

Effect of Mycorrhiza, Seaweed Extract Spray, Arginine Acid and Their Overlap Characteristics of Growing of Sweet Corn Plants

Amaal Abdul Wahab Abdul Karim AL-Badri *¹✉, Ridha Mustafa Abdul Hussein AL-Ubaidy ²✉

*¹ Department of Horticulture and Landscape Gardening College of Agricultural Engineering Sciences., University of Baghdad, Baghdad, Iraq

ABSTRACT

This study was conducted at a research station affiliated with the Department of Horticulture and Landscape Engineering, College of Agricultural Engineering Sciences, University of Baghdad, during the spring season of 2024. The study aimed to investigate the effect of inocul mycorrhiza fungi, seaweed extract, and the amino acid arginine, along with their interactions, on the chemical and root characteristics of sweet corn plants. The experiment involved three factors: inoculating sweet corn seeds with mycorrhizal fungi at two levels (M0, M1), foliar spraying with seaweed extract at three concentrations (0, 1, 2 mL L⁻¹), and foliar spraying with arginine at three concentrations (0, 125, 250 mg L⁻¹). The study was conducted using a randomized complete block design (RCBD) with a split-plot arrangement. Results showed that the three-way interaction (M1S2G2) showed significant superiority in the studied traits, including Percentage of Nitrogen, and potassium with the value 2.80% N , 0.416% P and 2.17%K respectively, root length (30.67 cm), number of root branches (40,475 branches per plant), and root dry weight (36.00 g).

Key words: amino acid , bio-fertilizers , organic nutrient.



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INTRODUCTION

The Gramineae family includes one secondary vegetable crop, which is sweet corn (*Zea mays* L.var *saccharata*). It is one of the most important, most valuable and most cultivated vegetable crops, as its grains contain a number of nutritional elements that are indispensable for the human body, and they also have important nutritional value because they contain carbohydrates, proteins, fibers, and some essential vitamins and minerals (Rózsa et al., 2023; Nivethitha et al., 2023). . Sweet corn, also known as sugar corn, is characterized by a high sugar content when harvested at the fresh stage (Chouhan et al., 2021). Biofertilizers are a substance that contains living microorganisms such as bacteria and fungi or their by-products, a promising alternative to traditional chemical fertilizers in modern agriculture (Masmoudi et al., 2023). Biofertilizers include microorganisms that can be applied to plants, and then settle

within the plant roots or internal plant structures. This colonization stimulates plant growth by enhancing the absorption of nutrients from the host (Ng et al., 2024). In addition to their important role in supplying the plant with phosphorus in the largest quantity, by reducing the area required for phosphorus to reach it, there is a direct relationship between phosphorus and fungi, as it increases the surface area of the plant to facilitate the absorption of phosphorus (Al-Kalabi, 2018; Al-Jammas, 2018; Fall et al., 2022; Abdel-Hussein et al., 2022). Amino acids also stimulate plant growth and development by improving production. Auxin and chlorophyll, increase germination rate, and water absorption (Popko et al., 2018). Foliar spraying has an important role in improving plant growth and increasing its productivity by supplying it with its needs for various nutrients that contribute to many diverse physiological activities in plant tissues (Al-bayati and Al-

Juboori, 2023). As well as improving growth characteristics, represented by plant height, stem diameter, leaf area, and biological yield, as in the sunflower plant (Al-Saadi and Al-Halafi, 2024). Therefore, it is necessary to provide foliar nutrients to help the plant regain growth and increase its early production, because plants are exposed to situations of stress, especially during the first period of growth, which causes injury to their roots, or due to heavy rains (Al-Mashhadany and Al-Mharib, 2023). It significantly and positively affects growth indicators, yield, and quantitative traits, as in spinach (Al-Mharib et al., 2022). Due to the lack of studies on sweet corn, as it is an uncommon crop in Iraq, the study aimed to know the effect of inoculation with mycorrhizal fungi and determine the best concentration of the organic nutrient and arginine acid on the chemical and root characteristics of the sweet corn plant.

MATERIALS AND METHODS

The study was conducted at a research station, Department of Horticulture and Landscape Engineering, College of Agricultural Engineering Sciences, University of Baghdad, Jadriyah, during the spring season of 2024. Study aimed to investigate the interaction effects of inoculation with mycorrhiza, foliar application of seaweed extract, and arginine on the chemical and root traits of sweet corn. The experiment was designed as a factorial arrangement within a randomized complete block design (RCBD) with a split-plot layout. The main plots included mycorrhizal inoculant with two levels (M0: without inoculation, M1: with inoculation), while the subplots comprised foliar applications of seaweed extract (S) at three concentrations (S0: 0, S1: 1 mL L⁻¹, S2: 2 mL L⁻¹) and arginine (G) at three concentrations (G0: 0, G1: 125 mg L⁻¹, G2: 250 mg L⁻¹). The treatments were distributed across three replicates, resulting in 18 combinations (3 × 3 × 2), with three replication, thus the total numbers of experimental unit, were 45. Sweet corn seeds were planted in mid-March, with all soil preparation practices completed. A drip irrigation system was employed, and plants were fertilized with 25% of the recommended chemical fertilizer dose (Al-Bayati, 2023).

Mycorrhizal fungi inoculation involved adding 10 g of inoculum per plant at a density of 50 spores. The leaf located beneath the cob (the supporting leaf) was sampled after the flowering stage was completed. The leaves were dried in an electric oven at a temperature of 65–70°C for 72 hours until a constant weight was achieved (Al-Sahaf, 1989). Subsequently, the samples were ground, and a 0.2 g portion was taken. The samples were digested using a mixture of sulfuric acid and perchloric acid in a ratio of 2:1 (Jones and Steyn, 1973). The chemical traits were then determined as follows:

Estimation of nitrogen percentage in leaves (%): Nitrogen content was Kjeldahl method as described by (Jackson, 1985).

Estimation of phosphorus percentage in leaves (%): It was determined by spectrophotometer with the wavelength fixed at 882 nm (Olsen and Sommers, 1982).

Estimation of potassium percentage in leaves (%): Potassium was analyzed using a flame photometer following the procedures outlined by (Walsh, 1970; Al-Sahaf, 1989)

Dry root weight (g): Roots were collected at the end of the experiment, air-dried initially in a ventilated room, and then oven-dried at 65–70°C until a constant weight was achieved. The dry weight was then recorded.

Number of root branches (branches per plant): The number of root branches was manually counted, including both primary and secondary roots and their branches, for 50% of the plants in each experimental unit after the experiment concluded.

RESULTS AND DISCUSSION

1. Effect of mycorrhizal fungi, seaweed extract, and arginine application on the chemical traits of sweet corn leaves

1.1 Nitrogen percentage in leaves: Table (1) illustrates the effect of the three-way interaction between all treatments on leaf nitrogen percent. The treatments (M₁S₂G₁) and (M₁S₂G₂) demonstrated superior performance, achieving the same highest nitrogen percentage of 2.800%, compared to other three-way interaction treatments. The lowest nitrogen percentages, 1.750%, were observed in the treatments (M₀S₀G₀), (M₀S₀G₁), (M₀S₀G₂), and (M₀S₁G₀). Similarly, the treatments (M₀S₁G₁), (M₀S₁G₂), and (M₀S₂G₀) recorded a slightly higher value of 1.820%.

Table 1. Effect of mycorrhizal fungi, foliar application of seaweed extract, arginine, and their interaction on the nitrogen percentage in sweet corn leaves

Interaction on the nitrogen percentage in sweet corn leaves						
Mycorrhiza Inocula (M)		seaweed (S)	Arginine (G)			M*S
			G ₀	G ₁	G ₂	
M ₀		S ₀	1.750	1.750	1.750	1.750
		S ₁	1.750	1.820	1.820	1.796
		S ₂	1.820	1.913	2.053	1.928
M ₁		S ₀	2.100	2.100	2.100	2.100
		S ₁	2.173	2.210	2.320	2.234
		S ₂	2.566	2.800	2.800	2.722
			Mean(M)			
M*G		M0	1.773	1.827	1.874	1.825
		M1	2.280	2.370	2.406	2.352
			Mean(S)			
S*G		S0	1.925	1.925	1.925	1.925
		S1	1.961	2.015	2.070	2.015
		S2	2.193	2.356	2.426	2.325
Mean (G)			2.026	2.098	2.140	
L.S.D 0.05						
M*S*G	S*G	M*G	M*S	G	S	M
0.098	0.069	0.056	0.056	0.040	0.040	0.032

1.2 Estimation of Phosphorus Percentage in Leaves (%): Table(2) shows the effect of the three-way interaction among all treatments. The treatment (M₁S₂G₂) recorded the highest

phosphorus percentage of 0.416%, compared to the treatment (M₀S₀G₀), which registered the lowest value of 0.230%.

Table 2. Effect of mycorrhizal fungi, foliar application of seaweed extract, arginine, and their interaction on the phosphorus percentage in sweet corn leaves

Interaction on the phenolic percentage in sweet corn leaves						
Mycorrhiza Inocula (M)		seaweed (S)	Arginine acid (G)			M*S
			G ₀	G ₁	G ₂	
M ₀	S ₀		0.230	0.240	0.270	0.246
	S ₁		0.270	0.273	0.280	0.274
	S ₂		0.280	0.300	0.300	0.293
M ₁	S ₀		0.306	0.320	0.333	0.320
	S ₁		0.340	0.350	0.370	0.353
	S ₂		0.370	0.393	0.416	0.393
			Mean(M)			
M*G	M0		0.260	0.271	0.283	0.271
	M1		0.338	0.354	0.373	0.355
			Mean(S)			
S*G	S0		0.268	0.280	0.301	0.283
	S1		0.305	0.311	0.325	0.313
	S2		0.325	0.346	0.358	0.343
Mean (G)			0.299	0.312	0.328	
L.S.D 0.05						
M*S*G	S*G	M*G	M*S	G	S	M
0.007	0.005	0.004	0.004	0.003	0.003	0.0025

1.3 Potassium Percentage in Leaves (%) Table (3) shows the effect of the three-way interaction among all treatments. The treatment (M₁S₂G₂) recorded the highest

potassium percentage of 2.170%, compared to the treatment (M₀S₁G₀), which registered the lowest value of 1.260%.

Table 3. Effect of mycorrhizal fungi, foliar application of seaweed extract, arginine, and their interaction on the potassium percentage (%) in sweet corn leaves

Mycorrhiza Inocula (M)	seaweed (S)	Arginine acid (G)			M*S	
		G ₀	G ₁	G ₂		
M ₀	S ₀	1.476	1.360	1.590	1.475	
	S ₁	1.260	1.730	1.866	1.618	
	S ₂	1.800	1.666	1.800	1.755	
M ₁	S ₀	1.666	1.793	1.993	1.817	
	S ₁	1.873	1.823	1.886	1.861	
	S ₂	1.340	1.650	2.170	1.720	
Mean(M)						
M*G	M0	1.512	1.585	1.752	1.616	
	M1	1.626	1.755	2.016	1.799	
Mean(S)						
S*G	S0	1.571	1.576	1.791	1.646	
	S1	1.566	1.776	1.876	1.740	
	S2	1.570	1.658	1.985	1.737	
Mean (G)		1.569	1.670	1.884		
L.S.D 0.05						
M*S*G	S*G	M*G	M*S	G	S	M
0.074	0.052	0.042	0.042	0.030	0.030	0.024

The results from Tables (1, 2, and 3) highlight the influence of mycorrhiza, that colonize plant roots or internal structures. These colonies stimulate plant growth by enhancing nutrient absorption from the host (Ng et al., 2024). The symbiosis between mycorrhiza and root plant enables plants to access essential nutrients, including nitrogen, phosphorus, and potassium, more effectively (Wahab et al., 2023), thereby increasing their concentrations in the plant and subsequently in the leaves. Furthermore, certain compounds secreted by mycorrhizal fungi play a significant role in supplying crops with macronutrients such as phosphorus, magnesium, and nitrogen, which are crucial for improving crop growth (Yang et al., 2021). The effect may also be due to the amino acid arginine, which acts as a plant growth stimulant and a rich nitrogen source, vital for the synthesis of enzymes and proteins involved in physiological processes (Al-Ealayawi and Al-Dulaimy, 2023). Additionally, arginine metabolism plays a critical role in nitrogen storage during the embryonic development stage and in supplying nitrogen to the plant during germination (Llebrés et al., 2018). Consequently, mineral elements in the plant, including nitrogen (Table 1), phosphorus (Table 2), and potassium (Table 3), are increased. The effect can also be attributed to

seaweed extracts, which contain over 30 natural compounds, macronutrients, micronutrients, and growth-promoting substances such as auxins, gibberellins, cytokinins, vitamins, amino acids, organic acids, and sugars. These components enhance plant resistance to salinity and drought, while increasing chlorophyll content in the leaves (Fatima and Al-Yasari, 2024). Seaweed extracts also accelerate carbon metabolism and plant growth by promoting chlorophyll breakdown and acting as biostimulants to enhance nutrient absorption, and their translocation to the leaves (Abbas et al., 2017). Moreover, seaweed extracts positively impact soil properties by increasing enzymatic activities and nutrient availability, thus improving crop nutrition. The active components in these extracts, including plant growth hormones and phenolic compounds, likely influence plant physiological processes and metabolic pathways, leading to improved plant growth, root development, crop yield, and nutrient uptake. They also enhance productivity, grain quality, and soil health (Gandhi et al., 2024).

2. Effect of mycorrhizal fungi, seaweed extract, and arginine application on the root traits of sweet corn

2.1 Dry root weight (g): Table (4) shows the results of all three-way interaction treatments.

The treatment ($M_1S_2G_2$) achieved the highest dry root weight of 36.00 g, compared to the control treatment ($M_0S_0G_0$), which recorded the lowest value of 20.667 g.

Table 4. Effect of mycorrhizal fungi, foliar application of seaweed extract, arginine, and their interaction on the dry root weight (g) of sweet corn plants

Interaction on the dry root weight (g) of sweet corn plants						
Mycorrhiza		seaweed (S)	Arginine acid (G)			M*S
Inocula (M)			G ₀	G ₁	G ₂	
M ₀		S ₀	20.667	22.000	23.000	21.889
		S ₁	23.000	24.000	24.000	23.667
		S ₂	24.667	25.000	25.000	24.889
M ₁		S ₀	26.000	26.333	27.000	26.444
		S ₁	28.333	29.000	30.333	29.222
		S ₂	31.667	34.667	36.000	34.111
Mean(M)						
M*G		M0	22.778	23.667	24.000	23.481
		M1	28.667	30.000	31.111	29.926
Mean(S)						
S*G		S0	23.333	24.167	25.000	24.167
		S1	25.667	26.500	27.167	26.444
		S2	28.167	29.833	30.500	29.500
Mean (G)			24.167	26.444	29.500	
L.S.D 0.05						
M*S*G	S*G	M*G	M*S	G	S	M
0.5974	0.4224	0.3449	0.3449	0.2439	0.2439	0.1991

2.2 Number of root branches (branches per plant): Table (5) shows the results of the three-way interaction treatments. The treatment ($M_1S_2G_2$) recorded the highest number of root branches at 36.000 branches per plant, compared to the control treatment ($M_0S_0G_0$), which registered the lowest value of 10,591 branches per plant.

Table 5. Effect of mycorrhizal fungi, foliar application of seaweed extract, arginine, and their interaction on the number of root branches (branches per plant) of sweet corn plants

Mycorrhiza Inocula (M)		seaweed (S)	Arginine acid (G)			M*S
			G ₀	G ₁	G ₂	
M ₀		S ₀	10591	13209	15014	12938
		S ₁	15403	19305	22588	19099
		S ₂	22897	23062	23552	23170
M ₁		S ₀	26.000	26.333	27.000	26.444
		S ₁	28.333	29.000	30.333	29.222
		S ₂	31.667	34.667	36.000	34.111
Mean(M)						
M*G		M0	16297	18525	20385	18402
		M1	29981	30341	33656	31326
Mean(S)						
S*G		S0	17236	18700	21727	19221
		S1	22830	24985	27322	25046
		S2	29351	29614	32013	30326
Mean (G)			23139	24433	27021	
L.S.D 0.05						
M*S*G	S*G	M*G	M*S	G	S	M
330.2	233.5	190.6	190.6	134.8	134.8	110.1

2.3 Root length (cm): Table (6) presents the results of the three-way interaction treatments. The treatment ($M_1S_2G_2$) achieved the highest root length of 30.667 cm, compared to the control treatment ($M_0S_0G_0$), which recorded the lowest value of 15.00 cm.

Table 6. Effect of mycorrhizal fungi, foliar application of seaweed extract, arginine, and their interaction on the Root length (cm) of sweet corn plants

Interaction on the root length (cm) of Sweet corn plants						
Mycorrhiza Inocula (M)		seaweed (S)	Arginine acid (G)			M*S
			G ₀	G ₁	G ₂	
M ₀		S ₀	15.000	16.000	16.000	15.667
		S ₁	16.667	17.000	17.000	16.889
		S ₂	18.000	18.333	19.000	18.444
M ₁		S ₀	20.000	21.000	21.000	20.667
		S ₁	22.000	22.667	26.333	23.667
		S ₂	27.667	29.667	30.667	29.333
Mean(M)						
M*G		M0	16.556	17.111	17.333	17.000
		M1	23.222	24.444	26.000	24.556
Mean(S)						
S*G		S0	17.500	18.500	18.500	18.167
		S1	19.333	19.833	21.667	20.278
		S2	22.833	24.000	24.833	23.889
Mean (G)			19.889	20.778	21.667	
L.S.D 0.05						
M*S*G	S*G	M*G	M*S	G	S	M
0.5108	0.3612	0.2949	0.2949	0.2085	0.2085	0.1703

The results from Tables (4, 5, and 6) indicate significant effects among the treatments due to the application of mycorrhiza. This effect can be attributed to its role in improving soil properties by solubilizing phosphorus. These processes facilitate the absorption of nutrients, which subsequently enhances hormone production, promoting plant growth. Sweet corn relies on mycorrhizal fungi for nutrient uptake, which is influenced by several root factors, including root surface area, the number and length of root hairs. This is evident in the observed increases in root length (Table 6) and the number of root branches (Table 5), which collectively contribute to an increase in dry root weight (Table 4) (Wahab et al., 2023). These findings align with (Al-Bayati, 2023), who studied the response of sweet corn (*Zea mays L. var saccharata*). The synthesis of arginine is critical for cell proliferation (Li and Hoppe, 2023), particularly under conditions where the plant's respiratory chain is inhibited. This promotes root elongation (Table 6), increases the number of root branches (Table 5), and ultimately enhances dry root weight (Table 4). Foliar application of arginine supplements alone is sufficient to support rapid cell growth (Malecki et al., 2020), which agrees with the results reported by (Shareef et al., 2021) in their study on corn (*Zea mays L.*). The positive effect of seaweed extract application may also be attributed to the increase in root

length (Table 6) and expansion, leading to a higher number of root branches (Table 5) and an increase in dry root weight (Table 4). This enables plants to extract nutrients more efficiently from deeper and more distant soil layers (Tryvedi et al., 2017), consistent with the findings of (Fatima and Al-Yasari, 2024) in their study on corn (*Zea mays L.*).

CONCLUSION

The study demonstrated that the interaction of mycorrhizal fungi inoculation, foliar application of seaweed extract, and arginine significantly improved both the chemical and root traits of sweet corn plants. The treatment combination of mycorrhizal fungi (M₁), seaweed extract at 2 mL L⁻¹ (S₂), and arginine at 250 mg L⁻¹ (G₂) consistently showed superior results in nitrogen, phosphorus, and potassium content in leaves, as well as root length, root branches, and dry root weight. These improvements are attributed to the synergistic effects of bio-fertilizers, growth-promoting substances in seaweed extract, and the physiological role of arginine in enhancing nutrient absorption, metabolic activity, and stress tolerance in plants.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHOR/S DECLARATION

The authors declare that this manuscript is original, has not been published previously, and is not currently under consideration by any other journal. All figures and tables are original and prepared by the authors. Any material obtained from third parties has been included with the required permissions. All authors have read and approved the final manuscript.

AUTHOR'S CONTRIBUTION STATEMENT

All authors made equal contributions to the study design, methodology, experimental work, data analysis, and manuscript writing. All authors reviewed and approved the final version of the manuscript.

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تأثير المايكورايزا ورش مستخلص الطحالب البحرية وحامض الأرجنين وتداخلهما في صفات النمو لنباتات الذرة الحلوة

آمال عبد الوهاب عبد الكريم البدري ، رضا مصطفى عبد الحسين العبيدي
قسم البستنة وهندسة الحدائق ، كلية علوم الهندسة الزراعية ، جامعة بغداد ، العراق

المستخلص

أجريت الدراسة في محطة بحثية تابعة لقسم البستنة وهندسة الحدائق، كلية علوم الهندسة الزراعية، جامعة بغداد، خلال الموسم الربيعي لعام 2024. هدفت إلى دراسة تأثير التلقيح بالمايكورايزا، مستخلص الطحالب البحرية، و الأرجنين وتداخلها على الصفات الكيميائية والجذرية لنبات الذرة الحلوة. تضمنت التجربة ثلاثة عوامل: تلقيح بذور الذرة الحلوة بفطر المايكورايزا بمستويين هما M0 و M1، الرش بمستخلص الطحالب البحرية بثلاثة تراكيز هي (0، 1، 2 مل لتر⁻¹)، والرش بحامض الأرجنين بثلاثة تراكيز (0، 125، 250 ملغم لتر⁻¹). نفذت التجربة وفق تصميم القطاعات العشوائية الكاملة (RCBD) بترتيب الألواح المنشقة. أظهرت نتائج التجربة ان التداخل الثلاثي بين فطر المايكورايزا ومستخلص الطحالب البحرية وحامض الأرجنين عند التراكيز M1 S2 (G2) تفوق معنوياً في الصفات المدروسة متمثلة بالنسبة المئوية لعنصر النتروجين والفسفور، والبوتاسيوم اذ بلغ N 2.8% و 0.416% و 2.170% على التتابع، وتمثلت الصفات الجذرية بطول الجذر بلغ 30.667 سم ، وعدد التفرعات الجذرية 40475 فرع نبات⁻¹ و الوزن الجاف للجذور 36.00 غم .

الكلمات المفتاحية: حامض اميني، المخصبات الاحيائية، المغذي العضوي.