Improving Growth and Productivity of Two Maize (*Zea mays* L.) Cultivars Through Foliar Application of Humic Acid Under Saline Soil Conditions

Amer Hashim Abdulmajeed[1], Harith Sadaa Madhan AlFahdawy[2], Mohammed Ismail Khalaf Al-Fahdawy[2], Omer Ismail Al-Fahdawi[1]

[1] Department of Field Crops, College of Agriculture, University of Anbar, Anbar, Iraq.

[2] Center of Desert Studies, University of Anbar, Anbar, Iraq.

Abstract

With the aim of evaluating the role of humic acid in mitigating the effects of soil salts on the growth and yield of two varieties of maize, this study was conducted in the fields of Al-Bu'aitha Agricultural Station during the autumn season of 2024. A land with a high salinity level was selected within the research station. The study was arranged in a split-plot layout within a randomized complete block design (RCBD) with three replications. Humic acid levels (H0, H1, H2, H3) were distributed in the main panels, while the varieties (Nahrain and Research 5082) were distributed in the sub-plots. The results indicated that humic acid reduced the adverse impact of soil salinity on most studied traits. The concentration H2 produced the highest values of grain weight per ear (46.96 g ear^{-1}) and 300-grain weight (53.71 g). While the high concentration of 3 ml H_2^{-1} was superior in most traits, it increased the average plant height (182.66 cm $plant^{-1}$), leaf area (4816.00 cm^2 $plant^{-1}$), total leaf chlorophyll content (55.40 Spad), total yield (4061.66 kg ha^{-1}) , No significant differences were observed between the varieties except in some traits, with the variety Buhouth 5082 exhibiting the highest average plant height (159.41 cm $plant^{-1}$) . As for the interaction between the two study factors, the high concentration of humic acid (H3) with the two varieties achieved a significant interaction, and the traits were distributed between the two varieties. However, the most important interaction was with the Nahrain variety, which recorded the highest average yield per unit area (4337.33 kg ha-1).

Keyword: zea mays, humic acid, Saline Soil, grain yield

تحسين نمو وانتاجية صنفين من الذرة الصفراء بالتغذية الورقية بحامض الهيومك النامية في الترب الملحية

عامر هاشم عبدالمجيد[1]، حارث صداع مضعن الفهداوي[2]، محمد إسماعيل خلف الفهداوي[2] وعمر إسماعيل الفهداوي[1]

[1] قسم المحاصيل الحقلية، كلية الزراعة، جامعة الانبار، الانبار، العراق.

[2] مركز دراسات الصحراء، جامعة الانبار، الانبار، العراق.

المستخلص

بهدف تقييم دور حامض الهيوميك في تخفيف آثار أملاح التربة على نمو وإنتاجية صنفين من الذرة الصفراء، أجريت هذه الدراسة في حقول محطة البعيثة الزراعية خلال الموسم الخريفي لعام ٢٠٢٤. اختيرت أرض ذات مستوى ملوحة مرتفع ضمن محطة الأبحاث. نُفذت الدراسة في نظام القطع المنشقة بتصميم القطاعات الكاملة العشوائية (RCBD) بثلاثة مكررات. توزعت مستويات حامض الهيوميك(H0) ، H1، H2، (H3في الألواح الرئيسية، بينما توزعت الأصناف (نهرين وأبحاث ٥٠٨٢) في القطع المنشقة. أظهرت النتائج قدرة حامض الهيومك في تخفيف تأثير املاح التربة في اغلب الصفات المدروسة، حيث اعطى التركيز (H2) اعلى معدل لصفتي وزن الحبوب بالعرنوص (46.96 غم عرنوص−1) و وزن 300 حبة (53.71 غم)، بينما تفوق التركيز العالي للحامض 3 ملل H لتر−1 في اغلب الصفات المدروسة، حيث زاد من متوسط ارتفاع النبات (182.66 سم نبات−1) والمساحة الورقية (4816.00 سم2 نبات−1) ومحتوى الاوراق من الكلوروفيل الكلي (55.40 Spad) وعدد العرانيص (1.59 عرنوص نبات−1) والحاصل الكلي (4061.66 كغم هــ−1). بينما بينت نتائج التجربة عدم وجود اختلافات معنوية بين الأصناف الا في بعض الصفات، حيث اعطى الصنف بحوث 5082 اعلى متوسط لصفة ارتفاع النبات (159.41 سم نبات−1)، اما بالنسبة الى التداخل بين تراكيز حامض الهيومك والاصناف فقد التركيز العالي لحامض الهيومك 3 ملم H لتر−1 مع الصنفين تداخلا معنويا وتوزعت الصفات بين الصنفين الا ان التداخل الأهم كان مع صنف نهرين الذي سجل اعلى متوسط للحاصل بوحدة المساحة (4337.33 كغم هــ−1)

الكلمات المفتاحية: الذرة الصفراء، حامض الهيومك، الترب الملحية، حاصل الحبوب.

Introduction

Maize (Zea mays L.) is considered a strategic cereal crop of economic and nutritional importance, ranking third globally after wheat and rice in terms of cultivated area and production volume (FAO, 2022). Many countries rely on it for food security and animal feed, as its grains are used in numerous industries such as pasta, oils, and dyes. It is also a component of poultry and

*Corresponding author.
Email: omer.ismail@uoanbar.edu.iq

https://10.36531/ijds.2025.167372.1108
Received 24 November 2025; Received in revised form 24 December 2025; Accepted 31 December 2025

livestock feed and is used as a food source for humans in developing countries due to its high protein, carbohydrate, mineral, and oil content, as well as some vitamins (Erenstein et al., 2022).

Despite its significant importance, maize cultivation and yield per unit, area in Iraq remain low compared to global production. This low productivity necessitates scientific and applied studies to address the underlying problems causing this decline. Improving growth characteristics and increasing yield are key objectives of modern agricultural technologies. Among these technologies is the, use of active organic compounds such as humic, acid, which contributes to enhancing growth efficiency and yield.

Humic acid improves pH regulation and nutrient availability to plants. It also stimulates several physiological processes in plants, such as photosynthesis rates and enzyme activity, under stress conditions that affect many vital and physiological functions. Numerous studies have shown that the use of humic acid, whether in the soil or as a foliar spray, at low concentrations, can improve root growth, increase nutrient absorption, and enhance yield characteristics in several crops, including maize, under stressful conditions (Ge et al, 2025). Varieties differ significantly in terms of growth and their genetic and physiological capacity to convert the products of carbon metabolism into economically viable yields. This difference is reflected in the increase or decrease in both the quantity and quality of the yield. Recent research has indicated that foliar spraying of organic materials may improve the performance of physiological processes related to photosynthesis, nutrient absorption, and the ability to resist stress conditions, especially saline conditions, because spraying on leaves allows plants to absorb nutrients and organic matter directly through the stomata, reaching the cells quickly (within hours). In contrast, when applied to the soil, the acid needs to decompose and migrate with the soil solution before being absorbed by the roots, a process that can take days or weeks. This method also avoids soil problems and the issues of humic acid fixation in the soil or its reaction with other soil components. (Pitann et al.; 2024), which have become characteristic of Iraqi soils due to the misuse of soils, old irrigation methods, and the decrease in the amount of rainfall and river water, which has caused an increase in salt concentrations in the soil. The effect of spraying with organic materials varies according to the concentration and the same variety. For this reason, two varieties of maize were used in this experiment to determine their response to spraying with humic acid and to know the extent of the effect of humic in reducing the effect of high salts in the soil (Al-gartani et al 2011). Based on the importance of the above, For the purpose of evaluating the role of humic acid in reducing the harmful effects of soil salts, this field research was conducted, which included four levels of humic acid feeding on two varieties of yellow corn, with the aim of reaching the best level of humic acid feeding that helps improve vegetative growth and productivity of two varieties of corn in soil with a high salinity level.

Materials and Methods

This study was conducted in one of the fields of the Al-Bu'aitha Agricultural Station for Field Crops Research during the autumn season of 2024, affiliated with the University of Anbar., and is located at latitude 33.22°N, longitude 44.24°E, and an altitude of 34.1 m above sea level. The experiment aimed to study the effect of foliar humic acid feeding on certain growth characteristics, yield, and its components in two varieties of maize (Zea mays L.) grown in saline soil. A randomized complete block design (RCBD) with a split-plot arrangement and three replications was used. The main sections were designated for fertilizing plants with humic acid via foliar spraying (0-, 1-, 2-, and 3-ml H. L^{-1}), and were labeled H0, H1, H2, and H3 respectively. An 18% humic acid product of Iraqi origin, manufactured by Al-Joud Company for Modern Industrial and Agricultural Technology, was used. Two sprays were applied: the first after the three-leaf stage and the second before flowering. A backpack sprayer was used for application, and the spraying was carried out in the early morning. The subplots included the two yellow corn varieties (Nahrain and Buhouth 5082), and were designated V1 and V2.

Land preparation and plot division were carried out according to the design. Each experimental unit measured 3 × 3 m and consisted of five rows, each 3 m long, with 75 cm spacing between rows and 20 cm between plants, resulting in a plant density of 66,666 plants ha^{-1}. Sowing took place on 15 April 2024 the experiment used nitrogen fertilizer (urea fertilizer 46% N) at a rate of 360 kg per hectare, applied in three equal doses during the growing season: at the four-leaf stage, when plants reached 30 cm height, and at the onset of flowering. Triple superphosphate (46% P_2O_5) was applied at 200 kg ha^{-1} and incorporated into the soil before sowing. Potassium sulfate (41% K) was applied twice: 30 days after planting and at the early flowering stage (Sahooki, 1990). Weeds were controlled manually as needed. Chemical and physical properties analysis of the field soil was carried out after taking random samples from the field at a depth of 0 to 40 cm. (Table 1).

Table 1. Characteristics of soil sample.

Characteristics	Unit	Value
Available N	$mg.kg^{-1}$	0.29
Available P	Ppm	9.6
Available K	Ppm	102
PH		7.81
EC	$ds.m^{-1}$	12.1
O. M.	$mg.\ kg^{-1}$	339.
Sand	$mg.\ kg^{-1}$	754
Clay	$mg.\ kg^{-1}$	260
Silt	$mg.\ k\ g^{-1}$	952

Studied Traits:

Ten plants were taken from the protected midlines to study the following characteristics:

Plant Height (cm):

Plant height was measured for ten randomly selected plants taken from the two central rows.

Leaf Area ($cm^2\ plant^{-1}$):

estimated by measuring the maximum leaf width, then multiplying leaf length × 0.65. The average value for the measured leaves was used to represent the leaf area per plant.

Total Chlorophyll Content (SPAD units):

Chlorophyll concentration was assessed for the same ten plants used for leaf area measurements using a SPAD Chlorophyll Meter (SPAD-502 Plus).

Number of ears per plant (ear of $plant^{-1}$):

The number of ears per plant was calculated from the harvested plants, and their average value was taken as a final estimate.

Number of Grains per Ear (grain ear^{-1}):

The number of grains was counted for the ears of the ten sampled plants, and the average was used for analysis.

Grain Weight per Ear (g ear^{-1}):

After shelling the ears of the ten harvested plants, the grains were weighed individually and the mean grain weight per ear was calculated.

Weight of 300 Grains (g):

A random sample of 300 grains from the harvested ears was taken and weighed to obtain the weight of 300 grains.

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

After harvesting the ten protected plants from each experimental unit, and after dehulling their grains, the resulting grains were weighed after adjusting the weight based on moisture content of 15.5 % (Williams and Hallauer 2000), and the average plant yield was taken and then multiplied by the plant density.

Statistical Analysis:

After data collection, the data were statistically analyzed using the GenStat statistical software with an analysis of variance (ANOVA) table. After confirming the existence of significant differences between the treatments, the means were compared to determine their superiority using the LSD test at a significance level of 5%. (Al-Rawi & Khalafallah, 2000).

Results and Discussion

Plant Height (cm)

Table 2 showed significant differences in plant height as a result of spray ing with humic acid. Plants fed with a high concentration (3 ml H_2/L) exhibited the highest average height of 182.66 cm, representing a significant increase of 70.45% compared to the control plants (H0), which showed the lowest average height of 107.16 cm. The significant difference in average plant height between treatments may be attributed to the negative impact of soil salts, which reduced plant height in the control treatment (H0). In contrast, the humic acid spray treatment improved growth and resistance to salt stress, contributing to enhanced growth with increasing humic acid concentration. Some studies indicate that humic acid treatment increases nutrient absorption and acts as a natural stimulant, encouraging the production of important growth hormones such as auxins and gibberellins. These hormones, in turn, stimulate cell division and elongation, leading to increased plant height and biomass (Abaka e t al., 2016). These findings are consistent with those of other researchers (Bilal e t al., 2016; El-Mekser e t al. 2014) demonstrated the positive role of humic acid in improving plant growth.

Table 2 also shows significant differences between varieties. The Research 5082 variety achieved the highest average length of the trait at 159.41 cm, compared to the Al-Nahrain variety, which yielded the lowest average length at 144.25 cm. These differences in some traits between varieties are attributed to genetic variation and their response to environmental conditions (Khan et al., 2015).

As for the interaction between the two study factors, the plants fed with high concentration of humic acid (3 ml H L-1) with the Research 5082 variety achieved the highest average plant height of 192.33 cm compared to the other interaction treatments, with a significant increase of 14.78% compared to the plants in the foliar feeding (H0) treatment of the Al-Nahrain variety, which gave the lowest average for the trait of 96.00 cm (Table 2).

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

Table (2) shows a significant effect of humic acid foliar application concentrations on leaf area. Plants treated with the highest concentration (H3) exhibited the highest average leaf area, reaching 4816.00 cm^2 $plant^{-1}$, compared to the control plants (H0), which showed the lowest average leaf area at 1963.50 cm^2 $plant^{-1}$. The improvement in leaf area with increased humic acid concentration during spraying contributed to reducing the absorption of toxic chloride ions from the soil. This, in turn, mitigated the appearance of scorched leaf tips and yellowing caused by salt toxicity. Furthermore, humic acid promotes plant production of growth hormones, which stimulate cell division and elongation, leading to an increase in the green area required for photosynthesis (Abaka et al., 2016). These results are cons istent with the findings of several researchers regarding the role of humic acid in increasing leaf area (Ge et al., 2025; Ghorbani et al., 2010).

Table 2 shows no significant differences between the varieties in the average trait. However, the table also indicates significant differences in leaf area due to the interaction between foliar feeding with humic acid and the varieties. Plants fed with high humic acid concentration, specifically the Buhouth 5082 (H3V2) variety, achieved the highest average leaf area of 5128.33 cm^2 $plant^{-1}$, compared to the control plants (H0V1) and the Al-Nahrain variety, which gave the lowest average leaf area of 1828.66 cm^2 $plant^{-1}$

Total Chlorophyll Content (SPAD)

Table (2) shows significant differences between humic acid concentrations and their interaction with different varieties in leaf chlorophyll content. Plants treated with a high humic acid concentration (3 ml H L1-) achieved the highest average chlorophyll content of 55.40 Spad, compared to control plants (HO), which gave the lowest average chlorophyll content of 37.16 Spad. The improved chlorophyll content in maize leaves grown in saline soils is attributed to the role of humic acid in creating optimal conditions within the soil and the plant. This is achieved by making magnesium and iron available for absorption, protecting chloroplasts from oxidative damage, and improving photosynthetic conditions through stomata opening. This directly results in increased dark green leaf color (a good field indicator of plant health), increased photosynthetic efficiency, and ultimately, improved growth and yield (Pitann et al.; 2024). These results are consistent with those of several other researchers (Ge et al. 2025, Liu et al.2019) This study highlighted the positive role of humic acid in enhancing chlorophyll synthesis in plants under salt stress.

Table 2 shows that plants fed with high humic acid foliar feeding, specifically the variety H3V2 (H3V2), exhibited the highest average 55.50 spad compared to other intervention treatments. This represents a significant increase of 57.52% compared to the control plants fed with humic acid foliar feeding, also using the same variety (H0V2), which yielded the lowest average Spad value of 35.23.

Table 2. Effect of feeding with humic acid on two varieties of corn in terms of plant height, leaf area and total chlorophyll grown in saline soils (SPAD units)

Treatment	Plant Height (cm)	L.S.D	Leaf Area (cm^2 $plant^{-1}$)	L.S.D	Leaf Chlorophyll Content (SPAD units)	L.S.D
H0	107.16	11.88	1963.50	882.36	37.16	6.19
H1	149.33		3472.83		46.41	
H2	168.16		4108.33		51.73	
H3	182.66		4816.00		55.40	
V1	144.25	8.40	3347.83	N.S	49.55	N.S
V2	159.41		3832.50		45.80	
H0V1	96.00	16.81	1828.66	1247.84	39.10	8.75
H0V2	118.33		2098.33		35.23	
H1V1	143.66		3313.66		50.19	
H1V2	155.00		3632.00		42.63	
H2V1	164.33		3745.33		53.60	
H2V2	172.00		4471.33		49.86	
H3V1	173.00		4503.66		55.30	
H3V2	192.33		5128.33		55.50	

Number of Ears per Plant

Humic acid levels showed a significant effect on the number of ears per plant, as well as an interaction between the two factors, while the varieties did not show any significant effect (Table 3). We observed an increase in the average number of ears with increasing humic acid concentration. The highest humic acid concentration (H3) resulted in the highest average number of ears per plant, at 1.59 ears per plant, an increase of 59.9% compared to the control plants for foliar feeding (H0), which recorded the lowest average number of ears per plant, at 1.00 ears per plant. The increase in the number of ears per plant with increasing humic acid concentration may be attributed to its ability to mitigate the negative effects of salt stress at each stage of growth. This enables the plant to maximize its genetic potential to achieve the highest number of ears per plant, which is directly reflected in an increased final maize yield (Abaka e t al., 2016). These results are consistent with the findings of several researchers (Eyheraguibel et al. 2008, Khalili and Khandan-Mirkohi, 2021). Table 3 shows that plants treated with high concentrations of humic acid foliar feeding with the variety Buhouth 5082 (H3V2) recorded the highest average interaction of 1.60 ears per plant, compared to other interaction treatments, and an increase of 60.0% compared to plants treated with humic acid (H0) with the varieties Nahrain and Buhouth, which gave a lower average interaction of 1.00 ears per plant.

Number of Grains per Ear (grain ear^{-1})

Table 3 shows significant differences between humic acid concentrations and the interaction between humic acid and cultivars in the number of grains per ear, while the cultivars themselves did not show any significant differences in this trait. Plants treated with foliar feeding at a high concentration of humic acid (H3) gave the highest average number of grains per ear, reaching 263.66 grain ear^{-1} significantly higher than the control plants (H0), which gave an average of 102.66 grains per ear. $^{-1}$. Humic acid does not increase the number of potential ovules in the ear; however, it enhances their fertilization and supports the development and retention of grains until physiological maturity. In saline soils, a large proportion of ovules fail to develop, resulting in ears with incomplete rows, fewer grains, and empty spaces especially at the apical region. With humic acid application, ears become fuller and more uniformly filled, allowing the plant to approach its genetic yield potential even under salinity stress (El-mekser et al, 2014; Ge et al , 2025)

The interaction results in Table (3) indicate that spraying 3 mL H L^{-1} combined with the cultivar Nahrain produced the highest number of grains per ear (272.00 grains ear^{-1}), whereas the lowest value (98.00 grains ear^{-1}) was recorded for the control (H0) with the cultivar Buhooth 5082.

Grain Weight per Ear (gm ear^{-1})

The results in Table 3 indicate a significant effect on grain weight per ear as a result of foliar feeding with humic acid and interaction with varieties, while the varieties did not show any significant effect on the trait. The results in the table above show an increase in grain weight per ear when foliar feeding with humic acid is applied. Plants treated with a concentration of (2 ml H L-1) gave the highest average for the trait, reaching 46.96 gm per ear, compared to plants treated with the control (H0), which gave the lowest average for the trait, reaching 8.35 gm per ear-1. Saline soils cause plants to suffer due to salt stress, which reduces the efficiency of photosynthesis, reduces the efficiency of the transport process, and shortens the grain filling period, leading to the production of small, unfilled, and lightweight grains. However, we observe the difference when treating plants with humic acid, which contributes to mitigating these imbalances and works towards a high production of dry matter and improves the efficiency of transporting this matter to the grains and storing it. Thus, we obtain larger, fuller, and heavier grains, which is directly reflected in the end in an increase in the yield in terms of grain weight. (Khaled and Fawy, 2011) This aligns with the findings of several researchers who concluded that humic acid significantly increased grain weight per ear (Ge et al, 2025).

Table 3 shows that plants treated with high concentrations of humic acid foliar feeding, along with the Nahrain variety (H3V1), achieved the highest average grain weight of 51.20 gm per ear-1, compared to the control group of plants treated with humic acid, along with the same variety (H0V1), which yielded the lowest average grain weight of 7.10 gm per ear-1.

Table 3. The effect of feeding with humic acid on two varieties of maize in terms of the number of ears per plant, the number of kernels per ear, and the weight of kernels per ear grown in saline soils.

Treatment	Number of ears of corn on the plant (plant ear^{-1})	L.S.D	Number of grains per ear (ear of corn^{-1})	L.S.D	Weight of grains in ears (g ear^{-1})	L.S.D
H0	1.00	0.13	102.66	23.57	8.35	5.07
H1	1.10		201.50		28.46	
H2	1.35		263.33		46.96	
H3	1.59		263.66		46.71	
V1	1.25	N.S	208.83	N.S	33.09	N.S
V2	1.27		206.75		32.15	
H0V1	1.00	0.19	107.33	33.33	7.10	7.17
H0V2	1.00		98.00		9.60	
H1V1	1.06		195.00		25.86	
H1V2	1.13		208.00		31.07	
H2V1	1.33		261.00		48.20	
H2V2	1.36		265.66		45.72	
H3V1	1.59		272.00		51.20	
H3V2	1.60		255.33		42.22	

Weight of 300 Grains (g)

Table 4 shows a significant effect of humic acid concentration and variety on average grain weight, while no significant differences were observed between varieties. Plants fertilized with humic acid (H2) showed the highest average grain weight at 53.71 g, significantly higher than the control (H0) plants, which had the lowest average grain weight at 19.34 g. This superiority of H2 is attributed to the higher grain weight per ear (Table 3).
Table (4) also shows the significant bilateral interaction between foliar feeding with humic acid and the varieties. Plants fed with the concentration with the Al-Nahrain variety (H2V1) achieved the highest average weight of the trait at 56.47 g, compared to the other interaction treatments, where the control plants fed with foliar feeding with the Buhouth 5082 variety (H0V2) gave the lowest average weight of the trait at 18.98 g.

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

Humic acid has demonstrated its effectiveness in improving the growth of maize plants in saline soils. Significant differences were observed in total grain yield due to the influence of humic acid and its interaction with different varieties, while the varieties showed no significant effect on the average yield (Table 4). The addition of high-concentration humic acid (H3) resulted in a significant increase in grain yield, reaching 4061.66 kg ha^{-1}, compared to the control treatment (H0), which yielded the lowest average grain yield of 443.00 kg ha^{-1}. The superiority of the high humic acid concentration is attributed to its superiority in most growth and yield characteristics, which positively impacted the increase in grain yield per unit area at the high humic acid concentration (Tables 2 and 3). This highlights the role of humic acid in improving most of the plant's vital and physiological activities.

Table 4 shows that the plants feed with high concentration of humic acid foliar feeding with the Al-Nahrain variety (H3V1) recorded the highest average grain yield of 4337.33 kg ha -1 compared to the other interaction treatments and with a significant difference from the control plants fed with foliar feeding with the same variety (H0V1), which gave the lowest average grain yield of 377.66 kg ha-1

Table 4 The effect of feeding with humic acid on two varieties of 300-grain wight, total grain yield, and biological yield grown in saline soils.

Treatment	Weight of 300 grams	L.S.D	Total yield (kg h^{-1})	L.S.D
H0	19.34	2.53	443.00	569.48
H1	42.33		1661.66	
H2	53.71		3341.66	
H3	52.91		4061.66	
V1	42.84	N.S	2396.25	N.S
V2	41.31		2357.75	
H0V1	19.71	3.58	377.66	843.55
H0V2	18.98		508.33	
H1V1	39.76		1475.00	
H1V2	44.90		1848.33	
H2V1	55.41		3395.00	
H2V2	52.01		3288.33	
H3V1	56.47		4337.33	
H3V2	49.35		3786.00	

Conclusion

The growth and yield characteristics of yellow corn grown in saline soil improved due to humic acid, which contributed to regulating many of the plant's vital activities. This was reflected positively in increased crop productivity compared to the control treatment, in which growth and yield decreased due to soil salinity. We recommend using higher levels of humic acid and growing the crop in soils with a higher salinity level to confirm the ability of humic acid to improve growth and yield in soils with a high salt content

References

Abaka, K., Khalil, S. K., Khan, F., Qahar, A., Sharif, M., & Zamin, M. (2016). Phenology, yield, and yield components of maize as affected by humic acid and nitrogen. *Journal of Agricultural Science, 6*(7), 286.

Abed, U. H. K., & Abed-Alazeez, A. A. (2020). The effect of pollen type on some fruit traits. *(Journal/Publisher not specified).*

Al-Gartani, A. K. A., Saba, S., & Al-Taie, S. H. M. (2011). Effect of biofertilization with *Glomus mosseae*, organic fertilization with humic acid, and chemical fertilization on growth traits of yellow maize grown in gypsum soil. In *Proceedings of the 5th Scientific Conference, College of Agriculture, Tikrit University* (pp. 548–555).

Al-Rawi, K. M., & Abdul-Aziz, M. Kh. (2000). *Design and analysis of agricultural experiments*. Ministry of Higher Education and Scientific Research, University of Mosul, Dar Al-Kutub for Printing and Publishing.

Al-Sahouki, M. M. (1990). *Yellow maize: Its production and improvement*. Ministry of Higher Education and Scientific Research, University of Baghdad.

Bilal, M., Umer, M., Khan, I., Munir, H., Ahmad, A., Usman, M., & Iqbal, R. (2016). Interactive effect of phosphorus and humic acid on growth, yield, and related attributes of maize. *Journal of Agricultural Research, 54*(3), 433–445.

Erenstein, O., Jaleta, M., Sonder, K., Mottaleb, K., & Prasanna, B. M. (2022). Global maize production, consumption, and trade: Trends and R&D implications. *Food Security, 14*, 1295–1319. https://doi.org/10.1007/s12571-022-01288-7

Eyheraguibel, B., Silvestre, J., & Morard, P. (2008). Effects of humic substances derived from organic waste on growth and mineral nutrition of maize. *Bioresource Technology, 99*, 4206–4212.

FAO. (2022). *World food and agriculture: Statistical yearbook*. Food and Agriculture Organization of the United Nations.

Ge, L., Yu, S., Weibo, N., Yan, S., Lijun, S., Weiyi, M., Zhi, Q., & Ting, Y. (2025). Humic acid improves water retention, maize growth, water use efficiency, and economic benefits in coastal saline-alkali soils. *Agricultural Water Management*. https://doi.org/10.1016/j.agwat.109323

Ghorbani, S., Khazaei, H. R., Kafi, M., & Bannayan Aval, M. (2010). Effect of humic acid application through irrigation water on yield and yield components of maize (*Zea mays* L.). *Journal of Agroecology, 2*(1), 123–131.

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

Khalili, S., & Khandan-Mirkohi, A. (2021). Humic acid improves morpho-physiological and biochemical traits of *Phyla nodiflora*. *Acta Physiologiae Plantarum, 43*, Article 11. https://doi.org/10.1007/s11738-021-03292-4

Khan, M. I., Qadoons, M., Suleman, M., Khan, H., Aqeel, M., & Rafiq, M. (2015). Response of maize crop to different levels of humic acid. *Life Science International Journal, 9*(1–4), 3116–3120.

Liu, M., Wang, C., Wang, F., & Xie, Y. (2019). Maize (*Zea mays*) growth and nutrient uptake following integrated improvement of vermicompost and humic acid fertilizer on coastal saline soil. *Applied Soil Ecology, 142*, 147–154. https://doi.org/10.1016/j.apsoil.2019.04.024

Mekser, H. K. A. El., Mohamed, Z. E. O. M., & Ali, M. A. M. (2014). Influence of humic acid and some micronutrients on yellow corn yield and quality. *World Applied Sciences Journal, 32*(1), 1–11. https://doi.org/10.5829/idosi.wasj.2014.32.01.14504

Pitann, B., Khan, K., & Mühling, K. H. (2024). Does humic acid foliar application affect growth and nutrient status of water-stressed maize? *Physiologia Plantarum*. Advance online publication. https://doi.org/10.1002/pei3.10156

Vaccaro, S., Ertani, A., Nebbioso, A., Muscolo, A., Quaggiotti, S., Piccolo, A., & Nardi, S. (2015). Humic substances stimulate maize nitrogen assimilation and amino acid metabolism at physiological and molecular levels. *Chemical and Biological Technologies in Agriculture, 2*, Article 5.

Williams, T. R., & Hallauer, A. R. (2000). Genetic diversity among maize hybrids. *Maydica, 45*, 163–171.

Zheng, J., & Xia, R. (2022). Flower development and sex determination in horticultural crops. *Fruit Research, 2*(1), 1–9.

Zubaidy, B. H. F. A., & Al-Mousawi, S. J. K. (2022). Effect of Gorogreen five fructus and pollen cultivar on physical and chemical properties of date palm fruits (*Phoenix dactylifera* L.) cv. Barhi derived from tissue culture. *University of Thi-Qar Journal of Agricultural Research, 11*(1), 102–110.