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Environmental Response of Maize to Organic Fertilization and Foliar Silicon Nutrition Under Different Levels of Mineral Fertilization (NPK)

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Abstract: A factorial experiment using a randomized complete block design (RCBD) was conducted in the spring of 2024 in a clay loam soil at Ibn Al-Bitar Vocational Preparatory School/Al-Husainiya District, Holy Karbala, to investigate the effects of mineral fertilizers (NPK), organic and foliar silicon application on maize growth and yield. The experiment included three factors: mineral fertilizers (N, P, and K) at three levels: without fertilization, symbolized by M_0, adding 50% of the fertilizer recommendation (150 kg N ha^{-1}, 50 kg P ha^{-1}, and 80 kg K ha^{-1}) and symbolized by M_1, and adding 100% of the fertilizer recommendation (300 kg N ha^{-1}, 100 kg P ha^{-1}, and 160 kg K ha^{-1}) and symbolized by M_2, the second factor was organic fertilization at two levels (0 and 40 kg ha^{-1}), Symbolizing it sequentially (O_0, and O_1). and the third factor was foliar feeding with organic silicon at three concentrations (0, 3, and 6 ml L^{-1}), Symbolizing it sequentially (Si_0, Si_1, and Si_2). The results of the study show that the studied traits, which include plant height, leaf area, chlorophyll index, plant yield, and harvest index, were significantly affected by individual and combined study factors. Level M2 recorded the highest means, reaching (196.503 cm, 63.837 dm $plant^{-1}$, 55.662 SPAD, 161.17 g $plant^{-1}$, and 48.958%) respectively. Meanwhile, the mean in the organic fertilizer level O_1 was (192.463 cm, 62.598 dm $plant^{-1}$, 54.544 SPAD, 157.60 g $plant^{-1}$, and 49.003%) respectively. As for the foliar spray with silicon Si_2, it achieved means of (190.184 cm, 61.157 dm $plant^{-1,}$ 54.234 SPAD, 150.35 g $plant^{-1}$, and 48.551%) respectively. Regarding the binary interaction, treatment M_1O_1 recorded the highest means for plant height, leaf area, and chlorophyll index in leaves, with an average of (201.396 cm, 66.217 dm $plant^{-1}$, and 51.058%) respectively. Meanwhile, treatment M_2O_1 achieved the highest means in chlorophyll index and plant yield, recording (57.504 SPAD and 176.00 g $plant^{-1}$) respectively. The interaction treatment M_2Si_2 recorded the highest means for plant height, leaf area, chlorophyll index, and plant yield, reaching (198.933 cm, 64.568 dm $plant^{-1}$, 57.270 SPAD, and 169.75 g $plant^{-1}$) respectively. As for treatment M_1Si_2, it achieved the highest mean in harvest index, reaching (50.522%). The interaction treatment O_1Si_2 achieved the highest mean in all mentioned traits (196.672 cm, 63.151 dm $plant^{-1}$, 55.922 SPAD, 167.77 g $plant^{-1}$, and 50.649%). Finally, the ternary interaction treatment $M_1O_1Si_2$ gave the highest means for the traits (208.580 cm, 66.922 dm $plant^{-1}$, 58.953 SPAD, 186.63 g $plant^{-1}$, and 53.473%) respectively, while the control treatment, which did not add fertilizer, had the lowest means for the studied plant traits.
Keywords: Mineral fertilizers, Organic fertilizers, Organic silicon, Maize, NPK,

INTRODUCTION

Maize (*Zea mays* L.), a globally significant cereal crop in the Poaceae family, ranks third worldwide in cultivation and production, after wheat and rice. maize production in Iraq is estimated at approximately 600,000 tons annually, covering an area of roughly 150,000 hectares (FAO., 2023)., corn is vital for its nutritional value, providing starches, calories, amino acids, and fiber that aid digestion. Its digestible oil is used in food and medicine, benefiting those with high cholesterol. Corn grain, rich in carotene, is also a key component in poultry and livestock feed. Effective crop management is crucial for maximizing yield (Dewettinck et al., 2023).

Maize requires a balanced supply of nutrients for optimal growth. Nitrogen, phosphorus, and potassium are particularly crucial due to their high demand and the negative impacts of their deficiency on yield. Fertilizers are used to replenish these essential nutrients when soil levels are insufficient due to depletion, fixation, leaching, or other causes, thereby promoting healthy growth and production (Nanganoa et al., 2020).

While mineral fertilizers efficiently boost crop yields and quality, their economic costs, environmental damage, and negative health impacts necessitate reduced usage (Fatima and Al-Yasari., 2024). Shifting towards organic supplements like humic acids allows for more rational use of NPK fertilizers. Humic acids improve soil properties and fertility, increase nutrient availability, and positively impact plant growth by enhancing cell permeability, stimulating enzymatic activity, improving cell division, promoting enzyme production, and fostering beneficial soil microorganisms (Ding et al., 2021).

Silicon, a beneficial plant nutrient, mitigates the negative impacts of salinity, drought, and heavy metal toxicity. It enhances photosynthesis, improves nutrient uptake, reduces sodium toxicity, boosts antioxidant enzyme activity, and strengthens cell walls, providing mechanical support (Pavlovic et al., 2021).

This study investigates the effect of organic fertilization and foliar silicon application on the growth and yield of yellow corn under varying levels of mineral fertilization (NPK).

MATERIALS AND METHODS

Executing the experiment

A factorial experiment using a randomized complete block design (RCBD) was conducted in the spring 2024 in a clay loam soil at Ibn Al-Bitar Vocational Preparatory School/Al-Husainiya District, Holy Karbala, to investigate the effects of mineral fertilizers (NPK) and foliar silicon application on maize growth and yield.

Table 1: Physicochemical properties of soil (0-30 cm) before maize planting.

Properties		Values
pH		7.1
EC (1:1)		2.11 ds m^{-1}
OM		1.31 g kg^{-1}
N available		29.65 mg kg^{-1}
K available		72.78 mg kg^{-1}
P available		14.5 mg kg^{-1}
Soil separators	Sand	250 G kg^{-1}
	Silt	360 G kg^{-1}
	Clay	390 G kg^{-1}
Texture		Clay loam

Field preparation and farming practices.

The experiment included three factors: levels of mineral fertilization (N, P, and K), which are: no fertilization, denoted as M_0; the addition of 50% of the recommended fertilization (150 kg N, 50 kg P, and 80 kg K) ha^{-1}, denoted as M1; and the addition of 100% of the recommended fertilization (300 kg N, 100 kg P, and 160 kg K) ha^{-1}, denoted as M_2. Secondly, organic fertilizer (humic acids 70%, fulvic acids 15%, potassium oxide 15%) was applied at two levels: O_0 (0 kg ha) and O_1 (40 kg ha) to the soil. The third factor was foliar feeding with organic silicon (80%) at three concentrations (0, 3, and 6 ml L^{-1}), Symbolizing it sequentially (Si_0, Si_1, and Si_2). The soil was prepared through processes that included plowing with a moldboard plow, leveling with disc harrows, and finally dividing it into experimental units, each with an area of 6 m^2. Seeds were planted on March 21, 2024, in rows spaced 75 cm apart, with 25 cm between each hole to achieve a plant density of 53,333.33 plants ha^{-1}. The field was fertilized with urea (46% N), triple superphosphate (21% P), and potassium sulfate (41.5% K) as sources of mineral fertilizer (N, P, and K) applied to the soil by banding at a distance of 10 cm from the planting line and at a depth of 5 cm. The phosphorus fertilizer was applied in one dose at planting, while the nitrogen and potassium fertilizers were applied in two equal doses: one at planting and the second 45 days after the first application.

Organic silicon was added as a spray to the plant, at two concentrations (3 and 6) ml L^{-1}, coded (Si_1 and Si_2) respectively, and the spraying was done in two stages: the first when the plants reached the stage of (6-8) true leaves, and the second stage when the male inflorescences began to appear. A manual backpack sprayer with a capacity of (16 liters) was used to carry out the spraying process in the early morning (to avoid high temperatures) until the plants were completely wet, while the control treatment (with water only) was sprayed with a spreading substance (bright cleaning solution) to reduce the surface tension of the water to ensure complete wetness of the leaves with the aim of increasing the efficiency of the spraying solution.

The following traits were measured:

Plant height (cm): This is the distance between the soil surface and the node bearing the male inflorescence (El-Sahookie., 1990).

Leaf area (cm^2 $plant^{-1}$): Calculated by multiplying the square of the leaf length of the main cob leaf by 0.75. The area was measured during the flowering stage for ten protected plants (El-Sahookie., 1990).

Evidence of Chlorophyll was measured during the male flowering stage using a SPAD meter. Readings were taken from five leaves on each plant, averaged, and then the overall average was calculated from five plants (Minotti et al., 1994).

Yield per plant (g $plant^{-1}$): Yield per plant was calculated from the average grain weight of ten plants from the experimental unit (El-Sahookie., 1990).

Harvest Index (%)**:** Calculated as: Grain Yield ÷ Biological Yield.

RESULTS AND DISCUSSION

Plant height (cm)

The results in Table (2) indicated significant differences in the average plant height due to the effect of mineral fertilization levels (NPK). The addition of mineral fertilization levels (M_2) had the highest average, reaching (196.503 cm), while the control levels (M_0) without fertilization gave the lowest average, reaching (171.556 cm). This may be due to the availability of essential nutrients (NPK), particularly nitrogen, which is necessary for the synthesis of the amino acid (Tryptophan), leading to cell division and expansion, increased internode length, and an increased number of nodes on the stem that bear the leaves. Furthermore, phosphorus promotes root growth, allowing the plant to better absorb water and plant nutrients from the soil, which helps accelerate growth and thus leads to increased plant height. Additionally, potassium increases the ability of cell walls to expand, contributing to the growth of plant parts such as the stem and leaves. This improvement in the plant's ability to retain water and nutrients significantly affects its height and overall growth (Ali et al., 2014; Al-Yasari., 2022). The results in the table show that organic fertilization significantly affected plant height, with the level (40 kg ha^{-1}) achieving the highest average (192.463 cm) compared to the control level (0 kg ha^{-1}), which recorded the lowest average (180.811 cm). The reason for this superiority may be attributed to the positive effect of organic fertilizers on increasing plant height, which results in increased cell division and expansion, and an increase in root branching, thereby enhancing their ability to absorb nutrients from the soil that organic fertilizers are important in physiological processes by enhancing the action of enzymes and their role in plant cell division and elongation, leading to an increase in plant height (Chen et al., 2022; Abbas and Al-Yasari., 2024)). The results in the table also show that there is a significant effect of foliar spraying with silicon on plant height. The concentration (6 ml L^{-1}) achieved the highest average (190.184 cm), while the concentration (0 ml L^{-1}) gave the lowest average plant height (181.794 cm). The reason for this superiority may be attributed to the role of silicon in increasing water and nutrient absorption and increasing the efficiency of carbon assimilation (Bhardwaj and Kapoor., 2021).

The results presented in the table indicated that all two-way interactions were significant in increasing plant height. The interaction between mineral and organic fertilization levels significantly impacted plant height. Treatment (M_1O_1) achieved the highest mean of (201.396 cm), while the control treatment (M_0O_0) recorded the lowest mean of (166.741 cm), representing an increase of (20.79%). The two-way interaction between mineral fertilization and foliar silicon spray also showed a significant effect on this trait. Treatment (M_2Si_2) achieved the highest mean of (198.933 cm), while treatment (M_0Si_0) recorded the lowest mean of (167.560 cm), representing an increase of (18.72%).

The results also demonstrated a significant effect of the two-way interaction between organic fertilization and foliar silicon spray on this trait. Treatment (O_1Si_2) yielded the highest mean of (196.672 cm), while treatment (O_0Si_0) recorded the lowest mean for the trait at (177.473 cm), representing an increase of 10.817%.

The same table results indicated a significant effect of the three-way interaction between the study factors on plant height. Treatment ($M_1O_1Si_2$) gave the highest mean of (208.580 cm), while treatment ($M_0O_0Si_0$) recorded the lowest mean for the trait at (161.590 cm), representing an increase of 29.07%.

Table 2: Effect of NPK fertilization, organic fertilization, and organic silicon foliar feeding on maize plant height (cm)

Fertilizer NPK levels	Organosilicon spray concentrations			Average (M)
	Si_0	Si_1	Si_2	
M_0	167.560	172.438	174.668	171.556
M_1	184.285	194.320	196.950	191.852
M_2	193.537	197.040	198.933	196.503
Fertilizer organic levels	**Organosilicon spray concentrations**			**Average (O)**
	Si_0	Si_1	Si_2	
O_0	177.473	181.263	183.696	180.811

O_1		186.114	194.602	196.672		192.463
Average (Si)		181.794	187.933	190.184		
Fertilizer NPK levels		Organosilicon spray concentrations				Average M * O
		Si_0	Si_1	Si_2		
M_0	O_0	161.590	167.647	170.987		166.741
	O_1	173.530	177.230	178.350		176.370
M_1	O_0	179.200	182.403	185.320		182.308
	O_1	189.370	206.237	208.580		201.396
M_2	O_0	191.630	193.740	194.780		193.383
	O_1	195.443	200.340	203.087		199.623
L.S.D $_{0.05}$						
M	O	Si	M*Si	O*Si	M*O	M*O*Si
0.337	0.275	0.337	0.584	0.477	0.477	0.826

Leaf Area (dm^2 plant^{-1})

The results in Table 3 indicated significant differences in the average leaf area of the plant due to the effect of mineral fertilizer (NPK) levels. The addition of mineral fertilizer levels (M_2) had a significant impact, giving the highest average of (63.837 dm^2 plant^{-1}), while the control levels (M_0) without fertilization gave the lowest average of (55.304 dm^2 plant^{-1}). The increase in leaf area of maize with the addition of mineral fertilizer levels may be attributed to its content of nitrogen (N), phosphorus (P), and potassium (K), each of which plays a fundamental role in plant growth. Nitrogen promotes the growth of leaves and stems and is an essential element for building proteins. Phosphorus contributes to the development of the root system and increases the ability to absorb nutrients. Potassium helps regulate vital processes within the plant and contributes to disease resistance and increased efficiency of photosynthesis with increased leaf area. Furthermore, NPK mineral fertilization enables the plant to improve the processes of photosynthesis and respiration, leading to increased energy production and improved growth and balanced nutrition through the availability of essential nutrients for the plant (Zhang et al., 2022; Al-Yasari and Al-Jbwry., 2024). The results in the table show that organic fertilization significantly affected leaf area, with the level (40 kg ha^{-1}) achieving the highest average of (62.598 dm^2 plant^{-1}) compared to the control level (0 kg ha^{-1}), which recorded the lowest average of (58.461 dm^2 plant $^{-1}$). This superiority may be attributed to the fact that increasing the amount of organic fertilizer leads to an increase in the division and expansion of meristematic tissues, which contributes to an increase in the leaf area exposed to light, thereby improving growth conditions. In addition, increasing humic acid enhances the availability of macro and micronutrients for absorption, which promotes vegetative growth and increases photosynthesis, thus expanding the leaf area of the plant (Sindhu et al., 2022).

As is evident from the table results, there is a significant effect of foliar silicon application on leaf area. The concentration of 6 ml L^{-1} achieved the highest average of 61.157 dm^2 plant^{-1}, while the

Table 3: Effect of NPK fertilization, organic fertilization, and organic silicon foliar feeding on maize leaves area (dm^2 $plant^{-1}$)

Fertilizer NPK levels	Organosilicon spray concentrations	Average (M)

concentration of 0 ml L^{-1} gave the lowest average leaf area of 59.685 dm^2 $plant^{-1}$. This superiority at the 6 ml L^{-1} concentration can be attributed to the positive effect of silicon when sprayed on the foliage of plants. Silicon enhances the efficiency of enzymatic activity, which positively affects the vital processes of the plant. Also, the accumulation of silicon in epidermal cells helps to incline the leaves, making them upright, which increases their exposure to light effectively. This contributes to increased amounts of chlorophyll, which in turn enhances photosynthetic processes. Furthermore, silicon reduces the rate of transpiration, enhancing water use efficiency in the plant (Bhardwaj and Kapoor., 2021).

The table results showed that all binary interactions were significant in increasing leaf area. The interaction between mineral and organic fertilization levels had a significant effect on increasing leaf area. The treatment (M_1O_1) achieved the highest average of 66.217 dm^2 $plant^{-1}$ while the control treatment (M_0O_0) recorded the lowest average of 54.511 dm^2 $plant^{-1}$, with an increase of 21.48%. The binary interaction between mineral fertilization and foliar silicon application also showed a significant effect on this trait. The treatment (M_2Si_2) achieved the highest average of 64.568 dm^2 $plant^{-1}$, while the treatment (M_0Si_0) recorded the lowest average of 54.917 dm^2 $plant^{-1}$, with an increase of 17.58%.

The results also demonstrated a significant interaction effect between organic fertilization and foliar silicon application on this trait. Treatment (O_1Si_2) yielded the highest mean, reaching (63.151 dm^2 $plant^{-1}$), while treatment (O_0Si_0) recorded the lowest mean for the trait, at (57.592 dm^2 $plant^{-1}$), representing an increase of 9.66%. The same table's results indicated a significant three-way interaction effect between the study factors on leaf area, with treatment ($M_1O_1Si_2$) giving the highest mean of (66.922 dm^2 $plant^{-1}$), while treatment ($M_0O_0Si_0$) recorded the lowest mean for the trait, at (54.071 dm^2 $plant^{-1}$), representing an increase of 23.77%.

		Si 0	Si 1	Si 2	
M_0		54.917	55.300	55.696	55.304
M_1		61.056	63.081	63.206	62.448
M_2		63.080	63.863	64.568	63.837
Fertilizer organic levels		Organosilicon spray concentrations			Average (O)
		Si 0	Si 1	Si 2	
O_0		57.592	58.630	59.162	58.461
O_1		61.778	62.865	63.151	62.598
Average (Si)		59.685	60.748	61.157	
Fertilizer NPK levels		Organosilicon spray concentrations			Average M * O
		Si_0	Si_1	Si_2	
M_0	O_0	54.071	54.469	54.992	54.511
	O_1	55.763	56.131	56.400	56.098
M_1	O_0	57.193	59.352	59.490	58.679
	O_1	64.920	66.809	66.922	66.217
M_2	O_0	61.511	62.070	63.004	62.195
	O_1	64.650	65.656	66.132	65.479

L.S.D 0.05						
M	O	Si	M*Si	O*Si	M*O	M*O*Si
0.0615	0.0502	0.0615	0.1065	0.0869	0.0869	0.1506

Index of chlorophyll in leaves (SPAD unit).

The results in Table 4 indicated significant differences in the average Index of chlorophyll in leaves (%) due to the effect of mineral fertilizer (NPK) levels. The addition of mineral fertilizer levels (M_2) had a significant impact, giving the highest average of (55.662 SPAD), while the control levels (M_0) without fertilization gave the lowest average of (47.148 SPAD). The increased chlorophyll content in maize leaves observed when mineral fertilizers—such as nitrogen, phosphorus, and potassium—are applied can be primarily attributed to nitrogen. As an essential component of chlorophyll, the availability of nitrogen in sufficient quantities enhances its production in the leaves. Phosphorus plays a crucial role in providing energy to the plant and promoting root growth, which facilitates better nutrient and water absorption, positively affecting leaf health. Meanwhile, potassium helps regulate the opening of stomata and improves gas exchange, thereby enhancing the efficiency of photosynthesis and further boosting chlorophyll production. Additionally, an increase in plant height and leaf area suggests a greater amount of green tissue that can contain chlorophyll. This improves light absorption efficiency and creates more surface area for photosynthesis, leading to greater energy production and, consequently, increased chlorophyll production (Ciampitti et al., 2014; Fatima and Al-Yasari., 2024).

The results in the table show that organic fertilization significantly affected the Index of chlorophyll in leaves, with the level (40 kg ha^{-1}) achieving the highest average of (54.544 SPAD) compared to the control level (0 kg ha^{-1}), which recorded the lowest average of (50.397 SPAD). The increase in the chlorophyll index in maize leaves may be attributed to the effects of organic fertilization, which improves soil properties and enhances its ability to absorb essential nutrients like nitrogen. Nitrogen is a crucial component of chlorophyll and plays a significant role in promoting plant growth. Additionally, improvements in growth characteristics, such as plant height and leaf area, indicate better plant health, as the plants can capture more light. This increased light absorption enhances the efficiency of photosynthesis, leading to a higher concentration of chlorophyll in the leaves (Amujoyegbe et al., 2007).

As is evident from the table results, there is a significant effect of foliar silicon application on the Index of chlorophyll in leaves. The concentration of (6 ml L^{-1}) achieved the highest average of (54.234

Table 4: Effect of NPK fertilization, organic fertilization, and organic silicon foliar feeding on maize Index of chlorophyll in leaves (SPAD).

Fertilizer NPK levels		Organosilicon spray concentrations			Average (M)
		Si_0	Si_1	Si_2	
M_0		45.327	47.565	48.552	47.148
M_1		51.855	55.070	56.882	54.602
M_2		53.865	55.852	57.270	55.662
Fertilizer organic levels		Organosilicon spray concentrations			Average (O)
		Si_0	Si_1	Si_2	
O_0		47.549	51.097	52.547	50.397
O_1		53.149	54.561	55.922	54.544
Average (Si)		50.349	52.829	54.234	
Fertilizer NPK levels		Organosilicon spray concentrations			Average M * O
		Si_0	Si_1	Si_2	
M_0	O_0	42.947	45.800	47.060	45.269
	O_1	47.707	49.330	50.043	49.027
M_1	O_0	48.420	53.080	54.810	52.103
	O_1	55.290	57.060	58.953	57.101
M_2	O_0	51.280	54.410	55.770	53.820
	O_1	56.450	57.293	58.770	57.504

L.S.D $_{0.05}$						
M	O	Si	M*Si	O*Si	M*O	M*O*Si
0.360	0.294	0.360	0.623	0.509	0.509	0.881

SPAD), while the concentration of (0 ml L^{-1}) gave the lowest average Index of chlorophyll in leaves of (50.349 SPAD). The increased levels of chlorophyll in maize leaves may be attributed to silicon spraying, which stimulates plant growth and enhances leaf health. This process strengthens the rigidity of leaf cells and supports photosynthesis, resulting in greater chlorophyll production. Additionally, the increase in plant height and leaf area improves the efficiency of light and nutrient absorption, further enhancing chlorophyll content and boosting photosynthesis efficiency (Teixeira et al., 2020). The table results showed that all binary interactions were significant in increasing the Index of chlorophyll in leaves. The interaction between mineral and organic fertilization levels had a significant effect on increasing the Index of chlorophyll in leaves. The treatment (M_2O_1) achieved the highest average of (57.504 SPAD) while the control treatment (M_0O_0) recorded the lowest average of (45.269 SPAD), with an increase of 27.02%. The binary interaction between mineral fertilization and foliar silicon application also showed a significant effect on this trait. The treatment (M_2Si_2) achieved the highest average of (57.270 SPAD), while the treatment (M_0Si_0) recorded the lowest average of (45.327 SPAD), with an increase of 26.34%. The results also demonstrated a significant interaction effect between organic fertilization and foliar silicon application on this trait. Treatment (O_1Si_2) yielded the highest mean, reaching (55.922 SPAD), while treatment (O_0Si_0) recorded the lowest mean for the trait, at (47.549 SPAD), representing an increase of 17.60%. The same table's results indicated a significant three-way interaction effect between the study factors on the Index of chlorophyll in leaves, with treatment ($M_1O_1Si_2$) giving the highest mean of (58.953 SPAD), while treatment ($M_0O_0Si_0$) recorded the lowest mean for the trait, at (42.947 SPAD), representing an increase of 37.26%.

Plant yield (g plant^{-1})

The results presented in Table 5 revealed significant differences in the average plant yield (g plant^{-1}) attributed to the effects of different levels of mineral fertilizer (NPK). The addition of the second level of mineral fertilizer (M_2) had a considerable impact, achieving the highest average yield of (161.17 g plant^{-1}), while the control group with no fertilization (M_0) recorded the lowest average yield of (111.74 g plant^{-1}). Mineral fertilization with nitrogen, phosphorus, and potassium enhances nutrient availability in the soil, improving its overall properties and increasing the plant's capacity to absorb these essential nutrients. The cumulative effect of these nutrients promotes better growth and boosts biomass production. This, in turn, leads to a higher number of flowers and larger grain sizes. Additionally, mineral fertilization improves key physiological processes such as respiration and photosynthesis, ultimately resulting in increased productivity (Morsy and Ahmed, 2021; Aljoubory and Al-Yasari.,2023). Furthermore, the results indicated that organic fertilization significantly influenced plant yield, with the level of (40 kg ha^{-1}) attaining the highest average yield of (157.60 g plant^{-1}) compared to the control level (0 kg ha^{-1}), which reported a lower average of (124.76 g plant^{-1}). Increasing soil organic matter, primarily through the addition of humic substances, significantly enhances soil health, which in turn promotes optimal plant growth and enhances agricultural productivity. Enhanced plant height, leaf area, and chlorophyll content collectively contribute to achieving higher crop yields (Sindhu et al., 2022).

The data demonstrate that foliar application of silicon had a significant effect on plant yield. The concentration of (6 ml L^{-1}) yielded the highest average of (150.35 g plant^{-1}), while the concentration of (0 ml L^{-1}) resulted in the lowest average plant yield of (126.99 g plant^{-1}). When the concentration of silicon spray was increased from 3 to 6 ml L^{-1}, the results demonstrated a significant improvement compared to the absence of any silicon addition (0 ml L^{-1}). This suggests that silicon plays a vital role in enhancing key processes in plants, particularly by strengthening cell walls. As a result, plants exhibited increased height and leaf area due to improved cell growth and a reduction in the impact of environmental stressors. Furthermore, silicon enhances chlorophyll production, which improves photosynthetic efficiency and boosts the plant's capacity to generate the energy required for growth. This effect is crucial for increasing maize productivity (Elmahdy et al., 2023).

The results also indicated that all binary interactions were significant in enhancing plant yield. The interaction between mineral and organic fertilization levels significantly affected the increase in plant yield; the treatment (M_2O_1) achieved the highest average of (176.00 g plant^{-1}), whereas the control treatment (M_0O_0) recorded the lowest average of (97.44 g plant^{-1}), indicating an increase of 88.62%.

Table 5: Effect of NPK fertilization, organic fertilization, and organic silicon foliar feeding on maize plant yield (g plant^{-1}).

Fertilizer NPK levels		Organosilicon spray concentrations			Average (M)
		Si_0	Si_1	Si_2	
M_0		102.03	114.09	119.09	111.74
M_1		131.28	158.44	162.22	150.65
M_2		147.66	166.09	169.75	161.17
Fertilizer organic levels		Organosilicon spray concentrations			Average (O)
		Si_0	Si_1	Si_2	
O_0		114.54	126.81	132.94	124.76
O_1		139.44	165.60	167.77	157.60
Average (Si)		126.99	146.21	150.35	
Fertilizer NPK levels		Organosilicon spray concentrations			Average M * O
		Si_0	Si_1	Si_2	
M_0	O_0	85.06	99.69	107.56	97.44
	O_1	119.00	128.50	130.63	126.04
M_1	O_0	121.44	132.31	137.81	130.52
	O_1	141.13	184.56	186.63	170.77
M_2	O_0	137.13	148.44	153.44	146.33
	O_1	158.19	183.75	186.06	176.00

L.S.D $_{0.05}$						
M	O	Si	M*Si	O*Si	M*O	M*O*Si
0.995	0.812	0.995	1.723	1.407	1.407	2.437

Moreover, the binary interaction between mineral fertilization and foliar silicon application also demonstrated a significant effect on this trait, with treatment (M_2Si_2) achieving the highest average yield of (169.75 g plant^{-1}), while treatment (M0Si0) recorded the lowest average of (102.03 g plant^{-1}), representing an increase of 66.37%.

Additionally, the results showed a significant interaction between organic fertilization and foliar silicon application on this trait. Treatment (O_1Si_2) yielded the highest mean of (167.77 g plant^{-1}), while treatment (O_0Si_0) recorded the lowest mean at (114.54 g plant^{-1}), reflecting an increase of 46.47%. Finally, the results in the same table indicated a significant three-way interaction effect among the study factors on plant yield, with treatment ($M_1O_1Si_2$) providing the highest mean of (186.63 g plant^{-1}), whereas treatment ($M_0O_0Si_0$) recorded the lowest mean yield of (85.06 g plant^{-1}), increasing by 119.40%.

Harvest Index (%)

The results presented in Table 6 demonstrated significant differences in the average harvest index due to varying levels of mineral fertilizer (NPK). Specifically, the addition of mineral fertilizer at level (M_2) resulted in a notably higher average harvest index of 48.958%, compared to the control treatment (M_0), which showed the lowest average of 44.182% without fertilization. The significant impact of adding mineral fertilizers—specifically nitrogen, phosphorus, and potassium—on the harvest index can be attributed to enhanced production efficiency. These essential nutrients promote overall plant growth, improving metabolic processes and increasing chlorophyll production. This, in turn, boosts the plant's ability to convert energy into grain. Consequently, the ratio of grain to biological yield rises, leading to an increased harvest index. This reflects better nutrient utilization, ultimately resulting in higher yields (Bindraban et al., 2020; Fatima and Al-Yasari., 2024).

Table 6: Effect of NPK fertilization, organic fertilization, and organic silicon foliar feeding on maize harvest index (%)

Fertilizer NPK levels		Organosilicon spray concentrations			Average (M)
		Si_0	Si_1	Si_2	
M_0		43.210	44.308	45.028	44.182
M_1		47.008	49.172	50.522	48.901
M_2		47.682	49.088	50.103	48.958
Fertilizer organic levels		Organosilicon spray concentrations			Average (O)
		Si_0	Si_1	Si_2	
O_0		44.650	45.970	46.453	45.691
O_1		47.283	49.076	50.649	49.003
Average (Si)		45.967	47.523	48.551	
Fertilizer NPK levels		Organosilicon spray concentrations			Average M * O
		Si_0	Si_1	Si_2	
M_0	O_0	41.783	43.120	43.743	42.882
	O_1	44.637	45.497	46.313	45.482
M_1	O_0	45.730	46.930	47.570	46.743
	O_1	48.287	51.413	53.473	51.058
M_2	O_0	46.437	47.860	48.047	47.448
	O_1	48.927	50.317	52.160	50.468

L.S.D $_{0.05}$						
M	O	Si	M*Si	O*Si	M*O	M*O*Si
0.1072	0.0876	0.1072	0.1858	0.1517	0.1517	0.2627

Furthermore, the data indicated that organic fertilization had a meaningful impact on the harvest index; the application of (40 kg ha^{-1}), yielded the highest average of 49.003%, in contrast to the control level of (0 kg ha^{-1}), which recorded a lower average of 45.691%. The significant increase in yields achieved by using organic fertilizer can be attributed to its essential role in improving soil fertility. Humic acid, which is present in organic matter, enhances soil fertility by facilitating nutrient uptake by plants. Moreover, organic fertilizer improves water and air penetration to the roots, boosts microbial activity in the soil, and aids in the decomposition of organic matter. This process increases the availability of nutrients to plants. When nutrients are supplied in a balanced manner, plants become more efficient at utilizing these elements, leading to a higher grain-to-biological yield ratio. These factors collectively contribute to an enhanced harvest index and greater overall productivity (AL-Yasari and Al-Hilli., 2018; Sindhu et al., 2022).

Additionally, the results illustrate a significant effect of foliar silicon application on the harvest index. A concentration of 6 ml L^{-1} resulted in the highest average of 48.551%, while the (0 ml L^{-1}) concentration provided the lowest average harvest index of 45.967%. The increase in the harvest index can be attributed to the role of silicon. Silicon enhances photosynthesis by improving leaf health and increasing chlorophyll content, which leads to greater food energy production. It also strengthens cell walls, promoting better plant growth and contributing to higher yields. Furthermore, silicon improves the utilization of nutrients in plants, resulting in a higher grain-to-plant ratio. All of these factors work together to enhance the harvest index and boost overall productivity (Elmahdy et al., 2023).

The data also indicated that all binary interactions significantly enhanced the harvest index. Notably, the interaction between mineral and organic fertilization levels substantially increased the harvest index. The treatment (M_1O_1) achieved the highest average of 51.058%, whereas the control treatment (M_0O_0)

recorded the lowest at 42.882%, marking an impressive increase of 19.06%. In addition, the combination of mineral fertilization and foliar silicon application also showed a significant effect on the harvest index; the treatment (M_1Si_2) reached an average of 50.522%, while (M_0Si_0) yielded a lower average of 43.210%, resulting in a 15.95% increase.

The interaction between organic fertilization and foliar silicon application also demonstrated significant results. The treatment (O_1Si_2) produced the highest mean harvest index of 50.649%, while the treatment (O_0Si_0) had the lowest mean of 44.650%, representing an increase of 13.43%. Lastly, the results from the same table highlighted a significant three-way interaction effect among the factors studied regarding the harvest index. The treatment ($M_1O_1Si_2$) produced the highest mean of 53.473%, whereas the treatment ($M_0O_0Si_0$) recorded the lowest mean at 41.783%, reflecting a remarkable increase of 27.97%.

CONCLUSIONS

These results lead us to conclude that the use of mineral fertilizers (NPK), organic fertilization, and foliar spraying with silicon promotes vegetative growth. This enhancement in growth improves photosynthesis, ultimately leading to better grain composition and increased corn yield. The interaction between mineral fertilizers (NPK), organic fertilization, and foliar spraying with silicon was identified as the most effective approach for improving both corn growth and yield.

REFERENCES

- Abbas, H. K., & Al-Yasari, M. N. H. (2024). Response of growth and yield traits of Vigna radiata L. to organic fertilization and foliar application of nano copper. *Journal of Kerbala for Agricultural Sciences*, *11*(4), 234-246.
- Ali, N., Rahi, H. S., & Shaker, A. W. A. (2014). Soil Fertility. Ministry of Higher Education and Scientific Research. *Scientific Books House for printing, publishing and distribution*.
- Aljoubory, S. K., & Al-Yasari, M. N. H. (2023). Response of growth, yield and quality of maize to the fertilizer combi-nation of nitrogen and potassium and spraying with the potassium humate. *Journal of Kerbala for Agricultural Sciences*, *10*(3), 110-126.
- Al-Yasari, M. N. H. (2022). Potassium and nano-copper fertilization effects on morphological and production traits of oat (Avena sativa L.). *SABRAO J. Breed. Genet*, 54(3), 678-685.
- AL-Yasari, M. N. H., & Al-Hilli, M. (2018). Effect of NPK and organic fertilization and iron and zinc paper spraying based on nanotechnology and normal methods in the growth and yield of Solanum tuberosum L. *Int. J. Agric. Stat. Sci*, *14*(1), 229-238.
- Al-Yasari, M. N. H., & Al-Jbwry, S. K. (2024). Effect of inorganic fertilizer combination and foliar application of organic nutrient on growth and yield traits of maize. *SABRAO J. Breed. Genet*, *56*(2), 875-888.
- Amujoyegbe, B. J., Opabode, J. T., & Olayinka, A. (2007). Effect of organic and inorganic fertilizer on yield and chlorophyll content of maize (Zea mays L.) and sorghum Sorghum bicolour (L.) Moench. African Journal of Biotechnology, 6(16).
- Bhardwaj, S., & Kapoor, D. (2021). Fascinating regulatory mechanism of silicon for alleviating drought stress in plants. *Plant Physiology and Biochemistry*, *166*, 1044-1053.
- Bindraban, P. S., Dimkpa, C. O., & Pandey, R. (2020). Exploring phosphorus fertilizers and fertilization strategies for improved human and environmental health. *Biology and Fertility of Soils*, *56*(3), 299-317.
- Chen, Q., Qu, Z., Ma, G., Wang, W., Dai, J., Zhang, M., & Liu, Z. (2022). Humic acid modulates growth, photosynthesis, hormone and osmolytes system of maize under drought conditions. Agricultural Water Management, 263, 107447.
- Ciampitti, I. A., & Vyn, T. J. (2014). Nutrient sufficiency concepts for modern corn hybrids: Impacts of management practices and yield levels. *Crop Management*, *13*(1), 1-7.
- Dewettinck, K., et al. (2023). "Nutritional and Health Benefits of Corn: A Comprehensive Review." *Food Research International*. [Link to journal or report if available].

- Ding, Z., Ali, E. F., Almaroai, Y. A., Eissa, M. A., & Abeed, A. H. (2021). Effect of potassium solubilizing bacteria and humic acid on faba bean (*Vicia faba* L.) plants grown on sandy loam soils. Journal of Soil Science and Plant Nutrition, 21, 791-800.
- Elmahdy, A. M., Ahmed, Y. M., Bakr, A. A., Abdallah, A. M., Abdelghany, A. M., El-Sorady, G. A., & Lamlom, S. F. (2023). Revolutionizing maize farming with potassium silicate foliar spray and water management techniques. *Silicon*, *15*(16), 7121-7135.
- El-Sahookie,M.M.(1990). Maize production and improvement. *High Education, Baghdad Uni. P*, *400*.
- FAO, 2023. FAO STAT. Food and Agriculture Organization of the United Nations.
- Fatima, M. M., & Al-Yasari, M. N. H. (2024). Effect of mineral fertilizer combination and foliar application of seaweed extract on the growth and yield traits of maize. *SABRAO Journal of Breeding & Genetics*, 56(3),1251-1261.
- Fatima, M. M., & Al-Yasari, M. N. H. (2024). Maize response to mineral fertilizers and seaweed extract for growth and yield-related traits. *SABRAO Journal of Breeding & Genetics*, 56(4),1738-1748.
- Mahmood, Y. A., Ahmed, F. W., Mohammed, I. Q., & Wheib, K. A. (2020). Effect of organic, mineral fertilizers and foliar application of humic acid on growth and yield of corn (*Zea mays* L.). *Indian Journal of Ecology*, *47*(10), 39-44.
- Minotti, P. L., Halseth, D. E., & Sieczka, J. B. (1994). Field chlorophyll measurements to assess the nitrogen status of potato varieties. *HortScience*, *29*(12), 1497-1500.
- Morsy, M., & Ahmed, A. (2021). Response of two yellow maize hybrids to amino acids, mineral Npk and nano-fertilizers under Toshka District conditions. *Alexandria Science Exchange Journal*, *42*(2), 327-340.
- Nanganoa, L. T., Ngome, F. A., Suh, C., & Basga, S. D.(2020). Assessing soil nutrients variability and adequacy for the cultivation of maize, cassava, and sorghum in selected agroecological zones of Cameroon. *International Journal of Agronomy*, 1-20.
- Pavlovic, J., Kostic, L., Bosnic, P., Kirkby, E. A., & Nikolic, M. (2021). Interactions of silicon with essential and beneficial elements in plants. *Frontiers in Plant Science*, *12*, 697592.
- Sana, A., et al. (2022). "Silicon and its role in increasing chlorophyll content and photosynthesis." *Photosynthesis Research*, 153(2), 189-202.
- Sindhu, S.S., Sehrawat, A., & Glick, B. R. (2022). The involvement of organic acids in soil fertility, plant health and environment sustainability. *Archives of Microbiology*, *204*(12), 720.
- Teixeira, G. C. M., de Mello Prado, R., Oliveira, K. S., D'Amico-Damião, V., & da Silveira Sousa Junior, G. (2020). Silicon increases leaf chlorophyll content and iron nutritional efficiency and reduces iron deficiency in sorghum plants. *Journal of Soil Science and Plant Nutrition*, *20*, 1311-1320.
- Zhang, Y., Xia, C., Zhang, X., Sha, Y., Feng, G., & Gao, Q. (2022). Quantifying the relationships of soil properties and crop growth with yield in a NPK fertilizer application maize field. *Computers and Electronics in Agriculture*, *198*, 107011.