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## EFFECT OF FOLIAR SPRAYING WITH CIFAMIN BK FERTILIZER ON GROWTH, YIELD, AND BIOACTIVE COMPOUNDS OF THREE MAIZE (*ZEAMAYS* L.) CULTIVARS

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### ABSTRACT

A field experiment was conducted at the College of Agriculture, University of Al-Qadisiyah, Iraq, during the spring 2025 season to investigate the effect of foliar application of CIFAMIN BK fertilizer on vegetative growth, grain yield, and bioactive compound accumulation in three maize (*Zea mays* L.) cultivars: Furat yellow, white maize, and sweet corn. The experiment was laid out in a Randomized Complete Block Design (RCBD) with a split-plot arrangement and three replications, where cultivars occupied the main plots and foliar treatments (distilled water as control versus CIFAMIN BK at 2 mL L<sup>-1</sup>) were assigned to the sub-plots. Foliar applications were made at the six-true-leaf (V6) and tasseling (VT) growth stages. Results demonstrated that CIFAMIN BK considerably ( $P \leq 0.05$ ) improved most of the characteristics examined in all cultivars as compared to untreated control. Of the cultivar  $\times$  treatment interactions, Furat yellow maize treated with CIFAMIN BK had the highest plant height (198.4 cm), chlorophyll content (43.7 SPAD), grain yield (7.84 t ha<sup>-1</sup>) and 100-grain weight (33.6 g) with an increase of 12.5%, 14.7%, 28.1% and 12.8% over its respective control. Likewise, the treated Furat yellow cultivar recorded the highest accumulation of bioactive substances with total phenolics of 11.8 mg GAE g<sup>-1</sup> DW and flavonoids 9.6 mg QE g<sup>-1</sup> DW. The cultivar  $\times$  treatment interaction was significant for most characteristics suggesting that the amplitude of response to foliar feeding is genotype-dependent. These findings suggest that integrating CIFAMIN BK into the foliar fertilization program of maize can substantially improve crop growth, productivity, and grain nutritional quality, with Furat yellow maize being the most responsive cultivar under the conditions of central Iraq.

**Keywords:** CIFAMIN BK, foliar fertilization, *Zea mays*, bioactive compounds, grain yield, split-plot design.

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### 1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops globally, ranking among the top crops in terms of production volume and versatility of use. It plays a fundamental role in human and animal nutrition and is extensively utilized in the food industry for starch, oil, feed, and bioethanol production. Maize is also considered a strategic crop that contributes to enhancing food security owing to its high productive capacity and adaptability to a wide range of environmental conditions when adequate nutritional and management requirements are met [6, 7]. Balanced nutrient supply is among the most critical factors

influencing maize growth and productivity. Both macro- and micronutrients play a pivotal role in chlorophyll formation, activation of enzymatic systems, and stimulation of photosynthesis and cell division, which directly increase dry matter accumulation and improve yield components. Nutritional imbalance leads to reduced efficiency of physiological processes and decreased productivity even under favorable environmental conditions [13, 19]. In recent decades, foliar fertilisation has become of growing interest as a new way to improve efficiency of plant nutrition. It permits nutrients to reach the leaves directly, thus decreasing losses by soil fixation or leaching, and

boosting the speed of plant response to applied nutrients, especially in calcareous soils or under situations of environmental stress. Several researches proved that foliar application of amino acid containing fertilisers is contributing to improve photosynthetic efficiency, increased dry matter accumulation and nutrient use efficiency which is beneficial for growth and output [1, 20]. CIFAMIN BK is a foliar fertiliser of Spanish origin with a balanced mixture of nutrients, free amino acids and microelements. The product (according to the manufacturer's standards) comprises 5% total nitrogen (N), 6% soluble potassium oxide (K<sub>2</sub>O), 10% free amino acids and chelated micronutrients including iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B) and molybdenum (Mo). These components are crucial in boosting plant metabolic activity, photosynthetic efficiency, photosynthates translocation into economic organs and plant tolerance to environmental stress. Amino acids are needed for protein synthesis and activation of various growth regulating enzymes [19]. Balanced mineral nutrition is one of the most critical variables for boosting field crop yield and quality [13]. Maize grains contain several important bioactive compounds, including total phenolics, flavonoids, organic acids, and soluble sugars, which possess antioxidant activity and contribute to enhancing the nutritional and health value of the crop. Studies have shown that improving the nutritional status of the plant increases accumulation of these compounds through activation of metabolic pathways associated with secondary metabolite production, thereby improving grain quality and nutritional value [10, 14]. Despite the increasing use of foliar fertilizers, information regarding the response of different maize cultivars to CIFAMIN BK remains limited, particularly under local environmental conditions characterized by calcareous soils and elevated salinity. Therefore, this study aimed to evaluate the effect of foliar spraying with this fertilizer on vegetative growth, yield, and bioactive compounds of three maize cultivars, and to identify the cultivar most responsive to foliar fertilization treatments.

## 2. MATERIALS AND METHODS

### 2.1. Experimental Site and Conditions

The field experiment was conducted during the spring growing season of 2025 at the agricultural fields of the College of Agriculture, University of Al-Qadisiyah, Iraq. The experimental site is characterized by clay loam soil and a semi-arid climate with high temperatures during the growing season and low rainfall, thus regular irrigation was adopted throughout the experimental period. The soil exhibited moderate salinity (EC = 3.2 dS m<sup>-1</sup>), which is a common feature of agricultural soils in central Iraq and may impose osmotic stress on maize, particularly during early seedling stages [13].

### 2.2. Land Preparation and Planting

The experimental field was prepared by two cross-ploughings with a disc plough and levelled to get an appropriate seedbed. The total field area was 540 m<sup>2</sup>. Seeds were seeded on 15 March 2025 at a seeding rate of 25 kg ha<sup>-1</sup>. Each experimental unit (3 × 2 m) covered an area of 6 m<sup>2</sup> and consisted of four rows with row spacing of 75 cm and plant spacing of 25 cm within rows, resulting in a plant density of about 53,333 plants ha<sup>-1</sup>. Basal fertiliser was urea (46% N) at 200 kg ha<sup>-1</sup> in two equal splits (at sowing and at six-leaf stage) and triple superphosphate (46% P<sub>2</sub>O<sub>5</sub>) at 100 kg ha<sup>-1</sup> at sowing. Irrigation was applied at 7–10 days intervals depending on the crop growth stage and weather conditions.

### 2.3. Soil Analysis

Composite soil samples were collected before planting from a depth of 0–30 cm at various locations within the field. Samples were air-dried, ground, and sieved through a 2 mm mesh. Physical and chemical analyses were conducted in the laboratories of the Department of Soil Sciences and Water Resources, College of Agriculture, University of Al-Qadisiyah. Soil pH was measured using a Hanna pH Meter, electrical conductivity using a Jenway EC Meter, and nutrient concentrations were determined according to the standard methods described by Page et al. [16]. Results are presented in Table 01.

Table 01: Physical and chemical properties of the experimental field soil before planting.

| Property                                    | Value     |
|---------------------------------------------|-----------|
| Texture                                     | Clay loam |
| pH                                          | 7.4       |
| EC (dS m <sup>-1</sup> )                    | 3.2       |
| Available nitrogen (mg kg <sup>-1</sup> )   | 42        |
| Available phosphorus (mg kg <sup>-1</sup> ) | 18        |
| Available potassium (mg kg <sup>-1</sup> )  | 210       |
| Organic matter (%)                          | 1.4       |

### 2.4. Irrigation Water Analysis

Standard irrigation water was used, and samples were collected before the experiment for analysis. Analyses were performed according to the standard methods of APHA [3], using a UV–Visible Spectrophotometer and Flame Photometer for determination of dissolved elements. Results are presented in Table 02.

Table 02: Chemical properties of irrigation water.

| Property                               | Value |
|----------------------------------------|-------|
| pH                                     | 7.2   |
| EC (dS m <sup>-1</sup> )               | 2.1   |
| Ca <sup>2+</sup> (mg L <sup>-1</sup> ) | 85    |
| Mg <sup>2+</sup> (mg L <sup>-1</sup> ) | 42    |
| Na <sup>+</sup> (mg L <sup>-1</sup> )  | 110   |
| K <sup>+</sup> (mg L <sup>-1</sup> )   | 6.5   |

| Property                                            | Value |
|-----------------------------------------------------|-------|
| Cl <sup>-</sup> (mg L <sup>-1</sup> )               | 96    |
| SO <sub>4</sub> <sup>2-</sup> (mg L <sup>-1</sup> ) | 132   |
| HCO <sub>3</sub> <sup>-</sup> (mg L <sup>-1</sup> ) | 145   |

## 2.5. Experimental Design and Treatments

The experiment was conducted using a Randomized Complete Block Design (RCBD) in a split-plot arrangement with three replications.

**Factor A (main plots) – Cultivars:** (1) Yellow maize (cv. Furat); (2) White maize; (3) Sweet corn.

**Factor B (sub-plots) – Foliar application:** (1) Control (spraying with distilled water); (2) CIFAMIN BK at 2 mL L<sup>-1</sup>.

## 2.6. CIFAMIN BK Fertilizer Composition

CIFAMIN BK (manufactured by CIFAMIN S.A., Spain) is an organic–mineral foliar fertilizer. Its guaranteed composition is presented in Table 03.

**Table 03.** Guaranteed chemical composition of CIFAMIN BK fertilizer.

| Component                                  | Content |
|--------------------------------------------|---------|
| Total nitrogen (N)                         | 5.0%    |
| Soluble potassium oxide (K <sub>2</sub> O) | 6.0%    |
| Free amino acids                           | 10.0%   |
| Iron (Fe) – EDTA chelated                  | 0.5%    |
| Manganese (Mn) – EDTA chelated             | 0.3%    |
| Zinc (Zn) – EDTA chelated                  | 0.2%    |
| Copper (Cu) – EDTA chelated                | 0.1%    |
| Boron (B)                                  | 0.05%   |
| Molybdenum (Mo)                            | 0.01%   |
| pH (1% solution)                           | 6.5–7.0 |

Foliar spraying was carried out twice during the growing season: the first application at the six-true-leaf stage (V6), and the second prior to tasseling (VT). A 16-liter knapsack sprayer was used, and spraying was performed in the early morning hours to ensure optimal absorption efficiency.

## 2.7. Studied Traits

**Vegetative growth traits:** plant height (cm), number of leaves per plant, leaf area (cm<sup>2</sup>), chlorophyll content (SPAD units), and stem diameter (mm).

**Yield traits:** number of ears per plant, ear length (cm), number of grains per ear, 100-grain weight (g), and grain yield (t ha<sup>-1</sup>).

**Bioactive compounds:** total phenolics, flavonoids, organic acids, and soluble sugars.

## 2.8. Analytical Methods

Total phenolics were determined by the Folin–Ciocalteu method [18] and expressed as mg gallic acid equivalent (GAE) per g dry weight. Flavonoids were determined according to Zhishen et al. [22] and expressed as mg quercetin equivalent (QE) per g dry weight. Soluble sugars were determined by the phenol–sulfuric acid method [5]. Organic acids were quantified

using High-Performance Liquid Chromatography (HPLC) according to AOAC [2] standard methods.

## 2.9. Statistical Analysis

Data were statistically analyzed using GenStat software (VSN International). Analysis of variance (ANOVA) was performed to study the effects of experimental factors and their interaction. Means were compared using the Least Significant Difference (LSD) test at the 0.05 probability level.

## 3. RESULTS AND DISCUSSION

### 3.1. Vegetative Growth Traits

The interaction effects of maize cultivars and foliar spraying with CIFAMIN BK on vegetative growth traits are presented in Table 04.

**Table 04:** Interaction effects of maize cultivars and foliar spraying with CIFAMIN BK on vegetative growth traits.

| Cultivar × Treatment      | Plant height (cm) | No. of leaves (leaf plant <sup>-1</sup> ) | Leaf area (cm <sup>2</sup> ) | Chlorophyll content (SPAD) | Stem diameter (mm) |
|---------------------------|-------------------|-------------------------------------------|------------------------------|----------------------------|--------------------|
| Furat Yellow + Control    | 176.3             | 13.4                                      | 4983.6                       | 38.1                       | 22.3               |
| Furat Yellow + CIFAMIN BK | 198.4             | 15.2                                      | 5765.3                       | 43.7                       | 25.6               |
| White Maize + Control     | 170.6             | 12.8                                      | 4721.4                       | 36.4                       | 21.4               |
| White Maize + CIFAMIN BK  | 184.5             | 14.1                                      | 5312.8                       | 41.2                       | 23.8               |
| Sweet Corn + Control      | 154.2             | 11.2                                      | 4108.5                       | 34.5                       | 19.3               |
| Sweet Corn + CIFAMIN BK   | 168.7             | 13.0                                      | 4756.2                       | 39.6                       | 22.1               |
| <b>LSD (0.05)</b>         | <b>9.2</b>        | <b>1.1</b>                                | <b>387.4</b>                 | <b>2.3</b>                 | <b>1.8</b>         |

Results in Table 04 revealed significant differences in the response of maize cultivars to foliar spraying with CIFAMIN BK. Foliar application increased all measured vegetative growth traits compared to the control across all three cultivars. Furat yellow maize treated with CIFAMIN BK recorded the highest values, with plant height of 198.4 cm, number of leaves of 15.2 leaves plant<sup>-1</sup>, leaf area of 5765.3 cm<sup>2</sup>, chlorophyll content of 43.7 SPAD units, and stem diameter of 25.6 mm. In comparison, Furat yellow maize under the

control treatment recorded 176.3 cm, 13.4 leaves plant<sup>-1</sup>, 4983.6 cm<sup>2</sup>, 38.1 SPAD, and 22.3 mm, respectively (Figure 01).

White maize also exhibited a positive response to foliar application, with plant height increasing from 170.6 to 184.5 cm, number of leaves from 12.8 to 14.1 leaves plant<sup>-1</sup>, leaf area from 4721.4 to 5312.8 cm<sup>2</sup>, chlorophyll content from 36.4 to 41.2 SPAD, and stem diameter from 21.4 to 23.8 mm. Sweet corn similarly showed improvement due to foliar spraying; however, its values remained lower than those of the other two cultivars.

The improvement in vegetative growth following foliar application can be attributed to the enhanced supply of nutrients and amino acids to the plant, which improves the efficiency of physiological processes and photosynthesis and increases dry matter formation. Chlorophyll content, as indicated by SPAD readings, serves as an important indicator of the nutritional status and photosynthetic apparatus efficiency; therefore, the elevated SPAD values associated with foliar spraying suggest an improved physiological status of the plant [8, 20].

The superiority of Furat yellow maize in response to foliar application suggests genetic differences among cultivars in the efficiency of nutrient absorption, utilization, and distribution of photosynthates. The improvement in vegetative growth was reflected in increased stem diameter, which can subsequently contribute to greater support capacity for reproductive growth and yield formation. These results are consistent with Marschner [13], who emphasized the importance of balanced mineral nutrition for vegetative growth, and with Januszkiewicz et al. [12], who demonstrated that foliar nutrient supplementation significantly improved maize growth parameters across different soil types. Similarly, Abdo et al. [1] reported significant increases in maize vegetative growth and yield following application of biological growth stimulants.

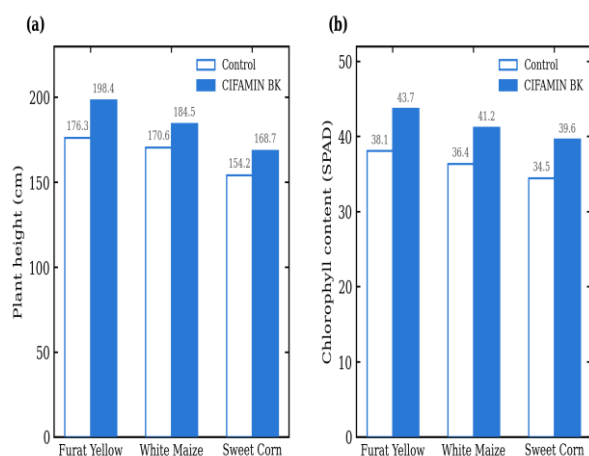


Figure 01: Effect of foliar spraying with CIFAMIN BK on (a) plant height and (b) chlorophyll content of three maize cultivars.

### 3.2. Yield and Yield Components

The interaction effects of maize cultivars and foliar spraying with CIFAMIN BK on yield traits are presented in Table 05.

Table 05: Interaction effects of maize cultivars and foliar spraying with CIFAMIN BK on yield and yield components.

| Cultivar × Treatment      | No. of ears plant <sup>-1</sup> | Ear length (cm) | No. of grains ear <sup>-1</sup> | 100-grain weight (g) | Grain yield (t ha <sup>-1</sup> ) |
|---------------------------|---------------------------------|-----------------|---------------------------------|----------------------|-----------------------------------|
| Furat Yellow + Control    | 1.0                             | 20.5            | 430                             | 29.8                 | 6.12                              |
| Furat Yellow + CIFAMIN BK | 1.2                             | 23.8            | 498                             | 33.6                 | 7.84                              |
| White Maize + Control     | 1.0                             | 19.8            | 412                             | 28.6                 | 5.94                              |
| White Maize + CIFAMIN BK  | 1.1                             | 22.1            | 470                             | 31.4                 | 7.02                              |
| Sweet Corn + Control      | 1.0                             | 17.1            | 350                             | 24.8                 | 4.81                              |
| Sweet Corn + CIFAMIN BK   | 1.1                             | 19.4            | 390                             | 27.5                 | 5.66                              |
| LSD (0.05)                | N.S.                            | 1.8             | 28                              | 2.1                  | 0.72                              |

Table 05 demonstrates that foliar spraying with CIFAMIN BK resulted in substantial improvements in yield traits for all maize cultivars compared to the control. Furat yellow maize treated with CIFAMIN BK recorded the highest values, with ear length of 23.8 cm, number of grains per ear of 498, 100-grain weight of 33.6 g, and grain yield of 7.84 t ha<sup>-1</sup>, compared to 20.5 cm, 430 grains, 29.8 g, and 6.12 t ha<sup>-1</sup>, respectively, under the control treatment (Figure 2). Number of ears per plant showed a slight numerical increase (1.0 to 1.2) in Furat yellow; however, the difference was not statistically significant ( $P > 0.05$ ).

White maize also responded to foliar application, with grain yield increasing from 5.94 to 7.02 t ha<sup>-1</sup>, while sweet corn grain yield increased from 4.81 to 5.66 t ha<sup>-1</sup>. These increases indicate that improving the nutritional status of the plant during growth stages was reflected in ear formation, grain number, and grain filling.

Number of grains per ear and individual grain weight are fundamental components determining maize yield; therefore, the increase in both components due to foliar spraying explains the increase in grain yield. Furthermore, the improvement observed in vegetative growth traits (Table 4), particularly chlorophyll content and plant height, provided a more efficient assimilatory apparatus for production and translocation of carbohydrates to reproductive organs. Ocwa et al.

[14], in their systematic review of maize biostimulant applications, similarly reported that amino acid-containing foliar products consistently enhanced grain yield through improved source-sink relationships. Furat yellow maize was the most responsive cultivar to foliar application, indicating genotypic differences in the efficiency of nutrient resource utilization and genetic capacity for grain formation and filling. Sweet corn recorded the lowest values, which can be attributed to its distinct genetic characteristics and breeding objectives compared to cultivars primarily bred for grain production. These findings are consistent with Islam et al. [11], who reported similar cultivar-dependent responses in maize grain yield following foliar amino acid application, and with Marschner [13]. The relationship between improved photosynthesis and increased yield also aligns with the physiological principles described by Taiz et al. [19].

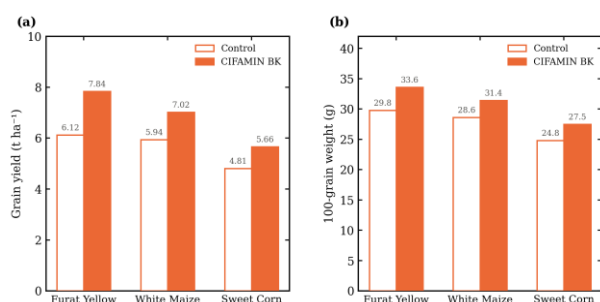


Figure 02: Effect of foliar spraying with CIFAMIN BK on (a) grain yield and (b) 100-grain weight of three maize cultivars.

### 3.3. Bioactive Compounds

The interaction effects of maize cultivars and foliar spraying with CIFAMIN BK on bioactive compound contents are presented in Table 06.

Table 06: Interaction effects of maize cultivars and foliar spraying with CIFAMIN BK on bioactive compounds of maize grains.

| Cultivar × Treatment      | Total phenolics (mg GAE g <sup>-1</sup> DW) | Flavonoids (mg QE g <sup>-1</sup> DW) | Organic acids (mg g <sup>-1</sup> DW) | Soluble sugars (mg g <sup>-1</sup> DW) |
|---------------------------|---------------------------------------------|---------------------------------------|---------------------------------------|----------------------------------------|
| Furat Yellow + Control    | 9.4                                         | 7.2                                   | 5.8                                   | 5.1                                    |
| Furat Yellow + CIFAMIN BK | 11.8                                        | 9.6                                   | 7.4                                   | 6.8                                    |
| White Maize + Control     | 8.7                                         | 6.5                                   | 5.4                                   | 4.8                                    |
| White Maize + CIFAMIN BK  | 10.6                                        | 8.4                                   | 6.9                                   | 6.0                                    |
| Sweet Corn + Control      | 7.4                                         | 5.6                                   | 4.8                                   | 4.1                                    |

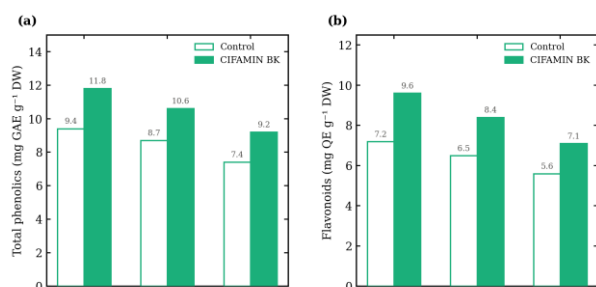
| Cultivar × Treatment    | Total phenolics (mg GAE g <sup>-1</sup> DW) | Flavonoids (mg QE g <sup>-1</sup> DW) | Organic acids (mg g <sup>-1</sup> DW) | Soluble sugars (mg g <sup>-1</sup> DW) |
|-------------------------|---------------------------------------------|---------------------------------------|---------------------------------------|----------------------------------------|
| Sweet Corn + CIFAMIN BK | 9.2                                         | 7.1                                   | 6.0                                   | 5.3                                    |
| LSD (0.05)              | 1.2                                         | 1.0                                   | 0.9                                   | 0.8                                    |

Table 06 demonstrates that foliar spraying with CIFAMIN BK increased the content of all measured bioactive compounds compared to the control across all three cultivars (Figure 3). Furat yellow maize treated with CIFAMIN BK recorded the highest values for total phenolics (11.8 mg GAE g<sup>-1</sup> DW), flavonoids (9.6 mg QE g<sup>-1</sup> DW), organic acids (7.4 mg g<sup>-1</sup> DW), and soluble sugars (6.8 mg g<sup>-1</sup> DW). In contrast, the same cultivar under the control treatment recorded lower values of 9.4, 7.2, 5.8, and 5.1, respectively.

The increase in phenolics and flavonoids can be attributed to the improved nutritional status of the plant and enhanced activity of metabolic pathways associated with secondary metabolite biosynthesis, particularly the phenylpropanoid pathway. Phenolics and flavonoids are important compounds in plant defense and resistance to oxidative stress; therefore, the improved physiological status of the plant may be associated with their increased accumulation [9, 17].

The rise in soluble sugars may be due to the increase in the photosynthetic activity, due to the increase in chlorophyll concentration, as seen in Table 4. Sugars are the main products of photosynthesis and act as carbon and energy sources for many metabolic pathways including those involved in the production of secondary metabolites. Also, increased organic acids could be connected with the increased metabolic activity of the plant due to the presence of nutrients [13].

Comparing across Tables 4, 5, and 6, it is evident that Furat yellow maize treated with CIFAMIN BK was the most superior in vegetative growth traits, yield components, and bioactive compounds, while sweet corn under the control treatment recorded the lowest values for most traits. This indicates genotypic variation in response to foliar fertilization. The moderate soil salinity (EC = 3.2 dS m<sup>-1</sup>) at the experimental site may have accentuated the benefits of foliar feeding, as nutrient uptake from saline soils through the root system is often impaired, making the foliar route a more efficient delivery pathway under such conditions [15, 21].



**Figure 03:** Effect of foliar spraying with CIFAMIN BK on (a) total phenolics and (b) flavonoid content of three maize cultivars.

#### 4. CONCLUSIONS

Based on the results obtained, the following conclusions can be drawn foliar spraying with CIFAMIN BK improved most vegetative growth traits of all three maize cultivars compared to the control, reflected in increased plant height, number of leaves, leaf area, chlorophyll content, and stem diameter. The reaction to foliar treatment across the tested cultivars was significantly different showing the genetic heterogeneity in the efficiency of using applied nutrients. Foliar application helped enhancing yield and its components especially ear length, number of grains per ear, 100-grain weight and grain yield. The use of CIFAMIN BK enhanced the accumulation of essential bioactive compounds such as total phenolics, flavonoids, organic acids and soluble sugars and hence improved the nutritional content of the grains. The interaction results of cultivars and foliar application showed that the response of the plant depended on the genotype and the efficiency of the foliar fertiliser, highlighting the necessity of choosing the correct cultivar together with an adequate fertilisation program to achieve maximum productivity.

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