	1.499	1.427	F2	

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0.033	0.058			LSD
	1.473	1.445	1.394	average silicon spraying
	0.033			LSD

Dry Matter Yield (Mg.ha^{-1}):

The results in Table (7) show that the addition of biofertilizer led to a significant increase in dry matter yield. Treatment (B1), which recorded an average of 8.28 Mg.ha^{-1}, ecelled on the non-added treatment (B0), which recorded 6.08 Mg.ha^{-1}, representing an increase of 36.10%.Regarding the addition of fulvic acid, the results showed a significant effect on increasing dry matter yield. Concentration F2 achieved the highest average of 8.42 Mg.ha^{-1}, compared to concentrations F1 and F0, which recorded 7.17 and 5.95 Mg.ha^{-1}, respectively. This represents an increase of 41.50% and 17.45% for concentration F2 compared to concentrations F0 and F1, respectively. The results indicated a significant response of the dry matter yield to silicone spraying, with the 0.8 L/h^{1} concentration recording the highest average yield of 8.47 Mg.ha^{1}, while the averages were 7.14 and 5.93 Mg.ha^{1} at the 0.4 L/h^{1} and no-spray concentrations, respectively. The 0.8 L/h^{1} concentration achieved increases of 42.81% and 18.62% compared to the no-spray and 0.4 L/h^{1} concentrations, respectively. Significant differences were observed in the interaction between biofertilizer and fulvic acid. Treatment B1F2 recorded the highest average at 9.64 Mg.ha^{1}, while treatment B0F0 recorded the lowest average at 5.09 Mg.ha^{1}, representing an 89.32% increase for the higher treatment compared to the lower one.The interaction between fulvic acid and silica spray also showed significant differences. Treatment F2S2 achieved the highest average at 10.30 Mg.ha^{1}, while treatment F0S0 recorded the lowest average at 5.17 Mg.ha^{1}, representing a 99.23% increase. The interaction between biofertilizer and silicon spraying showed significant differences, with treatment B1S2 recording the highest average yield of 9.28 Mg ha^{-1}, while treatment B0S0 recorded the lowest average yield of 4.72 Mg ha^{-1}, representing an increase of 96.69%.Similarly, triple interaction between the studied factors showed clear significant differences, with treatment B1F2S2 recording the highest value of 11.28 Mg ha^{-1}, while treatment B0F0S0 gave the lowest value of 4.04 Mg ha^{-1}, representing an increase of 179.21%.

Table (7) Effect of Biofertilizer, Fulvic Acid, Silicon Spraying, and their Interactions on Dry Matter Yield (Mg ha^{-1})

Average interaction of biofertilizer and fulvic acid	silicon spraying			fulvic acid	Biofertilizer
	S2	S1	S0	F	B
5.09	6.16	5.07	4.04	F0	
5.95	7.52	5.81	4.52	F1	
7.21	9.32	6.73	5.59	F2	B0
6.82	6.66	7.50	6.30	F0	
8.39	9.91	8.28	6.99	F1	
9.64	11.28	9.48	8.16	F2	B1

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0.294	0.509			LSD
Average biofertilizer	silicon spraying			The interaction of bio-fertilizer and silicone spraying
	S2	S1	S0	
6.08	7.67	5.87	4.72	B0
8.28	9.28	8.42	7.15	B1
0.169	0.294			LSD
average fulvic acid	silicon spraying			eraction of fulvic acid and silicone spraying
	S2	S1	S0	
5.95	6.41	6.28	5.17	F0
7.17	8.71	7.05	5.75	F1
8.42	10.30	8.10	6.87	F2
0.208	0.360			LSD
	8.47	7.14	5.93	average silicon spraying
	0.208			LSD

Number of Rows per cob (row.cob^{-1}):

The results in Table (8) show that the addition of biofertilizer significantly increased the number of rows per main ear. Treatment (B1), which recorded an average of 15.97 row.cob^{-1}, was excelled on treatment (B0), which recorded 13.37 row.cob^{-1}, representing an increase of 19.45%.Regarding fulvic acid, the results showed that the application concentration of 16 L ha^{-1} significantly increased the number of rows row.cob^{-1}, with an average of 16.20 rows per ear. The application concentrations of 8 L per hectare and no application resulted in averages of 15.41 and 12.41 row.cob^{-1}, respectively. The increase at the 16 L.ha^{-1} concentration was approximately 30.54% and 5.13%, respectively, compared to the no-add concentration and the 8 L.ha^{-1} concentration.Regarding silicone spraying, the results showed that concentration S2 achieved the highest average number of rows per main ear, reaching 15.40 rows, compared to averages of 14.76 and 13.86 rows at concentrations S1 and S0, respectively. This concentration also achieved increases of 11.11% and 4.34% compared to concentrations S0 and S1, respectively.Significant differences were observed in the interaction between biofertilizer and fulvic acid. Treatment B1F2 recorded the highest average yield of 18.20 row.cob^{-1}, while treatment B0F0 recorded the lowest average yield of 12.20 rows of ears¹, representing a 49.18% increase for the superior treatment compared to lowest treatment.The interaction between fulvic acid and silica spray also showed significant differences. Treatment F2S2 achieved the

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highest average yield of 18.60 rows of ears¹, while treatment F0S0 recorded the lowest average yield of 11.65 rows of ears¹, representing a 59.66% increase.The interaction between biofertilizer and silicon spraying showed significant differences. Treatment B1S2 recorded the highest average of 16.43 row.cob^{-1}while treatment B0S0 recorded the lowest average of 11.96 row.cob^{-1}representing an increase of 37.37%.Similarly, triple interaction between the studied factors showed clear significant differences. Treatment B1F2S2 recorded the highest value of 20.60 row.cob^{-1} while treatment B0F0S0 gave the lowest value of 11.30 row.cob^{-1}representing an increase of 82.30%.

Table (8) shows the effect of biofertilizer, fulvic acid, silicon spraying, and their interactions on the number of rows row.cob^{-1}

Average interaction of biofertilizer and fulvic acid	silicon spraying			fulvic acid	Biofertilizer
	S2	S1	S0	F	B
12.20	13.30	12.00	11.30	F0	B0
13.73	15.30	13.30	13.60	F1	
14.20	16.60	14.00	12.00	F2	
12.63	12.60	13.00	12.00	F0	B1
17.10	14.00	18.00	19.30	F1	
18.20	20.60	18.00	16.00	F2	
0.3541	0.6134			LSD	
Average biofertilizer	silicon spraying			The interaction of bio-fertilizer and silicone spraying	
	S2	S1	S0		
13.37	15.06	13.10	11.96	B0	
15.97	15.73	16.43	15.76	B1	
0.2045	0.3541			LSD	
average fulvic acid	silicon spraying			eraction of fulvic acid and silicone spraying	
	S2	S1	S0		
12.41	12.95	12.65	11.65	F0	
15.41	14.65	15.65	15.95	F1	
16.20	18.60	16.00	14.00	F2	

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0.2504	0.4337			LSD
	15.40	14.76	13.86	average silicon spraying
	0.2504			LSD

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

The results in Table (9) show that the addition of biofertilizer led to a significant increase in the number of grains per row. Treatment (B1), which recorded an average of 31.85 grains . row $^{-1}$ was excelled on treatment (B0), which recorded 27.70 grains per row, representing an increase of 14.98%.Regarding fulvic acid, the results showed that the application concentration of 16 L. ha¹ significantly increased the number of grains per row, with an average of 31.94 grains per row. The application concentrations of 8 L ha¹ and no application recorded averages of 29.83 and 27.56 grains . row $^{-1}$, respectively. The increase at the 16 L.ha^{-1} concentration was approximately 15.89% and 7.07%, respectively, compared to the no-adding and the 8 L.ha^{-1} concentration.Regarding silicone spraying, the results showed that level S2 achieved the highest average number of grains per row, reaching 36.33 grains . row $^{-1}$, compared to averages of 31.89 and 21.11 grains . row $^{-1}$at concentrations S1 and S0, respectively. This concentration achieved an increase of 72.10% and 13.92% compared to concentrations S0 and S1, respectively.Significant differences were observed in the interaction between biofertilizer and fulvic acid. Treatment B1F2 recorded the highest average yield of 38.22 grains . row $^{-1}$while treatment B0F0 recorded the lowest average yield of 25.78 grains . row $^{-1}$representing a 48.25% increase for the superior treatment compared to lowest treatment.The interaction between fulvic acid and silicone spraying also showed significant differences. Treatment F2S2 achieved the highest average yield of 39.33 grains . row $^{-1}$ while treatment F0S0 recorded the lowest average yield of 19.67 grains . row $^{-1}$representing a 99.95% increase.Triple interaction between the studied factors also showed clear and significant differences. Treatment B1F2S2 recorded the highest value of 41.00 grains . row $^{-1}$while treatment B0F0S0 gave the lowest value of 18.00 grains per row¹, representing an increase of 127.78%.

Table (9) Effect of biofertilizer, fulvic acid, and silicon spraying and their interactions on the number of grains per row (grains . row $^{-1}$)

Average interaction of biofertilizer and fulvic acid	silicon spraying			fulvic acid	Biofertilizer
	S2	S1	S0	F	B
25.78	32.33	27.00	18.00	F0	
27.11	33.33	29.00	19.00	F1	
30.22	37.67	32.00	20.33	F2	B0
29.33	34.67	32.00	21.33	F0	
34.22	39.00	35.67	23.00	F1	

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38.22	41.00	35.00	25.00	F2	B1
0.836	1.448			LSD	
Average biofertilizer	silicon spraying			The interaction of bio-fertilizer and silicone spraying	
	S2	S1	S0		
27.70	34.44	29.56	19.11	B0	
31.85	38.22	34.22	23.11	B1	
0.483	N.S			LSD	
average fulvic acid	silicon spraying			eraction of fulvic acid and silicone spraying	
	S2	S1	S0		
27.56	33.50	29.50	19.67	F0	
29.83	36.17	32.33	21.00	F1	
31.94	39.33	33.83	22.67	F2	
0.591	1.024			LSD	
	36.33	31.89	21.11	average silicon spraying	
	0.591			LSD	

Grain yield (Mg ha^{-1})

The results appeared in Table (10) that adding biofertilizer led to a significant increase in grain yield, as the addition treatment (B1), which recorded an average of 4.42 **Mg ha^{-1}**was excelled on the non-addition treatment (B0), which recorded 3.91 Mg ha^{-1} with an increase rate of 12.95%.The results showed that the grain yield responded significantly to the addition of fulvic acid, as the average gradually increased with increasing addition concentration, reaching 4.55 Mg ha^{-1} at the 16 liter Haμ¹ concentration, compared to 4.14 and 3.81 Mg ha^{-1} at the 8 L ha⁻¹ concentration and no addition, respectively. This was reflected in an increase of 19.32% and 9.90% for the 16 L ha⁻¹ concentration compared to the no addition and 8 L ha⁻¹ concentrations, respectively.As for spraying with silicon, the results showed a significant effect on grain yield, as the gradual increase in spraying concentrations led to a clear increase in this characteristic. Concentration S2 recorded the highest average grain yield of 5.91 Mg ha-¹, significantly excelled on concentrations S1 and S0, which recorded 4.10 and 2.49 Mg ha-¹, respectively. It is noted from the results that the increase in the concentration of silicone spraying had a positive impact on the grain yield, as the percentage of increase at concentration S2 reached about 137.16% compared to concentration S0, while it reached 43.90% compared to concentration S1.The interaction between fulvic acid and spraying with silicon showed significant differences, as treatment F2S2 achieved the highest average, amounting

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to 6.53 Mg ha^{-1}, while treatment F0S0 recorded the lowest average, amounting to 2.26 Mg ha^{-1} an increase of 188.52%.The triple interaction between the studied factors also showed clear significant differences, as treatment B1F2S2 recorded the highest value for grain yield, amounting to 6.97 Mg ha^{-1}, while treatment B0F0S0 gave the lowest value, amounting to 2.03 Mg ha^{-1} with an increase rate of 243.35% for the superior treatment B1F2S2 compared to the lower treatment

Table (10) The effect of biofertilizer, fulvic acid, spraying with silicon, and their interactions on Grain yield (Mg ha^{-1})

Average interaction of biofertilizer and fulvic acid	silicon spraying			fulvic acid	Biofertilizer
	S2	S1	S0	F	B
3.62	5.31	3.54	2.03	F0	
3.87	5.61	3.73	2.27	F1	
4.25	6.10	4.20	2.45	F2	B0
4.00	5.46	4.05	2.50	F0	
4.41	6.01	4.34	2.89	F1	
4.85	6.97	4.78	2.81	F2	B1
N.S	0.2653			LSD	
Average biofertilizer	silicon spraying			The interaction of bio-fertilizer and silicone spraying	
	S2	S1	S0		
3.91	5.67	3.82	2.25	B0	
4.42	6.14	4.39	2.73	B1	
0.0884	N.S			LSD	
average fulvic acid	silicon spraying			raction of fulvic acid and silicone spraying	
	S2	S1	S0		
3.81	5.38	3.79	2.26	F0	
4.14	5.81	4.03	2.58	F1	
4.55	6.53	4.49	2.63	F2	
0.1083	0.1876			LSD	
	5.91	4.10	2.49	average silicon spraying	
	0.1083			LSD	

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Biological Yield (Mg ha^{-1})

The results in Table (11) show that the addition of biofertilizer led to a significant increase in biological yield. Treatment (B1), which recorded an average of 14.58 Mg ha^{-1}, ecelled on the non-added treatment (B0), which recorded 11.66 Mg ha^{-1}, representing an increase of 25.04%.The results also showed a significant effect of fulvic acid concentrations on biological yield. Concentration F2 significantly excelled concentrations F0 and F1, recording the highest average of 15.61 Mg ha^{-1}, while the averages were 12.64 and 11.11 Mg ha^{-1} at concentrations F1 and F0, respectively. These results indicate that increasing the concentration of fulvic acid application positively impacted plant growth and dry matter accumulation, contributing to an increase in biological yield. The increase at concentration F2 was approximately 40.50% and 23.50% compared to concentrations F0 and F1, respectively.Regarding silicon spraying, the results showed a clear and significant effect on biological yield, as increasing the spray concentration led to a gradual increase in the average of this trait. Concentration S2 recorded the highest average at 14.96 Mg ha^{-1}, significantly exceeding concentrations S1 and S0, which recorded 13.78 and 10.61 Mg ha^{-1}, respectively. The response to silicon spraying was particularly pronounced at concentration S2, with an increase of 41.00% compared to concentration S0 and 8.56% compared to concentration S1.The interaction between fulvic acid and silicon foliar spraying showed significant differences, with treatment F2S2 achieving the highest average yield of 18.70 Mg ha^{-1}, while treatment F0S0 recorded the lowest average yield of 9.10 Mg ha^{-1}, representing an increase of 105.49%.Similarly, triple interaction between the studied factors showed clear and significant differences in biological yield. Treatment B1F2S2 recorded the highest value of 20.61 Mg ha^{-1}, while treatment B0F0S0 gave the lowest value of 8.53 Mg ha^{-1}, representing an increase of 141.62% for the superior treatment compared to the lowest treatment.

Table (11) Effect of Biofertilizer, Fulvic Acid, Silicon Foliar Spraying, and their Interactions on Plant Biological Yield (Mg ha^{-1})

Average interaction of biofertilizer and fulvic acid	silicon spraying			fulvic acid	Biofertilizer
	S2	S1	S0	F	B
10.07	11.39	10.29	8.53	F0	
11.03	12.59	10.65	9.85	F1	
13.88	16.78	15.13	9.73	F2	B0
12.15	12.33	14.46	9.66	F0	
14.24	16.06	14.74	11.92	F1	
17.34	20.61	17.43	13.99	F2	B1
N.S	1.517			LSD	
Average biofertilizer	silicon spraying			The interaction of bio-fertilizer and silicone spraying	
	S2	S1	S0		

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11.66	13.59	12.02	9.37	B0
14.58	16.33	15.54	11.86	B1
0.506	N.S			LSD
average fulvic acid	silicon spraying			eraction of fulvic acid and silicone spraying
	S2	S1	S0	
11.11	11.86	12.37	9.10	F0
12.64	14.33	12.69	10.89	F1
15.61	18.70	16.28	11.86	F2
0.619	1.073			LSD
	10.61	13.78	14.96	average silicon spraying
	0.619			LSD

Harvest Index (%)

The results in Table (12) show that the addition of biofertilizer led to a significant decrease in the harvest index. The no-add treatment (B0) recorded the highest average at 32.96%, compared to the addition treatment (B1), which recorded 30.06%, a difference of 9.65% in favor of the no-add treatment (B0).Regarding fulvic acid, the results showed that the harvest index was significantly affected by different application concentrations. The no-add treatment (F0) recorded the highest average at 33.82%, while the averages were 32.28% and 28.43% at application concentrations of 8 and 16 L ha^{-1}, respectively. The no-add treatment was 18.96% and 4.77% higher than the 16 and 8 L ha^{-1} concentrations, respectively.The no-add treatment was 18.96% and 4.77% higher than the 16 and 8 L ha^{-1} concentrations, respectively. Regarding silicon spraying, the results showed a significant effect on the harvest index. Concentration S2 achieved the highest average at 40.50%, followed by concentration S1 at 30.34%, while concentration S0 recorded the lowest average at 23.70%. The percentage increase for concentration S2 was approximately 70.89% and 33.49% compared to concentrations S0 and S1, respectively.

The interaction between biofertilizer and fulvic acid showed significant differences. Treatment B0F0 recorded the highest average at 34.93%, while treatment B1F2 recorded the lowest average at 27.10%, a difference of 28.89% between the two treatments.Similarly, the interaction between fulvic acid and silicon spraying showed significant differences. Treatment F0S2 achieved the highest average at 45.44%, while treatment F2S0 recorded the lowest average at 22.62%, representing an increase of 100.88%. The interaction between biofertilizer and silicon spraying showed significant differences, with treatment B0S2 recording the highest mean at 42.50%, while treatment B1S0 recorded the lowest mean at 23.40%, representing an increase of 81.62%.Similarly, triple interaction between

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the studied factors showed clear significant differences, with treatment B0F0S2 recording the highest value at 46.61%, while treatment B1F2S0 gave the lowest value at 20.08%, representing an increase of 132.12%.

Table (12) Effect of Biofertilizer, Fulvic Acid, Silicon Spraying, and Their Interactions on Harvest Index (%)

Average interaction of biofertilizer and fulvic acid	silicon spraying			fulvic acid	Biofertilizer
	S2	S1	S0	F	B
34.93	46.61	34.40	23.79	F0	
34.20	44.55	35.02	23.04	F1	
29.76	36.35	27.75	25.17	F2	B0
32.72	44.28	28.00	25.87	F0	
30.37	37.42	29.44	24.24	F1	
27.10	33.81	27.42	20.08	F2	B1
1.173	2.032			LSD	
Average biofertilizer	silicon spraying			The interaction of bio-fertilizer and silicone spraying	
	S2	S1	S0		
32.96	42.50	32.39	24.00	B0	
30.06	38.50	28.29	23.40	B1	
0.677	1.173			LSD	
average fulvic acid	silicon spraying			eraction of fulvic acid and silicone spraying	
	S2	S1	S0		
33.82	45.44	31.20	24.83	F0	
32.28	40.98	32.23	23.64	F1	
28.43	35.08	27.58	22.62	F2	
0.829	1.437			LSD	
	40.50	30.34	23.70	average silicon spraying	
	0.829			LSD	

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The results in Tables show that adding biofertilizer had a significant effect on increasing plant height, leaf area, total chlorophyll concentration, dry matter yield, number of rows per ear, number of grains per row, grain yield, and biological yield, while it led to a decrease in the harvest index compared to the control treatment. This is attributed to the ability of Azospirillum brasilense and Azotobacter chroococcum bacteria to colonize the rhizosphere, increasing nutrient availability and improving nutrient absorption efficiency. Furthermore, these bacteria can secrete plant growth regulators such as auxins, gibberellins, and cytokinins, which stimulate cell division and elongation, and increase the growth of both the shoot and root systems. This, in turn, improved the plant's vegetative growth traits[1,9].[7] indicated that plant growth-promoting bacteria contribute to improved mineral nutrition by increasing root growth and the secretion of plant growth regulators, which positively impacts water and nutrient uptake. The increase in plant height, leaf area, and chlorophyll content can be attributed to improved plant mineral nutrition, particularly nitrogen, which is directly involved in the formation of chlorophyll, proteins, and enzymes necessary for photosynthesis. Furthermore, the added bacteria play a role in increasing root growth and improving water and nutrient uptake, leading to increased leaf area, enhanced photosynthetic efficiency, and dry matter accumulation, which aligns with the findings of [14].The increase in dry matter yield and biological yield can be attributed to increased photosynthetic efficiency and improved vegetative growth resulting from the increased availability of nutrients and growth regulators. This leads to increased accumulation of carbohydrates and proteins in plant tissues, positively impacting dry matter production. [16] indicated that growth-promoting microorganisms contribute to improved vegetative growth, increased dry matter accumulation, and higher biological yield in field crops.The increase in number of rows per cob, number of grains per row, and grain yield is attributed to improved plant nutrition during critical growth, flowering, and fertilization stages. A balanced supply of nutrients leads to improved reproductive organ development, reduced flower abortion, and increased grain filling efficiency [11] which in turn positively impacts the overall yield and final yield. This aligns with the findings of [9].The results, shown in the tables, indicate that the addition of fulvic acid significantly increased plant height, leaf area, total chlorophyll concentration, dry matter yield, number of rows per ear, number of grains per row, grain yield, and biological yield, while the harvest index decreased with increasing application concentrations. This is attributed to the important role of fulvic acid in improving the chemical and biological properties of the soil and increasing the availability of nutrients to the plant. Furthermore, it contains effective functional groups that facilitate the formation of organic complexes with nutrients and prevent their fixation [6] thus increasing their absorption and utilization within the plant. This aligns with the findings of [4].

The increase in plant height, leaf area, and chlorophyll content is due to fulvic acid's role in enhancing the absorption of macro- and micronutrients, particularly nitrogen, magnesium, and iron, which are directly involved in the formation of chlorophyll, proteins, and enzymes responsible for photosynthesis. Fulvic acid contributes to increased root activity and improved cell membrane permeability, thereby enhancing nutrient translocation within the plant and promoting vegetative growth. These findings are consistent with those of [12,17].Fulvic acid also plays a crucial role in stimulating cell division, increasing root growth, and improving water and nutrient utilization, which positively impacts dry matter accumulation [13]. The increase in number of rows per ear, number of grains per row, and the grain yield is attributed to improved plant nutrition during various growth stages, particularly flowering and grain filling. The

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continuous availability of nutrients leads to improved reproductive organ development, increased pollination and fertilization efficiency [6] and enhanced translocation of nutrients to the grains, positively impacting the overall yield components and final yield [2].The decrease in the harvest index with increasing fulvic acid concentrations can be explained by the fact that the increase in biological yield was greater than the increase in grain yield. This is due to the significant stimulation of vegetative growth and increased dry matter accumulation in the stems and leaves, resulting in a lower percentage of grains relative to the total plant dry matter. These findings are consistent with those of [19].

The results in Tables show that silicon spraying significantly increased plant height, leaf area, total chlorophyll concentration, dry matter yield, number of rows per ear, number of grains per row, grain yield, biological yield, and harvest index. This is attributed to the important physiological role of silicon in improving plant growth and increasing the efficiency of various vital processes, as well as its role in improving nutrient uptake and reducing the negative effects of various environmental stresses [15]. This positively impacted plant growth and its productive components, which aligns with the findings of [8].The increase in plant height, leaf area, and chlorophyll content is due to silicon's contribution to maintaining cell membrane integrity, improving photosynthetic efficiency, and increasing water and nutrient utilization efficiency. Furthermore, silicon protects chlorophyll from degradation and stimulates the activity of enzymes involved in photosynthesis. [14] indicated that silicon improves plant physiological performance and increases vegetative growth under various conditions.

Conclusions:

Adding biofertilizers , fulvic acid and spraying of silicon to the corn plant improved the studied growth characteristics and this reflected in an increase in yield and its components .Superior level 16 L ha fulvic acid and 0.8 L ha concentration silicon in these traits .

References

[1] Aasfar, A., Bargaz, A., Yaakoubi, K., Hilali, A., Bennis, I., Zeroual, Y., & Meftah Kadmiri, I. (2021). Nitrogen fixing Azotobacter species as potential soil biological enhancers for crop nutrition and yield stability. Frontiers in microbiology, 12, 628379.

[2] Abd El-Mageed, T. A., & Semida, W. M. (2021). Acidified Biochar as a Soil Amendment to Drought Stressed (*Vicia faba* L.) Plants: Influences on Growth and Productivity, Nutrient Status, and Water Use Efficiency.

[3] Al-Sahouki, Medhat Majeed, and Karima Mohammed Wahib. 1990. Applications in the design and analysis of experiments. University of Baghdad, Ministry of Higher Education and Scientific Research.

[4] Amin, M., Ahmad, R., Ali, A., & Hussain, I. (2020). Fulvic acid improves nutrient uptake and yield of crops: A review. Journal of Soil Science and Plant Nutrition, 20, 120–135.

[5] Backer, R., Rokem, J. S., Ilangumaran, G., Lamont, J., Praslickova, D., Ricci, E., ... & Smith, D. L. (2018). Plant growth-promoting rhizobacteria: context, mechanisms of action, and roadmap to commercialization of biostimulants for sustainable agriculture. Frontiers in plant science, 9, 1473.

[6] Canellas, L. P., & Olivares, F. L. (2014). Physiological responses to humic substances. Chemical and Biological Technologies in Agriculture, 1(1), 3.

[7] Cassán, F., Coniglio, A., López, G., Molina, R., Nievas, S., de Carlan, C. L. N., ... & Mora, V. (2020). Everything you must know about Azospirillum and

ISSN 2072-3857

its impact on agriculture and beyond. Biology and fertility of soils, 56(4), 461-479.

[8] Coskun, D., Deshmukh, R., Sonah, H., Menzies, J. G., Reynolds, O., Ma, J. F., ... & Bélanger, R. R. (2019). The controversies of silicon's role in plant biology. New phytologist, 221(1), 67-85.

[9] Fukami, J., Cerezini, P., & Hungria, M. (2018). Azospirillum: benefits that go far beyond biological nitrogen fixation. Amb Express, 8(1), 73.

[10] Hassan Jreikh, Mohammed Baher Al-Qaddour, & Mohammed Waleed Kamel. (2023). The effect of adding silicon compounds on the growth and productivity of yellow corn under different concentrations of salinity and irrigation. Palestine Technical University Journal of Research, 11(1), 165-179.

[11] Hungria, M., Campo, R. J., Souza, E. M., & Pedrosa, F. O. (2010). Inoculation with selected strains of *Azospirillum brasilense* and *A. lipoferum* improves yields of maize and wheat in Brazil. *Plant and Soil*, 331(1), 413-425.

[12] Khaled, H., & Fawy, H. A. (2011). Effect of different concentrations of humic acids on the nutrient content, plant growth, and soil properties under conditions of salinity. *Soil and Water Research*, 6(1), 21-29.

[13] Li, F.G., Zhang, S.J., Chai, L.H., Guo, Z.Q., Li, P.P., Han, Y.L., & Wang, Y. (2024). Enhanced maize yield and nitrogen efficiency with low molecular weight fulvic acid: insights into chlorophyll a/b ratio and nitrogen metabolizing enzyme activity. Plant, Soil and Environment, 70(10), 632–643.

[14] Liang, Y., Nikolic, M., Bélanger, R., Gong, H.,&Song, A. (2015). Silicon in agriculture. From theory to practice, 45.

[15] Ma, J. F., & Yamaji, N. (2015). A cooperative system of silicon transport in plants. Trends in Plant Science, 20, 435–442.

[16] Nadeem, S. M., Ahmad, M., Zahir, Z. A., Javaid, A., & Ashraf, M. (2014). The role of mycorrhizae and plant growth promoting rhizobacteria (PGPR) in improving crop productivity under stressful environments. Biotechnology Advances, 32(2), 429–448.

[17] Nardi, S., Schiavon, M., & Francioso, O. (2021). Chemical structure and biological activity of humic substances define their role as plant growth promoters. Molecules, 26(8), 2256.

[18] Soil Survey Staff.2006. Key to soil taxonomy. 10th edition.

[19] Taiz, L., & Zeiger, E. (2014). *Plant Physiology and Development* (6th ed.). Sinauer Associates

ISSN 2072-3857