Research Article

Impact of Fulvic Organic Fertilizer and Planting Distance on Growth Attributes of Maize

Ghassan Adnan Abdul Ameer

Soil and Water Department, Technical College Al-Mussaib, Al-Furat Al-Awsat Technical University, Iraq.

Abstract | The experiment was conducted as a field trial during the spring of 2024 in the Mashroo sub-district area, within the fields of Technical College Al-Mussaib in Babylon Governorate. The study aimed to examine the response of different concentrations of organic fulvic fertilizer foliar application on maize variety Euphrates growth and yield characteristics. Three foliar spray treatments with a fulvic fertilizer (70% fulvic acid, 3ml/L) were included in the experiment. The first treatment was controlled with no spray, the second treatment involved one spray 18 days after planting and the third treatment applied two sprays, 18 and 36 days after planting. The experiment utilized a complete randomized block design with three replications. The results indicated that the number of foliar sprays had a significant positive effect on various growth parameters, including the number of leaves, plant height, ear length, number of corn cobs, and grain per cob. Increasing the planting distance also resulted in taller plants and more leaves, which positively affected the cob characteristics and number of grains. The highest productivity was achieved with the treatment of two sprays combined with a planting distance of 25 cm, resulting in a higher number of grains per cob.

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***Correspondence** | Ghassan Adnan Abdul Ameer, Soil and Water Department, Technical College Al-Mussaib, Al-Furat Al-Awsat Technical University, Iraq; **Email:** ghassan.adnan1@atu.edu.iq
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Introduction

The maize is one of the main economic crops in Iraq, as it occupies the third rank in cultivation area, production, and demand in the food market after wheat and rice (Jassim *et al*., 2020; Hadi and Hassan, 2021). It plays a significant role due to its high nutritional value for both humans and livestock. Maize contains high level of carbohydrates, proteins, fats, salts, and minerals (Karim *et al*., 2013). For instance, they are made up of approximately 65-70% carbohydrates, 9-12% protein, 4-6% fat, and 13-15% water. Notably, the kernel's fat content is concentrated in the embryo and account for a significant portion of the constituted components (i.e., 30-40% fat, 20% protein, and 10% mineral elements). However, maize has been widely used for human consumption, animal feed, and in industry (Moghadam *et al*., 2014; Alzubaidi, 2021).

The productivity of maize, like any crop, depends on soil fertility and availability of nutrients, kinds

of seeds used, and agronomic practices. Chemical fertilizers and foliar nutrients are an important part of individually tailored agricultural production boosters that relate to effective field management. But, improper use of fertilizers, without proper knowledge or understanding of the crops' needs, can lead to adverse effects like increasing soil nitrates. Over-fertilization may also result in ammonia volatilization, while nutrients leach to groundwater, degrading soil quality and potentially polluting water sources (Itelima *et al*., 2018).

Planting density is yet another important contributor to corn yield. Plant density that affects light interception during photosynthesis, and consequently growth and productivity (Egli, 2017; Djaman *et al*., 2022) is influenced by plant spacing. Managing this density is essential for optimizing the absorption of nutrients and sunlight, both critical for healthy crop development.

In recent years, there has been an increasing emphasis on the need for balanced fertilization in order to drive crop production. Fertilizers, whether macro or micro-nutrients, must be provided in proper amounts, and through appropriate methods to maximize growth and ensure healthy yields (Al-Sadoon and Al-Ubaidi, 2014). Organic fertilizers, such as fulvic acid, which contain humic substances, have also been identified as the sources of these benefits. Besides, these natural enhancers promote better transfer of nutrient uptake and protein synthesis, promoting better growth and enhanced yield quality (Revilla *et al*., 2021; Al-Fatlawy *et al*., 2022).

According to Karim *et al*. (2013) applying organic nutrients, especially through foliar spraying, can delay the aging of corn leaves and maintain the plant's vegetative system until maturity. This helps ensure a steady flow of essential nutrients, such as nitrogen, phosphorus, and potassium, throughout the plant, improving overall growth and root absorption capabilities.

To optimize fertilizer, it is vital to employ sustainable practices and apply the correct type and quantity of fertilizers. These practices not only help enhance plant growth but also support vital processes like photosynthesis, enzyme activity, and nutrient metabolism (Rahouma and Mahmud, 2021). The study aims to identify the optimal frequency of fulvic acid foliar applications on maize and the best planting distances to maximize crop growth and yield attributes. This research seeks to optimize fertilization practices and planting techniques to enhance both the quality and quantity of maize production. Applying organic fulvic acid as a foliar spray at optimal intervals, combined with best planting distances, will improve the growth characteristics and increase the yield of yellow corn, compared to traditional fertilization practices.

Materials and Methods

The experiment was conducted in the spring of 2024 at the fields of Al-Mussaib Technical College, Babylon Governorate. Soil samples were taken from the plowed layer (0-30 cm) to analyze the physical and chemical properties (Table 1). The mechanical properties of the soil were assessed using the hydrometer method. The study included two main factors:

Organic fulvic fertilizer sprays

Treatment 1 (Control) = No application of fulvic fertilizer, Treatment 2 = One spray of organic fulvic fertilizer (1000 ppm) applied 18 days after planting, once germination was completed, Treatment 3 = Two sprays of organic fulvic fertilizer, applied at 18 and 36 days after planting.

Planting distances

Four different planting distances between plants were tested: 10 cm, 15 cm, 20 cm, and 25 cm. The study included 36 experimental units, with each unit consisting of four rows of plants spaced 70 cm apart and measuring 5 meters in length. The experimental design used a split-plot arrangement, where the planting distances were assigned to the main plots and

Table 1: *Physical and chemical properties of soil field.*

Sand %	Silt %	Clay %	Soil texture	Organic matter g/kg	Available N mg/kg	Available P mg/kg	Available K mg/kg	pH	EC dSm^{-1}
24.92	46.32	28.76	Clay loam	7.75	20.35	31.43	71.35	7.8	3.78

The corn variety used in the experiment was Euphrates (hybrid), a Dutch-imported variety known for its early maturity (90-110 days), suitability for intensive planting, and yellow kernels.

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the fertilizer spray treatments were assigned to the subplots. Each treatment combination was replicated three times.

Soil preparation

The experimental soil was prepared through plowing, smoothing, leveling, and hoeing, and then divided into individual experimental units. Nitrogen fertilizer (urea, N 64%) was applied at a rate of 320 kg N/ha in two equal applications: the first 16 days after germination and the second 50 days after planting, following the guidelines of Walaa (2022). Phosphate fertilizer (triple superphosphate, 5P2O6, 64%) was applied at a rate of 86 kg P/ha at the time of planting.

Maize seeds were sown on March 25, 2024, and the field was irrigated immediately after planting, with a second irrigation applied one week later. Thinning was done to leave one plant per hole after germination.

Statistical analysis

The data were analyzed using GenStat statistical software, and the Least Significant Difference (LSD) test was used to compare the means at a 5% significance level. XLSTAT software version 2014.5.03 was used to find out the significant correlations, dendrogram and principle component analysis among studied attributes.

Results and Discussion

Number of leaves per plant

Application of fulvic organic fertilizer through spraying resulted in a higher number of leaves compared to the control treatment. The two-spray treatment increased the leaf count by 16.65 leaves compared to the control and by single-spray treatment (15.48 leaves). Additionally, the single-spray treatment showed a significant increase in leaf number compared to the no-spray treatment. Fulvic acid treatments and planting distances had an average of 16.54 leaves (Table 2).

The effect of planting distance was also significant, with a planting distance of 20 cm producing a higher leaf count (15.75 leaves) than the 15 cm planting distance with no-spray treatment. The 15 cm planting distance was more effective than the 10 cm distance, which resulted in an average of 14.20 leaves.

When considering both the foliar spraying and planting distances together, the highest average leaf count of 18 was observed in plants sprayed twice with fulvic organic fertilizer and planted at a distance of 25 cm. In contrast, the lowest leaf count of 13 occurred when no spraying was applied, and the plants were planted at a 10 cm distance.

Table 2: *Effect of spraying fulvic organic fertilizer and planting distances on the number of leaves plant^{-1}.*

Number of sprays of fulvic fertilizer	Planting distances				Average
	10	15	20	25	
Without spraying	13	14	14.28	15.00	14.07
one pinch	14.31	15.31	15.65	16.65	15.48
Spray twice	15.31	16	17.31	18	16.65
Average	14.20	15.09	15.75	16.54	15.39
LSD 5%		A.S=0.68	A=0.558	S=0.359	

The increased leaf count observed with foliar spraying can be attributed to the role of fulvic organic fertilizer in stimulating cell division, enhancing plant density, and promoting more leaves per unit area. These results are consistent with the findings of Hamid *et al*. (2022).

Plant height (cm)

The spraying treatments of fulvic organic fertilizer exhibited a significant effect. In fact, the spraying treatment outperformed reaching 193.56 cm. The one-time spraying treatment resulted in 188.33 cm plant height, while no spray treatment reached only 178 cm. The results clearly showed that the planting distance showed a significant impact on plant height. When the planting distance was 25 cm, the plant height increased significantly as compared to other plants where distance was less than 25 cm. The average height of the plants was 196.37 cm when the planting distance was 25 cm, 189.67 cm when the distance was 20 cm, and 184.41 cm when the distance was 15 cm. The highest average plant height (203.27 cm) was achieved with twice fulvic fertilizer and with a planting distance (25 cm). The results clearly showed that without spraying with fulvic organic fertilizer and a planting distance (10 cm), the plant height is (169.30 cm) (Table 3). This is because fulvic organic fertilizer provides elements ready for absorption by the vegetative system of the plant, which works and helps the plant to form a large number of meristem cells, elongate them and give them an increase in size,

thus increasing plant height. This is in line with the findings of Khalifah *et al.* (2017).

Table 3: *The effect of spraying fulvic organic fertilizer and planting distances on plant height (cm).*

Number of sprays of Fulvic fertilizer	Planting distances				Average
	10	15	20	25	
Without spraying	169.30	176.90	181.70	188.00	178.98
one pinch	178.17	186.13	191.17	197.83	188.33
Spray twice	184.63	190.20	196.13	203.27	193.56
Average	177.37	184.41	189.67	196.37	186.95
LSD 5%		A.S=1.859	A=1.861	S=0.629	

Corn ear length (cm)

The length of the corn kernel is an important production element. The relationship between the length of the corn ear length is clear from the results in Table 4, which showed that spraying with fulvic organic fertilizer is effective. If the spraying treatment is missed twice, the average length of ear is significantly reduced. The results clearly indicated that the one-time spraying treatment gave a superior result (19.38 cm), which outperformed the treatment without spraying (18.84 cm). The planting distances also demonstrated significant differences with an average of (22 cm) for the treatment with planting distance of 25 cm. The planting distance (20 cm) gave an average of (20.24 cm) for ear length, which outperformed the planting distance (15 cm) that gave (18.97 cm) to the ear length. This in turn outperformed the planting distance (10 cm) that gave an average of 16 cm. The study is in accordance with other workers who showed the plant activities such as carbon sequestration and the transfer of products to the rest of the plant parts (Al-Fatlawy *et al.*, 2022). It was found that the highest average ear length is 22.98 cm, while the lowest is 15.71 cm without spraying fulvic organic fertilizer and with a planting distance of 10 cm.

Number of corn kernel per plant

The treatments with fulvic organic fertilizer spraying showed no significant differences in the number of corn cobs (Table 5). Spraying the fertilizer did not induce a notable effect on the number of cobs produced. Similarly, the planting distances did not exhibit significant effects, except for the 25 cm planting distance. However, there was a significant difference in the no spraying treatment with other treatments, which highlighted the impact of the interaction between the two factors studied. The highest average number of corn cobs per plant was 1.27, observed when plants were sprayed twice with fulvic organic fertilizer and planted at a 25 cm distance (Table 4). The lowest average was 1 cob per plant, which occurred in the no-spray treatment with a 10 cm planting distance. This same result was seen in the one-spray treatment with a planting distance of less than 10 cm. These findings can be attributed to the genetic characteristics of the corn variety, as the structure and number of cobs are largely determined by the genetic traits of the plant, as noted by Al-Bahrani (2015).

Table 4: *Spraying fulvic organic fertilizer and varying the planting distances in corn ear length (cm).*

Number of sprays of Fulvic fertilizer	Planting distances				Average
	10	15	20	25	
Without spraying	15.71	18.51	19.81	21.31	18.84
one pinch	16.13	19.06	20.36	21.96	19.38
Spray twice	16.68	19.35	20.55	22.98	19.89
Average	16.17	18.97	20.24	22.09	19.37
LSD 5%		A.S=0.537	A=0.1833	S=0.349	

Number of grains per corn cob

The spray of fulvic fertilizer showed that the treatment exceeds twice the average number of grains per corn cob (Table 6). There is no significant difference in the attribute with one-time spraying treatment, which gave 361.63 grains. The treatment of spraying for one time outperforms the treatment without spraying with fulvic organic fertilizer, which gave 322 grains per cob. The results clearly showed that there are significant differences between the treatments and the planting distance i.e., 25 cm. The treatment for planting distance 20 cm exceeded the planting distance 10 cm. The results clearly showed that the planting distance of 15 cm at the planting distance of 10 cm is the most effective treatment. However, the highest average number of grains per cob being 421. The results clearly showed that no spray with fulvic fertilizer and planting distance 10 cm recorded the lowest value (286 grains). This is due to the fact that spraying with fulvic fertilizer and the appropriate planting distances led to an increase in the average length of the corn cob and the number of grains in one row. The results showed a reflection on the increase

in the number of grains on the corn cob as reported by (Daur and Bakhashwain, 2013; Moghadam *et al.*, 2014; Oktem and Oktem, 2020).

Dendrogram, heat map and principal component analysis

Dendrogram: The cluster analysis grouped the growth attributes. Plant height and number of grains per cob were grouped in a single cluster based on similarities with application of foliar organic fertilizer and planting distance. The corn cob, leaves per plant and ear length was placed in another cluster (Zafar *et al.*, 2015) (Figure 1).

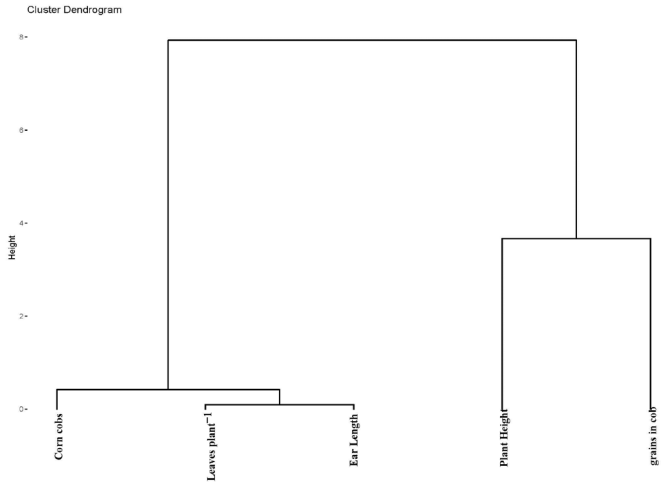

Figure 1: *Dendrogram/Cluster analysis_grouping of growth attributes of maize by combined foliar application of fulvic organic fertilizer and planting distances.*

Heat map: Histogram analysis was performed to illustrate the relationship amongst growth attributes with application of foliar fulvic organic fertilizer and planting distance. Remarkable distinctions were determined. The cyan color indicating the non-significant difference in treatments while other colors showed the significant difference in histogram study (Figure 2).

Histogram analysis indicating a considerable effective correlation of ear length, no. of grains per cob, corn cobs plant^{-1}, no. of leaves plant^{-1} and plant height (Zafar *et al.*, 2019).

Heat map correlation histogram showing various attributes of maize fulvic acid 0, planting distance 10 (1), fulvic acid 0, planting distance 15 (2), fulvic acid 0, planting distance 20 (3), fulvic acid 0, planting distance 25 (4), fulvic acid once, planting distance 10 (5), fulvic acid once, planting distance 15 (6), fulvic acid once, planting distance 20 (7), fulvic acid once, planting distance 25 (8), fulvic acid twice, planting distance 10 (9), fulvic acid twice, planting distance 15 (10), fulvic acid twice, planting distance 20 (11), fulvic acid twice, planting distance 25 (12).

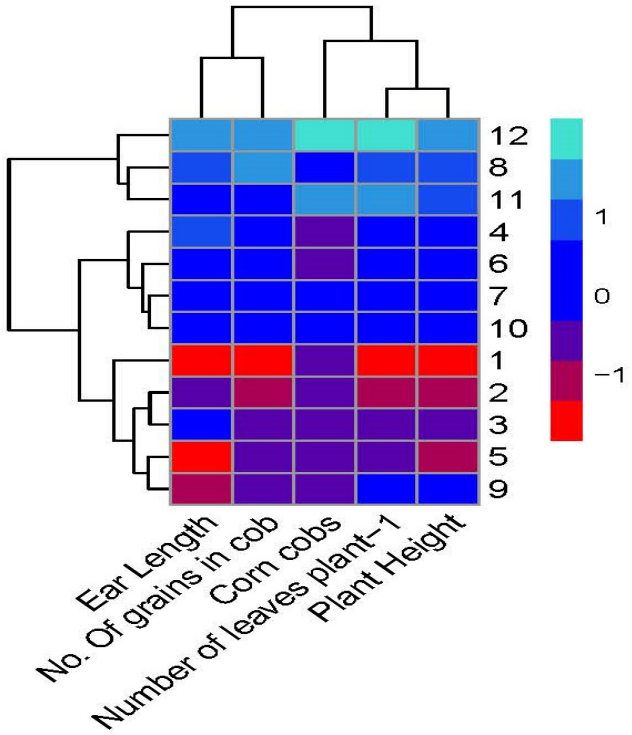

Figure 2: *Heat map correlation histogram showing various growth attributes of maize with foliar feeding of fulvic organic fertilizer and planting distance.*

Table 5: *The spraying of fulvic organic fertilizer and planting at varying distances of the number of corn cobs produced by a single plant.*

Number of sprays of Fulvic fertilizer	Planting distances				Average
	10	15	20	25	
Without spraying	1	1	1	1	1
one pinch	1	1.03	1.08	1.08	1.05
Spray twice	1.02	1.11	1.19	1.25	1.15
Average	1.01	1.05	1.09	1.11	1.06
LSD 5%		A.S=0.083	A=0.01	S=0.75	

Table 6: *The spraying of fulvic organic fertilizer and planting at varying distances of the number of grains in corn cob.*

Number of sprays of Fulvic fertilizer	Planting distances				Average
	10	15	20	25	
Without spraying	286	305.06	327.08	368	322.79
one pinch	319.66	305.06	367	420.14	361.63
Spray twice	321	335.31	372	421.14	362.37
Average	309.22	325.36	355.36	403.09	348.26
LSD 5%		A.S=0.83	A=0.41	S=0.55	

Principal component analysis

The plots of PCA showed the outcome of foliar treatments of fulvic organic fertilizer treatments and planting distances. A clear separation of various parameters was presented by Dim1 and Dim2 (Figure 3). In entire database, Dim 1 and Dim 2 illustrated the extreme influence and occupy more than 96.2% of whole databases, with Dim 1 shows 87.2% and Dim 2 shows 9%. A clear distinction of attributes with respect to fulvic organic fertilizer treatment and planting distance was detected in PC analysis (Zafar *et al.*, 2019).

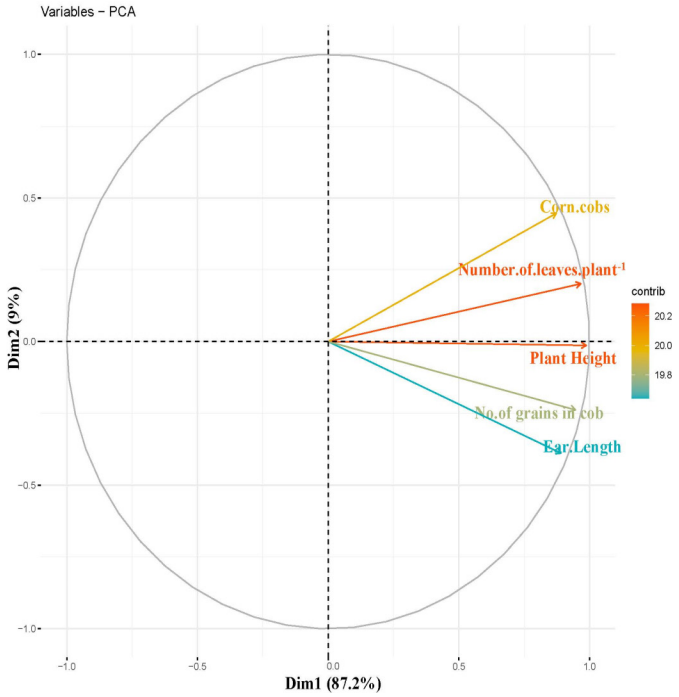

Figure 3: *Principal component analysis exhibiting relationship between growth, and yield attributes of maize with foliar feeding of fulvic organic fertilizer and planting distance.*

Conclusions and Recommendations

The spray with fulvic fertilizer with significant planting distances led to an increase in the number of leaves per plant, plant height, ear length, and the number of grains per cob compared with the treatment with no spray on the maize plant. The best result was achieved by spraying twice with a planting distance of 25 cm.

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Novelty Statement

This study uniquely explores the synergistic effect of foliar applications of organic fulvic acid fertilizer and varying planting distances on key growth parameters, such as leaf number, plant height, ear length, and grain production. The findings suggest that the dual application of fulvic acid at optimal intervals, combined with appropriate planting distances, can significantly enhance corn productivity, making it a promising strategy for sustainable agricultural practices with varying soil conditions.

Conflict of interest

The authors have declared no conflict of interest.

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