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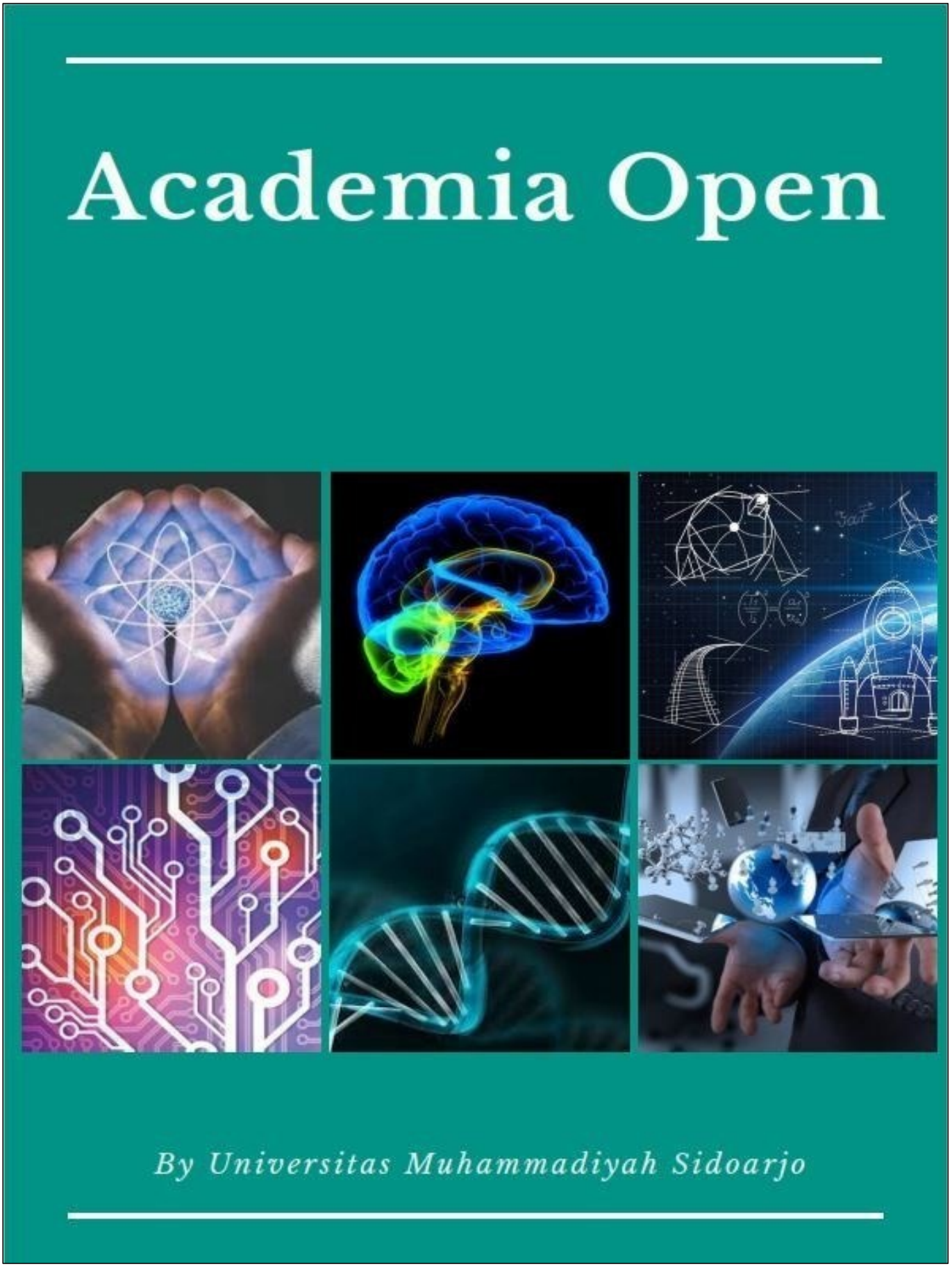

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Extent of Response of Corn Growth Traits to Potassium and Humic

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Abstract

General Background: Maize (Zea mays L.) is one of the world's most important cereal crops, serving as a key food, feed, and industrial raw material. In Iraq, maize productivity remains below the global average due to nutrient imbalances and suboptimal fertilization practices. Specific Background: Potassium plays a crucial physiological role in plant growth, yet its availability is limited in many Iraqi soils. Additionally, humic acid, when applied as a foliar spray, enhances nutrient absorption and photosynthetic efficiency. Knowledge Gap: Limited studies have explored the interactive effects of potassium fertilization and foliar-applied humic acid on maize vegetative growth under Iraqi soil conditions. Aims: This study aimed to evaluate the response of maize (cv. 5018) vegetative traits to different levels of potassium (120 and 140 kg ha^{-1}) and humic acid (3 and 4 ml L^{-1}) applied through foliar feeding. Results: The results showed that 120 kg ha^{-1} potassium significantly enhanced plant height (249.50 cm), stem diameter (2.38 cm), number of leaves (15.64 $plant^{-1}$), and dry weight (182.94 g). Foliar application of humic acid at 4 ml L^{-1} further improved stem diameter and leaf number. Novelty: This research highlights the synergistic potential of potassium and humic acid in optimizing maize vegetative performance in potassium-limited soils. Implications: The findings provide a practical basis for refining fertilization strategies to enhance maize productivity in similar agroecological regions.

Highlight :

- Potassium levels of 120 and 140 kg ha^{-1} increased plant height and stem diameter.
- Humic acid at 3 and 4 ml L^{-1} improved stem diameter and number of leaves.
- Combined potassium and humic treatments enhanced overall vegetative growth.

Keywords : Maize, Potassium, Foliar Feeding, Humic Acid, Growth Traits

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Introduction

The maize (Zea mays L.) is a significant crop in the worldwide, first ranking in production and planted terms of area [1]. Yellow corn is an necessary strategic crop in Iraq because it is important for human nutrition in addition to animal feed [2]. This is due to its high nutritional value, which is a result of its high and significant content of carbohydrates, proteins, vitamins, and pigments [3]. It is a major source for bioethanol production [4]. The crop still suffers from low productivity per unit area and low total production in Iraq. In 2008, 2009, 2010, and 2011, yellow corn production amounted to 288, 317, 291 and 297 thousand tons, respectively, which is less than the required production to cover the country's needs [5]. This low productivity per unit area also falls short of the global average. Therefore, it was imperative for specialists to improve service operations, particularly fertilization, which ensures effective growth, specifically liquid fertilization, sprayed on the vegetative part [6]. Studies suggest that the slow release of potassium, either fixed or exchanged between clay minerals, often results in the emergence of potassium deficiency symptoms in plants, even when large quantities of potassium are present in the soil or added directly as fertilizer. This is particularly true during critical periods of plant growth, when the plant requires potassium more than other times, leading to the appearance of deficiency symptoms in those plants. In addition, Iraqi soils have a large store of potassium, while the capacity and speed of its release are relatively low [7]. Potassium is the most important positive ion in plant physiology, and this is not only due to the content of plant tissues of this element but also to its important physiological and biochemical functions in the plant. The plant needs this element in the different stages of growth, as potassium ranks fifth in terms of content, but it does not enter into the composition of any organic compound inside the plant. Potassium helps open and close the stomata and increases the leaf's photosynthesis efficiency [8]. The foliar feeding method was used as a supplement to minimise nutrient loss in the soil. Additionally, foliar feeding is characterized by low costs and increases the efficiency of utilization of the added fertilizer [9]. [10] stated that humic fertilizers have plates similar to clay in their distribution and organization and have negative charges on their surfaces that are of high importance in the cation exchange process, while they contain nutrients, humic acids, and humin. Spraying humus and its nutrients on leaves allows them to enter and absorb through the stomata, then through the interstitial spaces in the cell wall, and finally through the plasma membrane and mesophyll cells [11]. The assay was implemented to know the impact of potassium and humic acid on some growth traits of yellow corn plant

Methods and Materials

A factorial experiment was implemented with RCBD design with 3 replicates in Diyala province, Al- Muqdadiyah District, Abu Saida Subdistrict, Abu Saba'a Village during the year 2023 to evaluate the two levels of potassium (120 and 140 kg h^{-1}) as potassium sulphate (K_2SO_4(K%)) and two levels of humic (3 and 4 ml L^{-1}) as foliar feeding on the yellow corn plant Zea mays L. (CV 5018). This experiment was done twice, after 21 days of germination and after 51 days of germination. The experiment included 27 experimental units. Samples of soil were analyzed in the Laboratory of the College of Agriculture, Diyala University (Table 1).

All experimental units received identical fertilization at the same time, urea (46% N) and triple superphosphate (21% P), each at an amount of 120 kg ha^{-1}. Triple superphosphate was added to the soil before cultivation, while nitrogen fertilizer was added 45 and 70 days after planting. Yellow corn seeds (CV 5018) were cultivated with three seeds in each hole on 4/1/2023 and left one plant after germination. The experimental unit covered an area of 14000 cm^2 and contained four lines, with each line spaced 25 cm apart and each hole spaced 35 cm apart; therefore, there were four plants in each line, resulting in a total of 16 plants in the experimental unit. Data were measured for a number of important growth traits at harvest for four plants for each experimental unit as follows:

1.1. Plant height (cm)

The measurement was taken with the tape measure.

1.2. Stem diameter (cm)

It is estimated through the equation:

Stem circumference (cm) = diameter x 3.14.

1.3. Number of leaves

The number of leaves was taken for a single plant.

1.4. Leaf area (dm^2)

It is estimated through the equation:

Leaf area = square of the leaf length under the corncob leaf × 0.75 (if the number of leaves is more than 13).

1.5. Leaf area index

It is estimated through the equation:

Leaf area index = average leaf area/area occupied by the plant on the ground.

1.6. Dry weight of the vegetative part (g $plant^{-1}$)

It was calculated after physiological maturity.

1.7. The data analysis

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The data was analyzed using SPSS program [12].

Table 1. A few of the soil chemical and physical characteristics

Characteristics	Value	Unit
Texture of soil	Clay sand	-
Clay	247.80	g. kg^{-1}
Silt	180.10	g. kg^{-1}
Sand	572.10	g. kg^{-1}
Ph	7.11	-
Ec	5.33	$ds.m^{-1}$
N	28.12	mg. kg^{-1}
P	10.74	mg. kg^{-1}
K	378.40	mg. kg^{-1}
Organic matter	18.00	g. kg^{-1}

Result

A. Plant height (cm)

The findings of Table (2) revealed notable distinctions between the various potassium concentrations, and no significant differences were observed in foliar feeding with humic and the interaction between potassium and humic in the plant height, as the potassium concentrations of 120 and 140 kg h^{-1} were superior with an average of 249.50 and 246.05 cm compared to the control treatment (216.35 cm) and an increase rate of 15.32 and 13.72%, respectively. [13] showed that added potassium levels have a notable impact on increasing this trait. The good impact of potassium in increasing plant height may belong to its activating the work of auxins and gibberellins, which have an effect on the division and elongation of plant cells, thus raising plant height [14]. There were no significant differences when adding humic or the interaction between adding potassium and humic. The interaction between potassium and humic acid was less effective than the effect of potassium alone.

Table 2. Impact of potassium addition and foliar feeding with humic acid on plant height (cm)

A	B	Humic acid (ml L^{-1})		Mean
Potassium (kg h^{-1})	**0**	**3**	**4**	
0	**193.75**	**227.16**	**228.16**	**216.35**
120	**245.75**	**251.00**	**251.75**	**249.50**
140	**242.16**	**257.83**	**238.16**	**246.05**
Mean	**227.22**	**245.18**	**239.35**	
LSD 0.05	**A= 18.22**	**B= N.S**	**A x B = N.S**	

B. diameter (cm)

Table (3) revealed notable differences in the stem diameter (cm) between potassium addition and foliar feeding with humic acid. The potassium at 120 and 140 kg h^{-1} outperformed the comparison treatment, resulting in an average of 2.38 and 2.30 cm, respectively, compared to the lowest average 2.03 cm in the comparison treatment and an increase rate of 17.24 and 13.30%, respectively. These results were consistent with both [15]**.** This increase in vascular bundles helps in increasing and accelerating the transport processes in the phloem wood vessels, especially the transport of molecules with large molecular weights such as carbohydrates and proteins, which assists in the construction processes and increases the stem thickness [16]**.** It helps in maintaining the greenness of the leaves and continuing their work in photosynthesis for a longer period [17]**.** Also, the reason may be due to the fact that potassium helps in the formation of the energy compound ATP by increasing the absorption of phosphorus [18], and helps in the activity of growth regulators, which in turn helps in increasing the division and elongation processes in the lateral meristematic cells, which helps in increasing the width and diameter of plant organs. These results are consistent with [19]**.** As for the addition of humic acid, the concentrations of 4- and 3-ml L^{-1} were superior for the same trait with an average of 2.33 and 2.30

cm compared to the comparison treatment, which recorded the lowest average of 2.08 cm and an increase rate of 12.01 and 10.57%, respectively. This may be attributed to the effect of humic acid in treating the deficiency of plant nutrients due to a physical or chemical problem in the soil or to encourage vegetative growth and increase the accumulation of dry matter in the plant by spraying it on the vegetative parts. This method of fertilization is faster in effect compared to ground fertilization, and this may be reflected in an increase in the diameter of the stem [20]

Table 3. Impact of potassium addition and foliar feeding with humic acid on stem diameter (cm)

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A	B	Humic acid (ml L-1)		Mean
Potassium (kg h-1)	0	3	4	
0	1.63	2.14	2.32	2.03
120	2.30	2.38	2.46	2.38
140	2.31	2.38	2.22	2.30
Mean LSD 0.05	2.08	2.30	2.33	
	A= 0.21	B= 0.21	A x B = N. S	

C. Number of leaves

The findings presented in Table (4) demonstrated significant differences between potassium addition and foliar feeding with humic acid with the number of leaves trait. Specifically, the concentrations of 120 and 140 kg h^{-1} outperformed the comparison treatment, resulting in an average of 15.64 and 15.14, respectively, compared to the lowest average of 14.59 and an increase rate of 7.19 and 3.76%. Both concentrations mentioned in Table 2 had the highest stem height, contributing to raise in the number of leaves, and this is called plant engineering plant engineering, which refers to the appropriate distribution of the plant's shape, including its height and leaf count [21]**.** The reason is also due to the increased efficiency of the fertilizer used, especially when the added quantities are appropriate and within the stages of the plant's need, as this ensures that the plant gets its nutritional needs at the right time. As a result, there will be an increase in vegetative growth. This will lead to raise in the number of leaves and their surface area, as they serve as the primary factory for food production and representation. Thus, the amount of manufactured materials and their transfer to storage sites will increase [22]**.** The added potassium encourages the work of more than 80 enzymes whose function in all stages of plant growth is to maintain the largest number of leaves in an active state until the end of the plant season [23]**.** The concentrations of 4- and 3-ml L^{-1} humic acid were better for the same trait, with an average of 15.62 and

15.05 compared to the control (14.71) and the lowest growth rates of 6.18 and 2.31%, respectively. Humic acid spray concentrations can produce the highest dry matter by enhancing photosynthesis efficiency, which in turn increases the growth traits [24]**.** The interaction between potassium and humic acid was less effective than the effect of potassium and humic alone.

Table 4. Impact of potassium addition and foliar feeding with humic acid on number of leaves

A	B	Humic acid (ml L-1)		Mean
Potassium (kg h-1)	0	3	4	
0	13.77	14.75	15.27	14.59
120	15.25	15.25	16.44	15.64
140	15.12	15.16	15.16	15.14
Mean LSD 0.05	14.71	15.05	15.62	
	A= 0.57	B= 0.57	A x B = N. S	

D. Leaf area (dm^2)

The findings of Table (5) revealed that there were no significant differences between potassium addition and foliar feeding with humic acid, while significant differences were observed combined between them in the trait of leaf area. The interaction between adding potassium at 120 kg h^{-1} and adding 4 ml L^{-1} of humic acid achieved a significant increase with an average of 84.57 dm^2, compared to the comparison treatment and adding 4 ml L^{-1}, which recorded 65.15 dm^2 and an increase rate of 29.80%. The presence of this element in sufficient quantities in the plant reflects its effective role and the resulting provision of carbohydrates, in addition to activating the construction of proteins and chlorophyll in cooperation with growth regulators that work on division and elongation, especially in the stage of newly formed leaves and raising their surface area [10]. The adding of potassium to the soil enhances vegetative growth and raises the number of leaves and their surface area, as they serve as the primary center for food production and representation [22]. A potassium deficiency in the plant causes the oxidation of an important enzyme cofactor in the electron transfer process of photophosphorylation. This, in turn, leads to the cessation of chlorophyll formation, which in turn affects the process of photosynthesis and negatively affects the leaf area [25]. The growth of maize plants is primarily dependent on leaf area efficiency, which is responsible for receiving and intercepting the largest possible amount of light rays reflected on the plant body [26]. The interaction between potassium and humic was more effective than potassium and humic alone.

Table 5. Impact of potassium addition and foliar feeding with humic acid on leaf area (dm^2)

A	B	Humic acid (ml L-1)		Mean

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Potassium (kg h-1)	0	3	4	
0	71.55	81.14	65.15	72.61
120	71.28	74.81	84.57	76.88
140	71.22	68.43	73.17	70.94
Mean LSD 0.05	71.35	74.79	74.29	
	A= N. S	B= N. S	A x B = 12.58	

E. Leaf area index

The findings of Table (6) revealed that there were no significant differences between potassium addition and foliar feeding with humic acid, while significant differences were observed when combined between them in the trait of leaf area index. The interaction between the comparison treatment and the humic 3 ml L^{-1} recorded a significant increase with an average of 5.98 compared to the comparison treatment and the humic 4 ml L^{-1}, which recorded the lowest average of 4.34 and an increase rate of 37.78%.The findings of this trait are consistent with the findings of leaf area, although there are no significant differences between potassium concentrations, it works to increase the averages of photosynthesis for CO_2 to enter through the stomata, which increased the growth and expansion of new leaves and increasing divisions that are reflected in increasing the leaf area and delaying its aging [27]. It also activates the formation of carbohydrates and proteins, as the new leaves are supplied with carbohydrates to a one-third of their final size and with proteins until the end of the growing season, which helps to increase the leaf area, this is in agreement with [28], who showed the raise in the leaf area index when potassium is added, and that organic acids have positive effects on the vegetative and root systems and enhance the utilization of nutrients, which is reflected in the leaf area index**.** The interaction between potassium and humic acid was more effective than potassium and humic acid alone.

Table 6. Impact of potassium addition and foliar feeding with humic acid on leaf area index

A	B	Humic acid (ml L^{-1})		Mean
Potassium (kg h^{-1})	0	3	4	
0	4.76	5.98	4.34	5.02
120	4.78	4.86	5.19	4.94
140	4.73	4.52	4.87	4.70
Mean LSD 0.05	4.75	5.12	4.80	
	A= N. S	B= N. S	A x B = 1.00	

F. Dry weight (g plant-1)

Table (7) showed that the potassium concentrations varied significantly, but the foliar feeding with humic and the combined between them did not show any significant differences in the dry weight. The potassium 120 kg h-1 outperformed the concentration of 140 kg h-1 and the control treatment, which recorded 119.72 and 141.05 g plant-1 with araise rate of 52.80 and 29.69%, respectively. The plant's dry weight increased due to potassium's role in stimulating the photosynthesis process by increasing the vegetative part and activating enzymes [10,14]. The potassium result in raise the dry weight of the vegetative part of the yellow corn plant. This is due to the raise in the availability and absorption of elements and the raise in the concentration of elements in the plant and thus the raise in the amount of manufactured materials and the raise in the yield and dry weight, which is positively and significantly correlated with the total yield in yellow corn, resulting in plants with high productivity [29]. The interaction between potassium and humic was less effective than potassium alone.

Table 7. Impact of potassium addition and foliar feeding with humic acid on dry weight of vegetative part (g $plant^{-1}$)

A	B	Humic acid (ml L^{-1})		Mean
Potassium (kg h^{-1})	0	3	4	
0	143.91	130.66	148.58	141.05
120	159.58	211.25	178.00	182.94
140	126.25	109.16	123.75	119.72
Mean	143.24	150.35	150.11	
LSD 0.05	A= 26.32	B= N.S	A x B = N.S	

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Conclusion

The study found that increasing the concentration of potassium and humic acid clearly improved most of the traits that were being looked at in corn plants (Zea mays L.). In particular, using these substances together or separately resulted in significant improvements in plant growth parameters such as plant height, stem diameter, number of leaves, leaf area, leaf area index, and dry weight of the vegetative part.

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