# Effect of spraying with equilibrium biostimulant compound, spraying stages and plant density on some growth and biochemical traits of maize plant

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## Abstract

This study evaluated the effects of plant density, a biostimulant (Equilibrium: a blend of amino acids and seaweed extract), and different spraying stages on maize growth and nutrient uptake using a split-split plot design with three replications. Conducted in Karbala Province during the 2023 autumn season, the experiment tested three Equilibrium levels (0, 2, and 4 $L \cdot ha^{-1}$), three spraying regimes (5–6 leaf stage; 5–6 leaf + tasseling; and 5–6 leaf + tasseling + grain filling), and three plant densities (38,095; 53,333; and 88,888 $plants \cdot ha^{-1}$). The 2 $L \cdot ha^{-1}$ level significantly improved traits like leaf area (4971 $cm^2$), leaf area index (2.89), and nutrient absorption (N, P, and K) without differing from the higher 4 $L \cdot ha^{-1}$ rate. Spraying at two stages enhanced potassium absorption and oil content (4.32%) and was as effective as three-stage spraying. Higher density (88,888 $plants \cdot ha^{-1}$) yielded superior vegetative traits and nitrogen uptake, while the medium density (53,333 $plants \cdot ha^{-1}$) maximized phosphorus and potassium absorption. Most interactions among treatments were not statistically significant, except specific combinations (e.g., 2 $L \cdot ha^{-1}$ + 53333 $plants \cdot ha^{-1}$) that enhanced P and K uptake. Overall, the 2 $L \cdot ha^{-1}$ application combined with optimal density and timing provided effective maize performance enhancement.

**Keywords:** *Zea mays*L. , plant densities, equilibrium biostimulant compound, spraying stages, biochemical traits

## Introduction

Maize is one of the most important cereal crops globally. Its grains contain 66.0–77.7% starch, 6.7–8.9% protein, and 3.8–4.2% oil, in addition to ash and fiber. Thus, it serves as food for humans and feed for animals and is used in various industries such as starch production and biofuels [1]. Due to its importance, it is essential to explore mechanisms and methods to enhance its productivity by improving traits such as oil content. One such mechanism is foliar feeding, which is an efficient and rapid method to fulfill the plant's nutritional requirements .

In recent years, biologically active bio-stimulants derived from seaweed have been utilized as a complement to inorganic fertilizers, enhancing crop productivity and quality. This is attributed to their complex chemical compounds, such as polysaccharides (alginate), beneficial nutrients, and growth hormones that promote plant growth [2]. Additionally, recent studies have shown that amino acids in bio-stimulants play a dual role in plants. They serve as the building blocks of proteins, participating in numerous cellular reactions, which influence various physiological processes such as growth, development, metabolic energy generation, redox strength, and resistance to biotic and abiotic stresses [3].

Timing and environmental conditions are crucial when applying foliar bio-stimulants to ensure effectiveness and prevent potential harm to plants. It is also important to adhere to local agricultural recommendations and necessary precautions. The vegetative growth stage is ideal for enhancing vegetative growth, improving branching, and increasing biomass. During the flowering stage, pollination and grain setting are enhanced, while during the grain-filling stage, the grains' quality and final yield are improved [4].

Plant density is another competitive factor among plants at varying densities. Balanced growth requires optimal plant density to efficiently utilize nutrients and maximize light interception, alongside other growth factors influencing plant development [5]. This study aims to determine the optimal concentration of a mixture of equilibrium, identify the most suitable spraying stage for achieving optimal growth, nutrient uptake, and oil content, and determine the ideal plant density to achieve these goals.

## Materials and Methods

A field experiment was conducted at Ibn Al-Bitar Vocational School in Al-Husseiniya District, Karbala Province, during the 2023 autumn season. Soil preparation and crop management practices were carried out. The field was divided into experimental units and furrows with 75 cm spacing between them and 1.5m between main plots with an area of 4.20×3 $m^2$ for the experimental unit. Planting was done in hills with varying distances according to plant density levels. The synthetic variety "Al-Maha" was used .

Diammonium phosphate (DAP) fertilizer was applied as a phosphorus source at 200 kg $P_2O_5$ $ha^{-1}$before planting. Nitrogen fertilizer (46% N) was applied at 320 kg N $ha^{-1}$in the form of urea in two doses: the first 10 days after emergence and the second after silk emergence. Potassium sulfate (50% $K_2O$) was used as a potassium source at 80 kg $K_2O$ $ha^{-1}$in two doses along with urea (Al-Abadi, 2011). Other agronomic practices, such as irrigation, weeding, and cultivation, were performed as needed .

The experiment was conducted using a split-split-plot design in a randomized complete block design (RCBD) with three replications. The study included three levels of the equilibrium biostimulant compound (amino acids and seaweed extract mixture) which were 0, 2, and 4 L $ha^{-1}$in the main plots. Spraying stages included: (1) spraying at the 5–6 leaf stage, (2) spraying at the 5–6 leaf stage and at the beginning of male flowering (VT), and (3) spraying at the 5–6 leaf stage, at VT, and during the grain-filling stage at the early milk stage. These were assigned to the subplots. Three plant densities (38095.23, 53333.33, and 88888.88 plants $ha^{-1}$) were achieved by altering the distances between hills (35, 25, and 15 cm, respectively), which were assigned to the sub-subplots .

Means were compared using the least significant difference ($LSD_{0.05}$) test (Steel and Torrie, 1980). The following traits were studied :

1- Plant height (cm): Measured for 10 plants per plot from the soil surface to the tassel node using a meter stick (Elsahookie, 1990).

2- Leaf area ($cm^2$): Measured for 10 random plants per plot using the formula :

Leaf area = The square of the leaf length under the leaf of the main ear multiplied by 0.75 (Elsahookie, 1985).

- Leaf Area Index (LAI): Calculated as :LAI = the area of leaves per plant/Land area occupied by the plant.

4-Total nitrogen uptake (kg $ha^{-1}$): Determined by measuring nitrogen concentration in straw and grains using the semi-micro Kjeldahl method (AOAC, 1992), and calculated using the formula :

Total plant uptake N= (Grain N concentrate x Grain dry weight) + (Strew N concentrate x Straw dry weight)

5-Total phosphorus uptake (kg $ha^{-1}$): Determined by measuring phosphorus concentration in straw and grains (AOAC, 1992), then calculated as described by Godebo et al. (2021).

6-Total potassium uptake (kg $ha^{-1}$): Determined using AOAC (1992) methods and calculated by multiplying the potassium concentration by the dry weight of straw and grains .

7-Grain oil content (%): Determined using Soxhlet extraction (AOAC, 1980), based on the dry weight of the sample :

Oil percentage = Weight of oil extracted / Weight of grain sample × 100

## Results and Discussion

### 1- Plant Height (cm)

Table (1) shows a significant difference in plant height due to the spraying treatments. The 4 L $ha^{-1}$ spraying level recorded the highest mean of 188.40 cm, which was not significantly different from the 2 L $ha^{-1}$ level, while the control recorded the lowest mean of 159.20 cm. The increase in height could be attributed to the presence of N, P, and K nutrients and organic compounds in the seaweed extract, which stimulated cell elongation and division, thus promoting vegetative growth. Nitrogen in the extract enhances meristematic tissue activity, promoting cell division and elongation, which forms the amino acid tryptophan—a precursor for auxin synthesis that elongates internodes and increases plant height. This agrees with the previous findings [6,7]. Plant density also significantly influenced plant height, with the highest density (88888 plants $ha^{-1}$) recording the highest mean (184.8 cm) and the lowest density (38095 plants ha-1) recording the lowest mean (172.5 cm). This is likely due to shading and competition for light, prompting internode elongation to access light, thus increasing height [8] .The table also indicates that spraying stages and all interactions did not significantly affect plant height.

**Table (1):** Effect of equilibrium biostimulant compound levels, spraying stages, and plant densities and their Interactions on plant height (cm).

| ×Extract Spraying stages | Plant Densities 88888 plants ha⁻¹ | 53333 plants ha⁻¹ | 38095 plants ha⁻¹ | Spraying stages | Extract Levels |
|---|---|---|---|---|---|
| 164.30 | 171.70 | 161.90 | 159.50 | 1 | 0 L ha$^{-1}$ |
| 163.40 | 168.60 | 160.10 | 161.50 | 2 | |
| 149.70 | 156.90 | 150.70 | 141.70 | 3 | |
| 184.80 | 195.70 | 172.80 | 185.70 | 1 | 2 L ha$^{-1}$ |
| 183.40 | 202.40 | 174.10 | 173.70 | 2 | |
| 187.10 | 182.00 | 196.00 | 183.30 | 3 | |
| 186.70 | 194.00 | 189.00 | 177.00 | 1 | 4 L ha$^{-1}$ |
| 186.30 | 191.70 | 181.90 | 185.30 | 2 | |
| 192.20 | 200.70 | 190.90 | 184.90 | 3 | |
| N.S | N.S | | | | LSD(0.05) |
| **Mean Extract** | 184.8 | 175.3 | 172.5 | **Plant Densities Mean** | |
| | 6.19 | | | | **LSD(0.05)** |
| 159.20 | 165.70 | 157.60 | 154.20 | 0L ha$^{-1}$ | **× Extract Densities** |
| 185.10 | 193.40 | 181.0 | 180.9 | 2L ha$^{-1}$ | |
| 188.40 | 195.40 | 187.30 | 182.40 | 4L ha$^{-1}$ | |
| 23.40 | N.S | | | | **LSD(0.05)** |
| **Mean Spraying stages** | | | | | |
| 178.60 | 187.10 | 174.60 | 174.10 | 1 | **Spraying ×stages Plant Densities** |
| 177.70 | 187.60 | 172.00 | 173.50 | 2 | |
| 176.30 | 179.90 | 179.20 | 169.90 | 3 | |
| **N.S** | **N.S** | | | | **LSD(0.05)** |

### Leaf Area (cm²)

The results presented in Table (2) show a significant effect on leaf area due to the application of the extract. The treatment with 2 L ha⁻¹ of the extract achieved the highest mean value of 4971 cm², while the 0 L ha⁻¹ treatment resulted in the lowest mean of 4679 cm². This improvement in leaf area due to the extract application can be attributed to the role of seaweed extract on the plant, as it contains essential macronutrients that enhance photosynthetic efficiency. This, in turn, stimulates cell division, elongation, and expansion, especially in leaves, leading to an increase in leaf area. These results are consistent with a previous [9]. The table also shows a significant effect of plant densities on leaf area. The density of 38095 plants ha⁻¹ resulted in the highest mean of 5385 cm², while the density of 88888 plants ha⁻¹ recorded the lowest mean of 4390 cm². The superior performance at this density can be attributed to the increased number of leaves due to the availability of nutrients, reduced shading, and decreased competition, allowing more light to reach the lower leaves. As a result, the size of the leaves increased, positively reflecting on the leaf area. These findings align with previous study [10], who noted that the leaf area per plant decreases with increasing plant density .The interaction between extract and spraying stages showed a significant effect on leaf area. The treatment with 2 L ha⁻¹ during the first spraying stage recorded the highest mean of 5153 cm², showing an improvement of 17.38% over the interaction with the 0 L ha⁻¹ treatment at the same spraying stage, which achieved the lowest mean of 4390 cm². The results also revealed that the interaction between spraying stages and plant densities significantly influenced leaf area. The third spraying stage at a plant density of 38095 plants ha⁻¹ recorded the highest mean of 5530 cm², which was 30.64% higher than the interaction between the second spraying stage and a density of 88888 plants ha⁻¹, which recorded the lowest mean of 4233 cm². Other interactions between spraying stages did not have a significant effect on the studied trait.

**Table (2):** Effect of Effect of equilibrium biostimulant compound levels, spraying stages, and plant densities and their Interactions on Leaf Area (cm²)

| ×Extract Spraying stages | Plant Densities | | | Spraying Stages | Extract Levels |
|---|---|---|---|---|---|
| | pl88888 ants ha⁻¹ | 53333 plants ha⁻¹ | 38095 plants ha⁻¹ | | |
| 4390 | 4173 | 4318 | 4680 | 1 | **0 L ha⁻¹** |
| 4733 | 4406 | 4406 | 5386 | 2 | |
| 4914 | 4286 | 5016 | 5440 | 3 | |
| 5153 | 5061 | 5078 | 5321 | 1 | **2 L ha⁻¹** |
| 4874 | 4156 | 4935 | 5531 | 2 | |
| 4885 | 4156 | 4935 | 5550 | 3 | |
| 5116 | 4870 | 5015 | 5462 | 1 | **4 L ha⁻¹** |
| 4861 | 4136 | 4949 | 5498 | 2 | |
| 4904 | 4249 | 4865 | 5599 | 3 | |

| | | | | | |
|---|---|---|---|---|---|
| 216.8 | **N.S** | | | | **LSD(0.05)** |
| **Mean Extract** | 4390 | 4835 | 5385 | **Mean Plant Densities** | |
| | 128.4 | | | | **LSD(0.05)** |
| 4679 | 4288 | 4580 | 5169 | 0L $ha^{-1}$ | **Extract × Densities** |
| 4971 | 4464 | 4981 | 5467 | 2L $ha^{-1}$ | |
| 4960 | 4418 | 4943 | 5520 | 4L $ha^{-1}$ | |
| **107.2** | **N.S** | | | | **LSD(0.05)** |
| **Mean Spraying stages** | | | | | |
| 4887 | 4701 | 4804 | 5155 | 1 | **Spraying ×stages Plant Densities** |
| 4823 | 4233 | 4763 | 5472 | 2 | |
| 4901 | 4237 | 4937 | 5530 | 3 | |
| **N.S** | **224.7** | | | | **LSD(0.05)** |

## Leaf Area Index (LAI)

The results presented in Table (3) show a significant effect on the leaf area index (LAI) due to the application of the extract. The treatment with 2 L·$ha^{-1}$ of the extract recorded the highest mean of 2.89, while the 0 L·$ha^{-1}$ treatment resulted in the lowest mean of 2.73. This is due to the Seaweed sap improves plant growth as well as leaf area index (LAI), the initial effects of seaweed application may be due to increased root reproduction and establishment, thus enabling plants to absorb more nutrients even from faraway places Soil horizons in a balanced ratio [11]. The table also indicates that plant densities had a significant effect on the LAI. The highest density of 88888 plants·$ha^{-1}$ achieved the highest mean of 3.897, while the density of 38095 plants·$ha^{-1}$ recorded the lowest mean of 2.047. The higher LAI at higher plant densities can be attributed to the reduced space occupied by each plant at high plant densities compared to the leaf area per plant. In contrast, plants grown at lower densities have more space, leading to a larger leaf area per plant, which in turn affects the LAI. This finding is consistent with the study conducted in a previous [12].The results also show that the interaction between extract and spraying stages significantly affected the LAI. The treatment with 2 L $ha^{-1}$ at the first spraying stage recorded the highest mean of 3.07, which is an 18.53% increase compared to the 0 L $ha^{-1}$ treatment at the same spraying stage, which recorded the lowest mean of 2.59. Furthermore, the interaction between spraying stages and plant densities significantly affected the LAI. The first spraying stage at a density of 88888 plants $ha^{-1}$ achieved the highest mean of 4.17, showing a 113.84% increase compared to the first spraying stage at a density of 38095 plants $ha^{-1}$, which recorded the lowest mean of 1.95. The interactions of extract levels with plant densities and triple interactions were not significantly effect on the studied trait.

**Table (3):** Effect of Effect of equilibrium biostimulant compound levels, spraying stages, and plant densities and their Interactions on Leaf Area Index (LAI)

| **×Extract Spraying stages** | **Plant Densities: 88888 plants ha$^{-1}$** | **53333 plants ha$^{-1}$** | **38095 plants ha$^{-1}$** | **Spraying stages** | **Extract Levels** |
|---|---|---|---|---|---|
| 2.59 | 3.70 | 2.29 | 1.77 | 1 | **0 L ha$^{-1}$** |
| 2.76 | 3.91 | 2.34 | 2.05 | 2 | |
| 2.84 | 3.80 | 2.66 | 2.06 | 3 | |
| 3.07 | 4.49 | 2.70 | 2.02 | 1 | **2 L ha$^{-1}$** |
| 2.80 | 3.68 | 2.62 | 2.10 | 2 | |
| 2.81 | 3.71 | 2.62 | 2.11 | 3 | |
| 3.02 | 4.32 | 2.66 | 2.07 | 1 | **4 L ha$^{-1}$** |
| 2.80 | 3.67 | 2.63 | 2.09 | 2 | |
| 2.83 | 3.77 | 2.59 | 2.13 | 3 | |
| 0.16 | N.S | | | | **LSD$_{(0.05)}$** |
| **Extract Mean** | 3.897 | 2.573 | 2.047 | **Mean Plant Densities** | |
| | **0.10** | | | | **LSD$_{(0.05)}$** |
| 2.73 | 3.80 | 2.43 | 1.96 | 0L ha$^{-1}$ | **× Extract Plant Densities** |
| 2.89 | 3.96 | 2.65 | 2.07 | 2L ha$^{-1}$ | |
| 2.88 | 3.92 | 2.63 | 2.09 | 4L ha$^{-1}$ | |
| 0.10 | N.S | | | | **LSD$_{(0.05)}$** |
| **Mean Spraying stages** | | | | | |
| 2.89 | 4.17 | 2.55 | 1.95 | 1 | **Spraying ×stages Plant Densities** |
| 2.79 | 3.75 | 2.53 | 2.08 | 2 | |
| 2.83 | 3.76 | 2.62 | 2.10 | 3 | |
| N.S | 0.17 | | | | **LSD$_{(0.05)}$** |

## Total Nitrogen Uptake (kg N ha$^{-1}$)

The results presented in Table (4) show a significant difference in total nitrogen uptake due to the effect of the extract. The treatment with 2 L·ha$^{-1}$ of the extract recorded the highest mean of 352.00 kg N ha$^{-1}$, while the 0 L ha$^{-1}$ treatment resulted in the lowest mean of 269.50 kg N ha⁻¹, with a 30.61% increase. The improvement in total nitrogen uptake at the 2 L ha⁻¹ spraying level can be attributed to the presence of active compounds in the seaweed extract, such as amino acids, vitamins, and hormones, which enhance nutrient uptake efficiency. These compounds help plants improve metabolic processes and increase the ability of roots to absorb nutrients, leading to a higher total nitrogen content [13] .The table also indicates that plant densities had a significant effect on total nitrogen uptake. The highest plant density of 88888 plants ha⁻¹ recorded the highest mean of 361.90 kg N ha⁻¹, while the density of 38095 plants·ha⁻¹ recorded the lowest mean of 261.40 kg N ha⁻¹. This increased nitrogen uptake at higher plant densities can be attributed to the increased competition between plants for nutrients, especially nitrogen. This competition drives plants to improve their nutrient uptake efficiency and retention to meet the growing demand [14]. The results also show that the interaction between the extract and plant densities significantly affected total nitrogen uptake. The treatment with 2 L ha⁻¹ at a plant density of 88888 plants·ha⁻¹ recorded the highest mean of 406.10 kg N ha⁻¹, while the treatment with 2 L ha⁻¹ at a plant density of 38095 plants ha⁻¹ recorded the lowest mean of 257.30 kg N ha⁻¹, showing a 57.83% increase. However, spraying stages and other interactions did not significantly affect the studied trait.

**Table (4):** Effect of Effect of equilibrium biostimulant compound levels, spraying stages, and plant densities and their Interactions on Total Nitrogen Uptake (kg N ha⁻¹)

| ×Extract Spraying stages | Plant Densities | | | Spraying stages | Extract Levels |
|---|---|---|---|---|---|
| | 88888 plants ha⁻¹ | 53333 plants ha⁻¹ | 38095 Plants ha⁻¹ | | |
| 254.90 | 267.90 | 242.10 | 254.70 | 1 | 0 L ha⁻¹ |
| 275.00 | 290.90 | 269.80 | 264.40 | 2 | |
| 278.50 | 284.40 | 271.80 | 279.30 | 3 | |
| 346.80 | 409.70 | 367.00 | 263.80 | 1 | 2 L ha⁻¹ |
| 348.40 | 395.20 | 404.50 | 245.60 | 2 | |
| 360.80 | 413.50 | 406.40 | 262.50 | 3 | |
| 347.50 | 399.80 | 372.30 | 270.40 | 1 | 4 L ha⁻¹ |
| 350.60 | 400.50 | 398.50 | 252.90 | 2 | |
| 348.80 | 395.70 | 392.10 | 258.70 | 3 | |
| **N.S** | **N.S** | | | | **LSD(0.05)** |
| **Extract Mean** | 361.90 | 347.20 | 0261.4 | **Mean Plant Densities** | |
| | **11.03** | | | | **LSD(0.05)** |
| 269.50 | 281.00 | 261.20 | 266.20 | 0L ha-1 | **Extract × Plant** |
| 352.00 | 406.10 | 392.60 | 257.30 | 2L ha-1 | |

| | | | | | |
|---|---|---|---|---|---|
| 349.00 | 398.60 | 387.60 | 260.70 | 4L $ha^{-1}$ | **Densities** |
| 16.45 | 20.14 | | | | **LSD(0.05)** |
| **Mean Spraying stages** | | | | | |
| 316.40 | 359.10 | 327.10 | 263.00 | 1 | **Spraying ×stages Plant Densities** |
| 324.70 | 362.20 | 357.60 | 254.30 | 2 | |
| 329.40 | 364.50 | 356.80 | 266.80 | 3 | |
| **N.S** | **N.S** | | | | **LSD$_{(0.05)}$** |

**Total Phosphorus Uptake (kg P $ha^{-1}$)**

The results in Table (5) indicate a significant effect of spraying with the amino acid mixture and seaweed extract on total phosphorus uptake (kg P $ha^{-1}$). The 2 L·$ha^{-1}$ level recorded the highest mean of 66.49 kg P $ha^{-1}$, which did not significantly differ from the 4 L $ha^{-1}$ level, while the 0 L$ha^{-1}$ level recorded the lowest total phosphorus uptake of 45.90 kg P $ha^{-1}$. This improvement can be attributed to the active role of amino acids and seaweed extract in enhancing nutrient uptake, including phosphorus. Amino acids increase the activity of plant enzymes and improve metabolism, which boosts the ability of roots to absorb phosphorus from the soil. Additionally, seaweed extract contains a range of biologically active compounds such as vitamins and natural hormones (e.g., auxins and cytokinins), which stimulate root growth and increase their effectiveness in nutrient absorption [15].The table also shows that plant density significantly affected total phosphorus uptake. The plant density of 53333 plants·$ha^{-1}$ recorded the highest mean of 67.39 kg P $ha^{-1}$, while the density of 38095 plants·$ha^{-1}$ recorded the lowest mean of 51.42 kg P $ha^{-1}$, with a 31.05% increase. The higher phosphorus uptake at the density of 53333 plants·$ha^{-1}$ can be attributed to the ability of plants to obtain the resources they need without significant pressure, reducing intense competition for phosphorus. This allows each plant to absorb a larger amount of phosphorus compared to higher or lower plant densities [16].The results also show that the interaction between the extract and plant densities significantly affected total phosphorus uptake. The treatment with 2 L $ha^{-1}$ at a plant density of 53333 plants·$ha^{-1}$ recorded the highest mean of 79.08 kg·$ha^{-1}$, while the treatment with 0 L·$ha^{-1}$ at a plant density of 88888 plants·$ha^{-1}$ recorded the lowest mean of 39.06 kg P $ha^{-1}$. Additionally, the interaction between plant densities and spraying stages significantly affected total phosphorus uptake. The second spraying stage at a plant density of 88888 plants·$ha^{-1}$ recorded the highest mean of 59.54 kg P $ha^{-1}$, while the second spraying stage at a plant density of 38095 plants·$ha^{-1}$ recorded the lowest mean of 49.32 kg $ha^{-1}$, with a 20.72% increase.

**Table (5):** Effect of Effect of equilibrium biostimulant compound levels, spraying stages, and plant densities and their Interactions on Total Phosphorus Uptake (kg P $ha^{-1}$)

| ×Extract Spraying stages | Plant Densities 88888 Plants $ha^{-1}$ | 53333 Plants $ha^{-1}$ | 38095 Plants $ha^{-1}$ | Spraying stages | Extract Levels |
|---|---|---|---|---|---|
| 42.63 | 36.52 | 40.62 | 50.76 | 1 | 0 L $ha^{-1}$ |
| 47.45 | 41.84 | 47.47 | 53.05 | 2 | |
| 47.61 | 38.83 | 47.84 | 56.15 | 3 | |
| 64.66 | 70.40 | 71.50 | 52.07 | 1 | 2 L $ha^{-1}$ |
| 65.46 | 67.87 | 81.11 | 47.42 | 2 | |
| 69.36 | 71.54 | 84.63 | 51.90 | 3 | |
| 66.12 | 70.54 | 75.23 | 52.60 | 1 | 4 L $ha^{-1}$ |
| 65.30 | 68.92 | 79.48 | 47.49 | 2 | |
| 65.28 | 65.81 | 78.64 | 51.39 | 3 | |
| **N.S** | | **N.S** | | | **LSD(0.05)** |
| **Mean Extract** | 59.14 | 67.39 | 51.42 | **Mean Plant Densities** | |
| | | 2.42 | | | **LSD(0.05)** |
| 45.90 | 39.06 | 45.31 | 53.32 | L $ha^{-1}$ 0 | **× Extract Plant Densities** |
| 66.49 | 69.94 | 79.08 | 50.46 | L $ha^{-1}$ 2 | |
| 65.57 | 68.42 | 77.78 | 50.49 | L $ha^{-1}$ 4 | |
| 4.50 | | 4.98 | | | **LSD(0.05)** |
| **Mean Spraying stages** | | | | | |
| 57.80 | 59.16 | 62.45 | 51.81 | 1 | **Spraying ×stages Plant Densities** |
| 59.40 | 59.54 | 69.35 | 49.32 | 2 | |
| 60.75 | 58.73 | 70.37 | 53.15 | 3 | |
| N.S | | 4.04 | | | **LSD(0.05)** |

**Total Potassium Uptake (kg K $ha^{-1}$)**

The results in Table (6) show a significant effect of spraying with the equilibrium biostimulant compound on total potassium uptake. The 2 L $ha^{-1}$ level recorded the highest mean of 220.00 kg K $ha^{-1}$, which did not significantly differ from the 4 L $ha^{-1}$ level, while the 0 L $ha^{-1}$ level recorded the lowest mean of 150.50 kg K $ha^{-1}$, with a 46.17% increase. This improvement in total potassium uptake at the 2 L $ha^{-1}$

level may be attributed to the components of the seaweed extract, which enhance the efficiency of nutrient absorption in plants. According to a previous study [17], seaweed extracts contain bioactive compounds such as amino acids, plant hormones, and minerals that enhance the activity of enzymes responsible for absorbing and transporting nutrients, including potassium .The table also indicates that plant density significantly affected total potassium uptake. The plant density of 53333 plants·ha$^{-1}$ recorded the highest mean of 222.20 kg K ha$^{-1}$, while the density of 38095 plants·ha$^{-1}$ recorded the lowest mean of 170.00 kg K ha$^{-1}$. The table also shows a significant effect of spraying stages on total potassium uptake. The third spraying stage recorded the highest mean of 199.80 kg ha$^{-1}$, which did not significantly differ from the second stage, while the first spraying stage recorded the lowest mean of 189.20 kg K ha$^{-1}$ .The results further show that the interaction between the extract and plant densities significantly affected total potassium uptake. The treatment with 2 L·ha$^{-1}$ at a plant density of 53333 plants·ha$^{-1}$ recorded the highest mean of 261.40 kg K ha$^{-1}$, while the 0 L ha$^{-1}$ treatment at a plant density of 88888 plants·ha$^{-1}$ recorded the lowest mean of 126.30 kg ha$^{-1}$. Additionally, the interaction between plant densities and spraying stages significantly affected total potassium uptake. The plant density of 53333 plants ha$^{-1}$ at the second spraying stage recorded the highest mean of 230.00 kg K ha$^{-1}$, while the plant density of 38095 plants·ha$^{-1}$ at the first spraying stage recorded the lowest mean of 171.70 kg K ha$^{-1}$.

**Table (6):** Effect of equilibrium biostimulant compound levels, Spraying Stages, Plant Densities, and their Interactions on Total Potassium Uptake (kg K ha$^{-1}$)

| **×Extract Spraying stages** | **Plant Densities** | | | **Spraying stages** | **Extract Levels** |
|---|---|---|---|---|---|
| | **88888 Plants ha$^{-1}$** | **53333 Plants ha$^{-1}$** | **38095 Plants ha$^{-1}$** | | |
| 138.30 | 118.00 | 129.70 | 167.40 | 1 | **0 L ha$^{-1}$** |
| 155.30 | 134.10 | 156.50 | 175.40 | 2 | |
| 157.90 | 126.70 | 159.10 | 187.80 | 3 | |
| 215.10 | 228.20 | 242.90 | 174.20 | 1 | **2 L ha$^{-1}$** |
| 218.60 | 228.20 | 270.20 | 157.30 | 2 | |
| 226.40 | 238.60 | 270.90 | 169.80 | 3 | |
| 214.20 | 221.40 | 247.90 | 173.40 | 1 | **4 L ha$^{-1}$** |
| 213.60 | 220.30 | 263.20 | 157.30 | 2 | |
| 215.00 | 217.60 | 259.80 | 167.60 | 3 | |
| N.S | N.S | | | | **LSD$_{(0.05)}$** |
| **Mean Extract** | 192.60 | 222.20 | 170.00 | **Mean Plant Densities** | |
| | 7.74 | | | | **LSD$_{(0.05)}$** |

| | | | | | |
|---|---|---|---|---|---|
| 150.50 | 126.30 | 148.40 | 176.90 | 0L ha $^{-1}$ | **× Extract Plant Densities** |
| 220.00 | 231.70 | 261.40 | 167.10 | 2L ha $^{-1}$ | |
| 214.30 | 219.80 | 257.00 | 166.10 | 4L ha $^{-1}$ | |
| 15.24 | 16.50 | | | | **LSD $_{(0.05)}$** |
| **Mean Spraying stages** | | | | | |
| 189.20 | 189.20 | 206.80 | 171.70 | 1 | **Spraying ×stages Plant Densities** |
| 195.80 | 194.20 | 230.00 | 163.30 | 2 | |
| 199.80 | 194.30 | 229.90 | 175.10 | 3 | |
| 6.46 | 12.38 | | | | **LSD $_{(0.05)}$** |

**Oil Content (%)**

The results in Table (7) show a significant effect of spraying with the equilibrium biostimulant compound on oil content. The 4 L ha$^{-1}$ treatment recorded the highest oil content of 4.33%, which did not significantly differ from the 2 L ha$^{-1}$ treatment, while the 0 L ha$^{-1}$ treatment recorded the lowest mean of 3.93%, with an increase of 10.17%. This improvement is attributed to the fact that extracts contain growth-promoting substances such as cytokinins, auxins, and gibberellins, which contribute to improving seed quality, including oil content. These findings are consistent with those study [18], who found that spraying with seaweed extract It achieved a moral superiority over not spraying treatment by achieving an oil content of 5.26%. They also observed that repeated spraying resulted in a significant increase compared to a single spray. The results of this study are also in agreement with those of study [19], which indicated that spraying with seaweed extract led to increased overall yield and improved grain quality characteristics, such as oil content, compared to untreated plants . The table further shows a significant effect of spraying stages on oil content. The second spraying stage recorded the highest mean of 4.35%, which did not significantly differ from the third stage (three sprays during the vegetative growth, male flowering, and grain filling stages). The first spraying stage recorded the lowest mean of 3.90%, representing a 10.34% decrease. This improvement is attributed to the fact that spraying during the flowering stage helps enhance seed quality and provides the necessary nutrients, positively affecting oil content in yellow corn. Spraying during the flowering stage is more influential on increasing oil content compared to spraying during the vegetative growth stage alone [20]. The plant densities did not significantly affect the oil content, which is consistent with the findings [21], where increasing plant densities from 44444 to 88888 plants ha$^{-1}$ did not significantly affect the oil percentage. Furthermore, the interactions did not significantly affect the studied trait.

**Table (7):** Effect of equilibrium biostimulant compound levels, Spraying Stages, Plant Densities, and their Interactions on Oil Content in Grains(%)

| ×Extract Spraying stages | Plant Densities 88888 Plants $ha^{-1}$ | 53333 Plants $ha^{-1}$ | 38095 Plants $ha^{-1}$ | Spraying stages | Extract |
|---|---|---|---|---|---|
| 3.73 | 3.68 | 3.84 | 3.68 | 1 | 0 L $ha^{-1}$ |
| 4.03 | 4.02 | 4.18 | 3.90 | 2 | |
| 4.03 | 4.07 | 3.92 | 4.10 | 3 | |
| 3.97 | 4.09 | 3.85 | 3.96 | 1 | 2 L $ha^{-1}$ |
| 4.39 | 4.37 | 4.52 | 4.29 | 2 | |
| 4.61 | 4.47 | 4.79 | 4.56 | 3 | |
| 4.01 | 4.13 | 4.02 | 3.87 | 1 | 4 L $ha^{-1}$ |
| 4.62 | 4.71 | 4.64 | 4.50 | 2 | |
| 4.37 | 4.52 | 4.32 | 4.27 | 3 | |
| **N.S** | **N.S** | | | | **LSD(0.05)** |
| **Extract Mean** | 4.23 | 4.23 | 4.12 | **Mean Plant Densities** | |
| | N.S | | | | **LSD(0.05)** |
| 3.93 | 3.92 | 3.98 | 3.89 | 0L $ha^{-1}$ | **× Extract Plant Densities** |
| 4.32 | 4.31 | 4.39 | 4.27 | 2L $ha^{-1}$ | |
| 4.33 | 4.45 | 4.33 | 4.21 | 4L $ha^{-1}$ | |
| 0.33 | N.S | | | | **LSD(0.05)** |
| **Mean Spraying stages** | | | | | |
| 3.90 | 3.97 | 3.90 | 3.84 | 1 | **Spraying × stages Plant Densities** |
| 4.35 | 4.36 | 4.45 | 4.23 | 2 | |
| 4.34 | 4.35 | 4.34 | 4.31 | 3 | |
| 0.33 | N.S | | | | **LSD(0.05)** |

The plants responded positively to the treatments of equilibrium biostimulant compound levels. The spraying treatment with equilibrium biostimulant compound at the level of 2 L $ha^{-1}$ performed the best, achieving the highest averages for most growth traits and total NPK uptake. It was also found that increasing plant density led to an improvement in growth traits, such as plant height, leaf area, and its index. It is recommended to use the 2 L $ha^{-1}$ level of equilibrium biostimulant compound levels in combination with plant densities of either 53333 or 88888 plants $ha^{-1}$, depending on the desired goal of cultivation. The choice of plant density depends on the intended purpose of the crop—whether to improve vegetative growth (higher density) or to enhance nutrient uptake (medium density).

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