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Improving Chemical Properties of Fig Seedlings (cv. Aswad Diyala) Using Reed Biochar and Tryptophan

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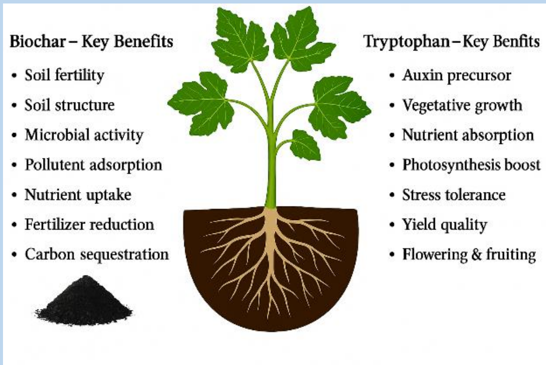
Abstract: The research was carried out in the lath house belonging to the Department of Horticulture and Landscape Gardening at the College of Agriculture - Anbar University for the period from March 15, 2024, to November 15, 2024, to study the effect of adding Reed biochar three levels: 0, 2, 4%, which It is symbolized by the symbols B0, B1, and B2, respectively, and sprayed with the amino acid "Tryoptophan" at four concentrations: 0 50, 100, and 150 mg L^{-1}, which are symbolized as T0, T1, T2, and T3, respectively, in some chemical characteristics of fig seedlings cv. Aswad Diyala. 108 seedlings were selected that were as homogeneous as possible in vegetative growth. A two-factor 3 x 4 factorial experiment was implemented according to a completely randomized block design. The experiment contained 12 treatments, three replicates, and four seedlings per experimental unit. The effect of adding Reed biochar was significant on all the studied traits except for the percentage of calcium, especially the high level B2, which achieved the best values for the traits total chlorophyll 1.41 mg g^{-1} fresh weight, total carbohydrates 15.54%, nitrogen 1.86%, phosphorus 0.32%, potassium 0.64%, magnesium 0.47%, iron 169.37 mg kg^{-1}, zinc 44.94 mg kg^{-1}, and manganese 65.91 mg kg^{-1}. Spraying with tryoptophan showed an effect that reached the level of significance on all traits, treatment T3 achieved the best significant effect on the traits total chlorophyll, total carbohydrates, nitrogen, phosphorus, potassium, magnesium, calcium, iron, zinc, manganese, which amounted to 1.48 mg g^{-1} fresh weight, 15.32%, 1.83%, 0.34%, 0.61%, 0.48%, 1.30%, 171.01 mg kg^{-1}, 43.37 mg kg^{-1} and 65.35 mg kg^{-1}. The interaction of the two study factors reached the level of significance in affecting all the studied traits except for the chlorophyll content of the leaves. The interaction treatment (B2T3) was distinguished in achieving the best values depending on the type of the studied trait, where the lowest values were in the control treatment (B0T0) for all the studied traits.



Keywords: fig seedlings, biochar, tryoptophan, sustainable agriculture, environmental conservation

Introduction

The fig Ficus carica L. belongs to the Moraceae family and the genus Ficus, which includes more than 800 species of plants [1,2]. The original homeland of figs is considered to be West Asia, and its cultivation has been spread in the Mediterranean basin [3]. While [4] mentioned that the homeland of the fig is the fertile part of the Arabian Peninsula and it still grows in its wild state from there it has been spread to southern Syria and then to the shores of the Mediterranean Sea. At present, its cultivation has been spread to different regions of the world, including Turkey, Egypt, Spain, Greece, America, Italy, Brazil, and other places in the world [5,6].

The fig cultivar “Aswad Diyala” (Ficus carica L.) is considered one of the prominent local varieties in Iraq. It is characterized by high productivity, ranging between 20 to 30 kg tree-1. When compared to other commonly cultivated fig cultivars in Iraq, most of which are imported from Turkey,such as Kadota, White Genoa, and Smyrna, Aswad Diyala is surpassed them in terms of yield and its ability to withstand harsh environmental conditions. For instance, the average yield of the Waziri cultivar is estimated about 18–25 kg tree-1, while Kadota produces approximately 15–20 kg tree-1, The yield of White Genoa ranges between 12–18 kg tree-1, and Smyrna is considered a moderate-yield cultivar, producing 10–22 kg tree-1 under optimal conditions. The superiority of the Aswad Diyala fig cultivar in terms of yield is attributed to its high tolerance to drought, adaptability to poor soils, and its success under the arid climatic conditions prevailing in Iraq. This makes it more suitable for extensive cultivation compared to other cultivars that require special care or more fertile soils. For this reason, local farmers prefer to grow this cultivar in order to achieve good economic returns under the difficult agricultural conditions in Iraq. This cultivar is also distinguished by its dark purple to black fruits, which are considered of high quality. The fruit has a pear-like shape, is medium in size, and the pulp is juicy and sweet-making it highly suitable for fresh consumption. This cultivar originates from Diyala Province, located in the eastern region of Iraq, where it is widely grown in both home gardens and commercial farms [7].

Not long ago, many countries realized the importance of plant waste in the economy and industry, and began working to

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transform these wastes into a material of economic value, and there is competition over how to exploit it. The interest of these countries does not stop at the limit of agricultural production and how to increase the quantity of the crop to achieve the highest possible productivity, but rather extends to how to find a new integrated method that guarantees the benefit of plant waste by reusing it and transforming it from the usual concept that it is a huge burden on the farmer and the environment by accumulating and burning it to economic value with diversified uses and investments [8]. Plant waste is used in animal nutrition, energy generation, fertilization, paper pulp manufacturing, high-quality wooden boards such as sunflower waste, cotton, and grape pruning waste, and the production of manufactured materials such as ethyl alcohol, biogas, vinegar, carbon dioxide liquid, and others [9].

The process of preparing biochar from recycling plant wastes rich in nutrients is considered one of the important directions for optimal exploitation of these wastes, and the quality of biochar depends on the type of original material from which it is made. The process of direct burning of organic matter leads to the loss of part of the carbon, which is evaporated in the form of carbon dioxide gas into the atmosphere, while the obtained biochar will ensure that 50% of the original carbon remains to be stored again in the soil, which increases soil fertility [10]. In addition to the important role of biochar in increasing the soil's storage capacity for nutrients and water, biocarbon added to the soil improves the chemical and physical properties of the soil, and is more stable than the organic materials that can be added to the soil. Therefore, all the benefits associated with using biochar, including the ability to preserve nutrients in the soil and increase fertility, are considered more permanent compared to alternative soil management methods or adding fertilizers [11,12]. Over the years, improving soil fertility for agricultural production has been limited to the use of chemical fertilizers, which have recently shown their negative impact on the deterioration of soil properties and the microorganisms, as well as their cumulative impact on human and animal health. Therefore, biochar fertilizer has been proposed as one of the effective options for Improving soil traits and increasing its ability to retain moisture, which reflects positively in increasing crop growth and production [13].

Numerous studies have been conducted to demonstrate the positive effect of adding biochar to growth media in improving the chemical content of plants, [14] showed that when biochar produced from the shrub sunflower (*Tithonia diversifolia*) was added to soil planted with broccoli plants at levels of 10, 20, 30, and 40 tons per hectare, there was a significant increase in the nutrient content of the leaves. The nitrogen content reached 4.02%, phosphorus was 0.68 mg kg^{-1}, potassium was 3.98 mg kg^{-1}, calcium was 2.85 mg kg^{-1}, and magnesium was 1.28 mg kg^{-1}. [15] observed that adding biochar (from jojoba tree residues) to petunia plants at a concentration of 2% resulted in a significant increase in the total chlorophyll content of the leaves, which reached 1.09 mg g^{-1} dry weight. A study conducted by [16] on spinach plants showed that adding 6 g of biochar per 1 kg of soil contributed to increasing the leaf content of iron, zinc, and calcium compared to the control treatment. On the other hand,

Amino acids are considered natural chelating compounds with low molecular weights that have a high ability to dissolve in water and penetrate through cell membranes easily, especially if they are sprayed on plants in the form of nutrient solutions. Therefore, they directly or indirectly affect the physiological activities that contribute to building basic compounds such as carbohydrates, proteins, fats, vitamins, etc. [17,18]. Amino acids also contribute to increasing pollen germination and pollen tube growth, which increases the percentage of setting [19], and they have an important role in improving vegetative growth and the health condition of the plant, which increases its resistance to disease and insect infections and stress conditions [20]. Amino acids are considered also one of the most important biostimulants that are rapidly transported within the plant and have a role in forming important and necessary hormones and enzymes for the plant at all stages of its growth [21]. The amino acid Tryptophan, or its precursor Indole-3-glycerol phosphate, is knows as the initiator of the biosynthesis of IAA. Four biological pathways have been found in plants to manufacture it, three of which are dependent on the amino acid Tryptophan-dependent Auxin biosynthesis, which are the indole-3-pyruvic acid (IPyA) pathway), the tryptamine (TAM) pathway, and also the indole-3-acetonitrile (IAN). As for the fourth path, it does not depend on the amino acid tryptophan, as IAA is built from the compound indole-3-glycerol phosphate. This multiplicity of paths in the biosynthesis of IAA, especially from the amino acid tryptophan, shows the important role of this hormone and its initiator in plant growth and development [22].

Various studies have been conducted to demonstrate the positive effect of spraying the amino acid tryptophan in improving the chemical content of fruit trees and their seedlings. [23] found that spraying tryptophan on Red Roomy grapevines at concentrations of 100 and 200 mg L^{-1} resulted in an increase in leaf content of total chlorophyll and the elements N, P, K, and Mg, especially at the concentration of 200 mg L^{-1}, at which the values reached 2.75 and 3.04 mg g^{-1}, 2.31 and 2.50%, 0.71 and 0.75%, 1.84 and 1.94%, and 0.77 and 0.86%, respectively, in both research seasons. [24] confirmed that spraying tryptophan on papaya seedlings at concentrations of 50 and 100 mg L^{-1} resulted in an increase in leaf content of N, P, K, and relative chlorophyll, particularly at the concentration of 100 mg L^{-1}, where the values reached 4.76%, 0.41%, 3.92%, and 70.68 SPAD units, respectively. Moreover, [25] observed that spraying the amino acid tryptophan on Le Conte pear trees at concentrations of 50, 100, and 150 mg L^{-1} led to an increase in the leaf content of relative chlorophyll and the elements N, P, K, Fe, and Zn, especially at the concentration of 150 mg L^{-1}, at which the values were recorded 46.20 and 49.89 SPAD units, 2.12 and 2.19%, 0.643 and 0.720%, 1.73 and 1.81 mg L^{-1}, 160.46 and 165.10 mg L^{-1}, and 126.17 and 133.8 mg L^{-1}, respectively, in both study seasons. In addition, [26] found in his study on the effect of spraying tryptophan at concentrations of 75 and 150 mg L^{-1} on the chemical content of olive seedlings (Manzanillo and Baashiqi cultivars) that there was a significant increase in leaf content of total chlorophyll, total carbohydrates, nitrogen, phosphorus, potassium, magnesium, iron, and zinc, particularly at the concentration of 150 mg L^{-1}.

Due to the lack of sufficient studies addressing the combined effects of biochar application and foliar spraying with the amino acid tryptophan-particularly on fig seedlings (cv. Aswad Diyala) grown under the climatic and soil conditions of Anbar Governorate-this study was conducted to investigate and enhance the chemical composition and overall vigor of fig seedlings through the application of environmentally friendly agricultural treatments. The research aims to support seedling development, especially during the early growth stages, which are critical periods marked by high nutrient demand for metabolic and physiological processes. This study also seeks to reduce the reliance on synthetic chemical fertilizers, which are known to pose risks to the environment, human health, and biodiversity when used excessively or improperly. By exploring alternatives such as biochar derived from sugarcane residues and the amino acid tryptophan, the research promotes the use of sustainable, low-cost, and eco-friendly agricultural inputs. Additionally, this research presents a practical solution for managing the overabundant growth of reed plants (Phragmites spp.) along the banks and beds of the Tigris and Euphrates rivers. These plants have become invasive and obstructive to water flow, forming dense thickets that are difficult to control. Utilizing reeds as a raw material for biochar production represents an innovative way to transform a problematic weed into a valuable resource that contributes to agricultural sustainability and river management efforts. Thus, the overarching goal of this study is not only to improve seedling quality and nutrient use efficiency in fig cultivation but also to offer environmentally responsible alternatives that support long-term agricultural productivity, resource conservation, and ecological balance.

Materials and Methods

Experiment implementation site

The study was conducted in the lath house of the Department of Horticulture and Landscape Gardening - College of Agriculture - Anbar University for the period from mid-March of the year 2024 until mid-November of the same year in order to determine the response of two-year-old fig seedlings cv. Aswad Diyala to the addition of biochar and spraying with the amino acid "Tryoptophan".

Seedlings that were as homogeneous as possible were brought on 3/1/2024 and were planted in 15 kg plastic pots containing a mixture of river soil and peat moss at a ratio of 3:1. Service operations were carried out including pest control, irrigation (drip irrigation) equally for all treatments under study, In addition, all seedlings were fertilized with NPK (20:20:20) in an amount of 7 gm per seedling and for three dates (5/3, 5/6 and 5/9). An analysis was carried out of some chemical and physical characteristics of the soil, as shown in Table 1

Table (1): Some physical and chemical characteristics of culture medium.

Av. P mg kg-1	Total N %	CaCO3 g kg-1	Bulk density g cm-3	O.M %	EC ds m-1	pH
2.68	0.095	117.49	1.13	0.24	0.82	7.47
Cl- mq L-1	HCO3= mq L-1	CO3= mq L-1	Na+ mq L-1	Mg++ mq L-1	Ca++ mq L-1	Av. K mg kg-1
1.92	1.27	Nil	0.36	3.57	4.16	83.30
Texture			Clay g kg-1	Silt g kg-1	Sand g kg-1	SO4= mq L-1
Sandy clay loam			239.4	79.2	681.4	1.63

*(Av. P Available Phosphorus, Total N Total Nitrogen, CaCO3 Calcium Carbonate, O.M Organic Matter, EC Electrical Conductivity, pH potential of Hydrogen, Cl- Chloride, HCO3= Bicarbonate, CO3= Carbonate, Na+ Sodium, Mg++ Magnesium, Ca++ Calcium, Av. K Available Potassium, SO4= Sulfate)

Treatments used in the experiment

1. Biochar

The Reed biochar was air-dried, manually cut, and assembled into individual piles, which were then pyrolyzed for 6–7 hours until the temperature reached 300–380°C [27]. The combustion was then extinguished by gradually adding water and soil to the pile to seal ventilation openings while creating small perforations at various locations to allow controlled aeration. (To speed up the combustion process, the number of ventilation openings could be increased) This method allowed for slow combustion, with the temperature gradually dropping to about 60°C at the halfway point, and the completion of the combustion process was indicated by a change in the color of the flame from black to blue. The biochar was then allowed to cool completely before being considered ready [28].

Table (2): Characteristics of the biochar used in the experiment

pH	8.03
EC ds m-1	11.14
Nitrogen (%)	0.348
Phosphorus (%)	17
Potassium (%)	0.553
Zinc (mg kg-1)	51.8

*(pH potential of Hydrogen, EC Electrical Conductivity)

Three levels (weight/weight) of biochar were added to the seedlings on March 15, 2024: 0%, 2%, and 4% (labeled B0, B1, and B2, respectively).

2. Amino acid "tryptophan"

The amino acid "tryptophan" was sprayed on the seedlings' leaves until they were completely wet at four different concentrations: 0, 50, 100, and 150 mg L^{-1} (designated as T0, T1, T2, and T3, respectively). March 15, April 15, May 15, June 15, and September 15 were the dates on which the spraying was conducted.

Experimental Design

Three replicates were used in a randomized complete block design (RCBD) factorial experiment (3 × 4). A total of 108 seedlings were employed in the experiment, with 36 experimental units (seedlings) in each block. This means that each treatment was duplicated four times within each block. The Least Significant Difference (L.S.D.) test was used to evaluate the means of the traits under study at a 0.05 probability level after the data were statistically processed using the Genstat statistical software [29].

Studied Traits

Total chlorophyll content of leaves (mg g-1 fresh weight): The acetone method was used to estimate the chlorophyll content of leaves according to the method described by [30].

The percentage of carbohydrates in the branches: The percentage of carbohydrates in the branches was measured in October 2024, according to what was mentioned by [31].

Estimation of macro and macroelements: Leaf samples of seedlings were taken at the end of the experiment and their content of macro and microelements (N, P, K, Mg, Zn, and Mn) was estimated according to the method described by [32].

Results and Discussion

Total chlorophyll content of leaves (mg g-1 fresh weight)

According to the statistical data shown in Figure (1), the amount of total chlorophyll in the leaves was significantly impacted by the addition of Reed biochar. With the greatest chlorophyll content of 1.41 mg g^{-1} fresh weight 6.8% increase over the B0 (no spraying) treatment, which recorded 1.32 mg g^{-1} fresh weight B2 treatment was demonstrated a statistically significant superiority over B0 and B1. In contrast, 1.35 mg g^{-1} fresh weight of chlorophyll was found in the B1 treatment. In a similar vein, the applied amino acid "tryptophan" significantly affected the trait under investigation. With the highest chlorophyll content of 1.48 mg g^{-1} fresh weight 17.5% increase over the lowest value of 1.26 mg g^{-1} fresh weight recorded by the T0 (no spraying) treatment, T3 treatment was showed a statistically significant advantage over all other treatments. Chlorophyll contents in the T1 and T2 treatments were 1.33 and 1.38 mg g^{-1} fresh weight, respectively. The findings also showed that the two research components' interaction was not found to influence the feature under investigation to a statistically significant degree (Table 3).

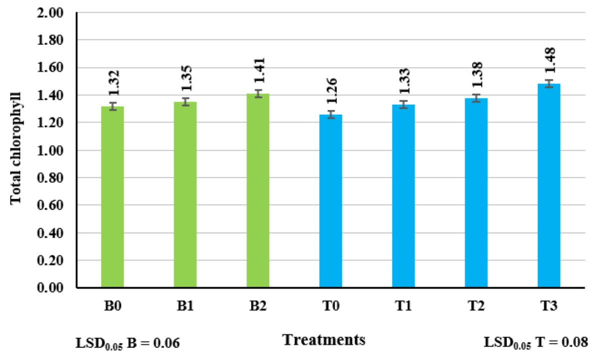

Figure (1): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) on total chlorophyll (mg g-1 fresh weight) in leaves of fig seedlings cv. Aswad Diyala.

*The error bars represent the 95% confidence intervals, calculated as ±0.066 for B0,B1 and B2, ±0.077 for T0,T1,T2 and T3.

The percentage of total carbohydrates in the branches

The results displayed in Figure (2) indicate that the branch's carbohydrate content was considerably raised by the addition of biochar to fig saplings. A statistically significant difference was observed between the B0 and B1 treatments, which were recorded with the lowest carbohydrate amounts at 14.45% and 14.91%, respectively, and the B2 treatment, which was recorded with the highest at 15.54%. Furthermore, tryptophan spraying had a statistically significant effect was observed due to tryptophan spraying on the feature under investigation, as seen by the highest carbohydrate levels in the T2 and T3 treatments (15.26 and 15.32%t, respectively). T hese results were found to be much greater than those of the T0 (no spraying) treatment, which was recorded with the lowest proportion at 14.34%. Similar trends were shown by the interactions between the two research components, particularly the B2T3 interaction, which was associated with the highest glucose content in branches (16.65%). Conversely, Table 3 shows that the B0T0 (control) therapy was yielded with the lowest recorded percentage, 13.67%.

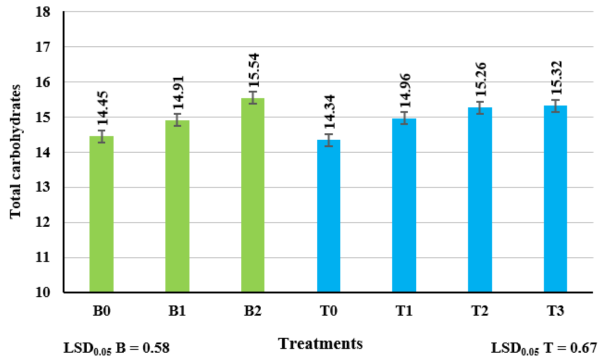

Figure (2): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) on the percentage of total carbohydrates in branches of fig seedlings cv. Aswad Diyala.

*The error bars represent the 95% confidence intervals, calculated as ±0.581 for B0,B1 and B2, ±0.671 for T0,T1,T2 and T3.

Nitrogen (%)

The statistical data presented in Figure (3) indicate that the proportion of nitrogen in leaves was substantially affected by the addition of biochar. A statistically much better performance was observed for the B2 treatment than for B0 and B1, with the greatest nitrogen percentage of 86.1%, while B1 was recorded with the second-highest value at 1.77%. At 74.1%, the nitrogen proportion was recorded as the lowest in the B0 treatment. Furthermore, the highest nitrogen percentage (1.83%) was recorded in the T3 treatment, which was found to be statistically significant in comparison to the T0 (no spraying) group, which was recorded with the lowest value (1.73%). This suggests that the trait under investigation was significantly impacted by tryptophan spraying. The T1 and T2 treatments were associated with respective outcomes of 1.79% and 1.80%. A statistically significant effect was exhibited by the interaction between the two study components, especially in the B2T3 interaction, which was recorded with the greatest nitrogen percentage at 1.94%. However, B0T3, B1T2, B2T0, and B2T2 were not found to differ significantly from one another. At 1.65%, the nitrogen concentration was recorded as the lowest in the B0T0 (control) treatment (Table 3).

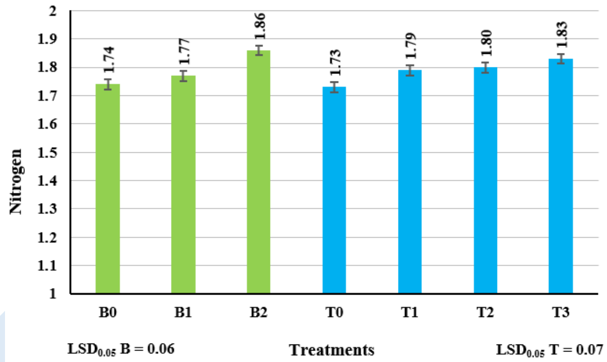

Figure (3): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) on percentage of Nitrogen in leaves of fig seedlings cv. Aswad Diyala.

*The error bars represent the 95% confidence intervals, calculated as ±0.058 for B0,B1 and B2, ±0.067 for T0,T1,T2 and T3.

Phosphorus (%)

The statistical data presented in Figure (4) indicates that the percentage of phosphorus in the leaves was considerably impacted by the addition of biochar. A statistically significant difference was shown by the B2 treatment, with the highest phosphorus percentage (0.32%) compared to B1 and B0. Phosphorus content was recorded as lowest in the B0 therapy (0.23%), and then was found to be highest in the B1 treatment (0.28%). The characteristic under investigation was significantly impacted by spraying with the amino acid "tryptophan" since the highest phosphorus percentage (0.34%) was recorded by the T3 treatment, which was found to be statistically different from all other treatments. The lowest phosphorus percentage was found in the T0 (no spraying) condition, which was at 0.20%. Although the lowest figure was yielded by the B0T0 (control) treatment, at 0.17%, a statistically significant effect was had by the interaction between the two study components, especially in the B2T3 interaction, in which the highest phosphorus percentage at 0.46% was recorded and was found to differ significantly from all other treatments (Table 3).

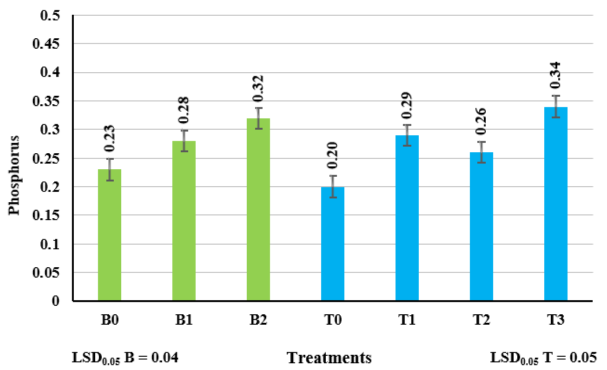

Figure (4): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) on a percentage of Phosphorus in leaves of fig seedlings cv. Aswad Diyala.

*The error bars represent the 95% confidence intervals, calculated as ±0.042 for B0,B1 and B2, ±0.048 for T0,T1,T2 and T3.

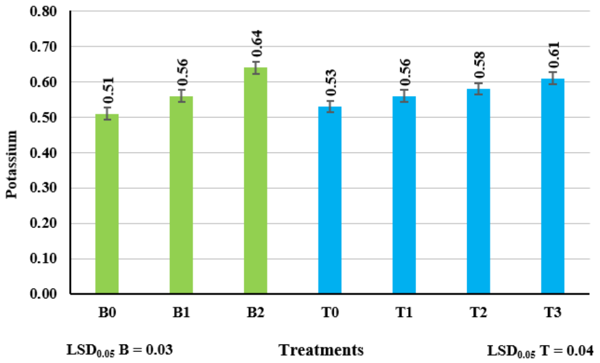

Figure (5): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) on percentage of potassium in leaves of fig seedlings cv. Aswad Diyala.

*The error bars represent the 95% confidence intervals, calculated as ±0.035 for B0,B1 and B2, ±0.040 for T0,T1,T2 and T3.

Potassium (%)

The potassium content in seedling leaves was significantly impacted by the biochar addition treatments, according to the data shown in Figure (5). In particular, a statistically significant outperformance was recorded by the B2 treatment over B1 and B0, with the greatest potassium percentage being recorded at 0.64%. The lowest percentage, at 0.51%, was recorded by the B0 (no addition) treatment, while the B1 treatment was ranked second with 0.56%. Likewise, a noteworthy effect on the trait under investigation was had by the tryptophan spray, particularly in the T3 treatment, which was shown to be statistically significantly different from T2 and T0 and was recorded as having the greatest potassium percentage. The lowest percentage, 0.53%, was recorded by the T0 (no spraying) treatment, while the T1 and T2 treatments were recorded at 0.56% and 0.58%, respectively. Particularly in the B2T3 interaction, the highest potassium percentage at 0.74% was recorded, which was found to differ considerably from all other treatments. A statistically significant effect was had by the interaction between the two research components (Table 3). In contrast, the lowest figure, at 0.47%, was produced by the B0T0 (control) therapy.

Table (3): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) in the leaf content of total chlorophyll, total carbohydrates, N, P, and K of fig seedlings cv. Aswad Diyala.

(B) Biochar	(T) Tryptophan	Treatments	Total Chlorophyll (mg g-1)	Total Carbohydrates (%)	N (%)	P (%)	K (%)
B0 (0 %)	T0 (0 mg L-1)	B0T0	1.21	13.67	1.65	0.17	0.47
	T1 (50 mg L-1)	B0T1	1.36	15.04	1.79	0.21	0.49
	T2 (100 mg L-1)	B0T2	1.32	15.23	1.67	0.23	0.56
	T3 (150 mg L-1)	B0T3	1.40	13.86	1.83	0.29	0.50
B1 (2%)	T0 (0 mg L-1)	B1T0	1.32	14.52	1.71	0.20	0.53
	T1 (50 mg L-1)	B1T1	1.27	15.06	1.77	0.31	0.55
	T2 (100 mg L-1)	B1T2	1.35	14.91	1.85	0.33	0.59
	T3 (150 mg L-1)	B1T3	1.48	15.14	1.73	0.27	0.57
B2 (4%)	T0 (0 mg L-1)	B2T0	1.26	14.82	1.82	0.24	0.61
	T1 (50 mg L-1)	B2T1	1.37	14.78	1.80	0.35	0.63
	T2 (100 mg L-1)	B2T2	1.45	15.63	1.89	0.22	0.58
	T3 (150 mg L-1)	B2T3	1.56	16.95	1.94	0.46	0.74
LSD 5%			N.S	1.16	1.12	0.08	0.06

Magnesium (%)

Figure (6) shows that a considerable effect on the magnesium percentage of fig seedling leaves was had by the addition of biochar. Both B0 and B1 were statistically outperformed by the B2 therapy, which was recorded as having the highest dry matter percentage of 0.47%. Second place was taken by the B1 therapy with 0.41%. The lowest proportion at 0.35% was recorded by the B0 treatment (no addition). Similar to this, the T2 treatment's highest percentage of 0.48%, which was statistically found to be distinct from all other treatments, demonstrated that a significant impact on the trait being studied was had by tryptophan spraying. With the lowest proportion (0.36%), the T0 (no spraying) treatment was followed by the T1 and T3 treatments. A statistically significant effect was found between the two study components, especially in the B2T2 interaction, in which the highest percentage at 0.55% was recorded with no discernible difference from B0T3 and B2T3. In contrast, the lowest figure, at 0.28%, was yielded by the B0T0 (control) treatment (Table 4).

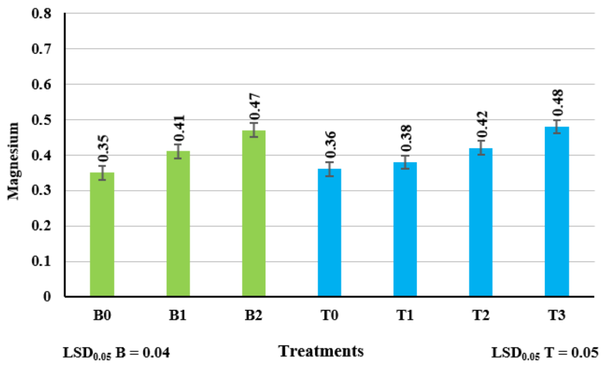

Figure (6): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) on a percentage of magnesium in leaves of fig seedlings cv. Aswad Diyala.

*The error bars represent the 95% confidence intervals, calculated as ±0.047 for B0,B1 and B2, ±0.055 for T0,T1,T2 and T3.

Calcium (%)

Figure (7) indicates that no discernible effect on the proportion of calcium in the fig seedlings' leaves was had by the addition of biochar. However, a major effect on the trait being examined was had by tryptophan spraying. A statistically significant advantage over T0 and T1 was shown by the T3 therapy with the highest percentage (1.30%). With respective outcomes of 1.22% and 1.29%, the T1 and T2 treatments were followed by the T3 treatment. However, the lowest proportion, at 1.16%, was recorded by the T0 (no spraying) treatment. A statistically significant effect was had by the interaction between the two components of the study, particularly in the B2T3 interaction, in which the highest percentage (1.39%) was recorded and was found to be significantly different from all other options. At 1.13%, the lowest value ever seen was yielded by the B0T0 (control) treatment (Table 4).

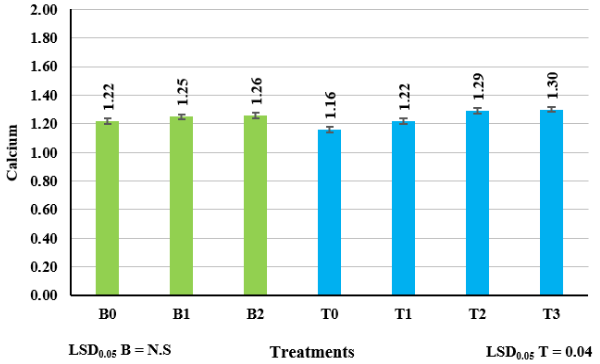

Figure (7): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) on percentage of calcium in leaves of fig seedlings cv. Aswad Diyala.

*The error bars represent the 95% confidence intervals, calculated as ±0.041 for B0,B1 and B2, ±0.047 for T0,T1,T2 and T3.

Iron content of leaves (mg kg^{-1})

The addition of biochar was indicated by the statistical data in Figure (8) to have had a considerable effect on the iron content of leaves. With a higher iron concentration of 169.37 mg kg^{-1}, a statistically significant difference from B0 was shown by the B2 treatment, in which the lowest iron level (153.17 mg kg^{-1}) was recorded. 166.35 mg kg^{-1} was then detected by the B1 treatment. Compared to T0 and T1, the highest iron concentration (171.01 mg kg^{-1}) was exhibited by the T3 treatment, a statistically significant difference that suggests the feature being studied was significantly impacted by tryptophan spraying. Then came the T1 and T2 treatments, with values of 158.89 mg kg^{-1} and 165.85 mg kg^{-1} being recorded, respectively. Iron levels were recorded as lowest in the T0 (no spraying) condition at 156.01 mg kg^{-1}. A statistically significant effect was found in the interaction between the two study components, especially in the B2T3 interaction, in which the highest iron level (178.21 mg kg^{-1}) was recorded with no noticeable difference from B1T2, B1T3, and B2T1. The B0T0 (control) treatment, on the other hand, yielded the lowest amount, measured as 142.86 mg kg^{-1} (Table 4).

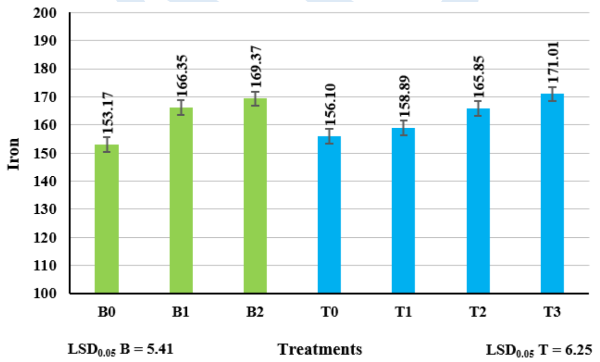

Figure (8): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) on Iron content (mg kg^{-1}) in leaves of fig seedlings cv. Aswad Diyala.

*The error bars represent the 95% confidence intervals, calculated as ±5.414 for B0,B1 and B2, ±6.251 for T0,T1,T2 and T3.

Zinc content of leaves (mg kg^{-1})

The addition of biochar was indicated by the statistical data in Figure (9) to have had a substantial effect on the zinc concentration of leaves. With a zinc concentration of 44.94 mg kg^{-1}, the B2 treatment was shown to be the most zinc-rich and was found to differ statistically significantly from the other treatments. The lowest zinc level was found in the B1 treatment (35.45 mg kg^{-1}) and was also recorded in the B0 (no addition) treatment (31.72 mg kg^{-1}). With the highest zinc level of 43.37 mg kg^{-1}, the T3 therapy was found to differ significantly from the others. Likewise, the trait being examined was significantly impacted by tryptophan spraying. Zinc levels in the T1 and T2 treatments were gradually decreased to 34.30 mg kg^{-1} and 38.65 mg kg^{-1}, respectively, whereas the T0 (no spraying) treatment was shown to have the lowest result at 33.16 mg kg^{-1}. A statistically significant effect was exhibited by the interaction between the two research components, especially in the B2T3 interaction, in which the greatest zinc concentration in leaves (58.28 mg kg^{-1}) was documented and was found to differ significantly from all other treatments. On the other hand, the B0T0 (control) treatment was shown to have yielded the least quantity ever recorded, at 27.48 mg kg^{-1} (Table 4).

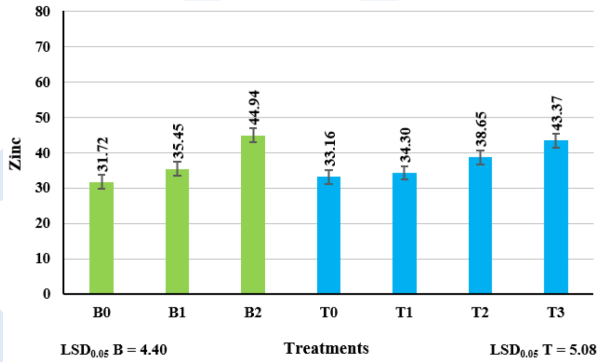

Figure (9): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) on Zinc content (mg kg^{-1}) in leaves of fig seedlings cv. Aswad Diyala.

*The error bars represent the 95% confidence intervals, calculated as ±4.395 for B0,B1 and B2, ±5.075 for T0,T1,T2 and T3.

Manganese content of leaves (mg kg^{-1})

The data displayed in Figure (10), however, were found to indicate that the addition of biochar had been associated with a considerable effect on the manganese concentration of seedling leaves. With the highest manganese concentration (65.91 mg kg^{-1}) compared to the lowest (59.21 mg kg^{-1}) in B0, a statistically significant difference was observed. 62.23 mg kg^{-1} was recorded as the intermediate value for the B1 therapy. The feature being studied was likewise strongly impacted by tryptophan spraying; the T3 treatment was shown to have the highest manganese content (65.35 mg kg^{-1}), while the T0 treatment was found to have the lowest concentration (57.76 mg kg^{-1}). Manganese concentrations were reduced to 64.14 mg kg^{-1} with T1 treatment and 62.56 mg kg^{-1} under T2 treatment. Except for B0T2, B1T2, B1T3, B2T0, and B2T1, all other treatments were shown to differ significantly from the B2T3 interaction, in which the highest manganese level (70.42 mg kg^{-1}) was recorded. This interaction was found to be statistically significant. However, the B0T0 (control) treatment was found to have yielded the lowest value, with a total of 53.28 mg kg^{-1} as shown in Table 4.

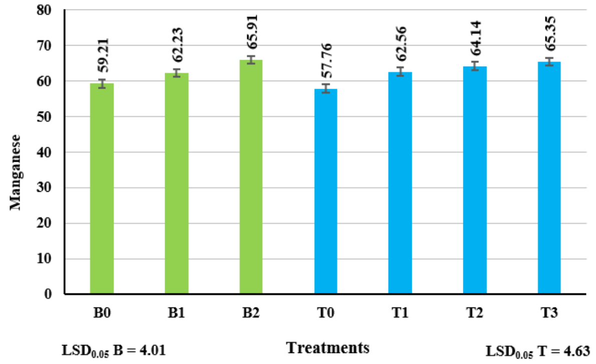

Figure (10): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) on manganese content (mg kg^{-1}) in leaves of fig seedlings cv. Aswad Diyala.

*The error bars represent the 95% confidence intervals, calculated as ±4.009 for B0,B1 and B2, ±4.629 for T0,T1,T2 and T3.

Table (4): Effect of adding biochar (B0 0%, B1 2%, and B2 4%) and spraying with Tryoptophan (T0 0, T1 50, T2 100, and T3 150 mg L^{-1}) in the leaf content of Mg, Ca, Fe, Zn, and Mn of fig seedlings cv. Aswad Diyala.

(B) Biochar	(T) Tryptophan	Treatments	Mg (%)	Ca (%)	Fe (mg kg-1)	Zn (mg kg-1)	Mn (mg kg-1)
B0 (0 %)	T0 (0 mg L-1)	B0T0	0.28	1.13	142.86	27.48	53.28
	T1 (50 mg L-1)	B0T1	0.32	1.17	148.63	31.34	56.84
	T2 (100 mg L-1)	B0T2	0.32	1.31	156.71	35.67	65.15
	T3 (150 mg L-1)	B0T3	0.47	1.27	164.47	32.39	61.58
B1 (2%)	T0 (0 mg L-1)	B1T0	0.43	1.19	163.95	29.94	53.87
	T1 (50 mg L-1)	B1T1	0.36	1.27	155.89	38.86	62.32
	T2 (100 mg L-1)	B1T2	0.40	1.30	175.20	33.56	68.79
	T3 (150 mg L-1)	B1T3	0.45	1.25	170.35	39.43	64.05
B2 (4%)	T0 (0 mg L-1)	B2T0	0.38	1.15	161.48	42.05	66.13
	T1 (50 mg L-1)	B2T1	0.46	1.22	172.16	32.71	68.51
	T2 (100 mg L-1)	B2T2	0.55	1.26	165.64	46.72	58.47
	T3 (150 mg L-1)	B2T3	0.51	1.39	178.21	58.28	70.42
LSD 5%			0.10	0.08	10.83	8.79	7.02

Discussion

The addition of Reed biochar to the growing media may have been attributed to the increase in chlorophyll, carbohydrates, and macro- and micronutrient content (except the percentage of calcium in leaves) of fig seedlings Aswad Diyala cv. By doing this, plants are enabled to improve their photosynthetic process and produce more carbohydrates, which can be used to supply the energy required for vegetative development. Furthermore, by encouraging the growth of roots and lengthening them-especially those involved in nutrient absorption-biochar is played a critical role in boosting plant activity. According to [33], this therefore is found to have had a favorable effect on the quantity of mineral nutrients that are taken up by the roots and accumulate in different plant tissues. Additionally, biochar can be used to enhance the physical and chemical characteristics of soil, particularly by lowering pH and boosting nutrient availability [34]. Moreover, it is known to prevent nutrients-especially phosphorus-from being precipitated or fixed with calcium carbonate by being retained and delivered to plants gradually as needed [35]. As a result, the soil solution is made to contain more phosphorus, which is found easier to be absorbed by plant roots and eventually promotes plant development [36,37]. Furthermore, nitrogen, phosphorous, potassium, and zinc-all vital elements for plant growth-are found to be present in sugarcane biochar (Table 2). These components are assigned several functions in plant feeding. For instance, the creation of energy molecules like ATP, NADPH, and $NADPH_2$ as well as nucleic acids (DNA and RNA) is dependent on nitrogen [38]. Moreover, it is directly used to aid in the synthesis of amino acids, which are known to encourage cell elongation and division. Since nitrogen is required to speed up cell division and elongation, which results in larger leaves, it is needed for the majority of biochemical processes in plants [39,40]. Furthermore, because nitrogen is involved in the contribution to the creation of porphyrin units, which are known to be essential to the structure of chlorophyll, it is considered essential for the biosynthesis of chlorophyll [41,42]. In the end, this is found to increase the photosynthetic rate, which is known to cause leaves to produce more carbohydrates. Phosphorus is significantly contributed to the formation of meristematic tissue, cell division, photosynthesis, photosynthetic product translocation, and enzymatic system activation [43]. Furthermore, phosphorus is known to aid in the synthesis of high-energy molecules that are required for the synthesis of other substances including phospholipids, carbohydrates, and enzyme cofactors, all of which are found to promote biochemical reactions and are known to boost vegetative development [44]. In contrast, potassium is considered an essential component of numerous metabolic activities, such as photosynthesis and the metabolism of carbohydrates, and it is used as a cofactor in the creation of proteins and chlorophyll [45,46]. Additionally, it is used to improve stomatal opening by being responsible for raising guard cells' osmotic potential, which is known to facilitate nutrient passage through leaves and is found to promote vegetative development [47]. Furthermore, potassium is found to facilitate water uptake and, as a result, is known to increase leaf area by being involved in establishing low osmotic pressure in the cell vacuole [48]. Zinc is regarded as essential for several cellular processes including the construction of plasma membranes. It is known to shield plant cells from oxidative damage and is found to improve the plant's capacity to absorb various nutrients from the soil [49]. Additionally, zinc is used to aid in the production of chlorophyll and tryptophan, an amino acid that is regarded as a precursor to indole-3-acetic acid (IAA), a crucial hormone that is found to promote cell elongation and higher photosynthetic efficiency [50]. In particular, zinc is used to serve as a cofactor for the carbonic anhydrase enzyme, which is known to promote photosynthesis and is found to increase the production of energy compounds and carbohydrates in leaves [51]. As a result, the amount of chlorophyll and leaf area is found to increase overall. Moreover, zinc is found essential for improving root nutrient uptake efficiency, which is shown to have a favorable effect on vegetative development. Additionally, it is known to have a direct impact on sugar transformation mechanisms and is found to affect glucose metabolism at several levels [52].

The results of the study show that all chemical parameters were significantly impacted when fig seedlings (Aswad Diyala cultivar) were treated with foliar tryptophan. Because nutrients are more quickly absorbed into plant cells through stomatal penetration, the epidermis, or wounds, foliar fertilization is promoted for fast nutrient transport. This is improved for metabolic functions, is guaranteed for a steady supply of nutrients, and eventually is encouraged for vegetative development [53]. The enhanced chlorophyll concentration in leaves, which is known to speed up the photosynthetic rate and increase the generation of carbohydrates, may be caused by tryptophan's beneficial effects. Following their translocation to all plant organs, including the roots, these carbohydrates are used to promote the growth of the plants and increase the effectiveness of their nutrient intake [54]. Additionally, tryptophan is considered an essential part of proteins and several cofactors for enzymes. Additionally, it is used to function as a biological precursor in the manufacture of the important hormone indole-3-acetic acid (IAA), which is controlled for the growth and development of plants. IAA is regarded as essential for cell elongation and expansion because cell walls are made more elastic and flexible, which enables cells to grow and be able to take in more nutrients and water [55,56]. In addition to aiding in the synthesis of proteins, auxins are found important for the movement of nutrients from the plant's sites of synthesis to those for use or storage. Auxins also are used to stimulate responses to tropisms, root formation, vascular tissue differentiation, and cell division. By preventing lateral bud formation due to their high concentration in shoot apices, they are found to prolong leaf senescence and be used to control apical dominance [57]. Auxins also are used to promote cell growth by altering the transcription and translation of genes, which is found to result in increased synthesis of RNA and proteins. Additionally, they are found to increase cell growth by being involved in breaking and rearranging cell wall connections under turgor pressure, which is used to promote cell wall flexibility. According to [58], meristematic cell division is promoted by auxins, which is found to raise plant height, leaf area, and vascular cambium expansion. By suppressing or lowering chlorophyllase activity, IAA also is used to stop the breakdown of chlorophyll [59]. Furthermore, by altering the activity of cytokinin oxidase enzymes, which are used to regulate cytokinin homeostasis during several developmental phases, auxins are known to influence the amounts of cytokinin in different plant tissues [60]. Apical dominance and lateral bud suppression are facilitated by the auxin-mediated control of cytokinin levels, which is accomplished by cytokinin oxidase or adenosine phosphate-isopentenyltransferase (IPT) enzymes. On the other hand, when given externally, cytokinins are known to reverse the effects of auxin and be used to encourage the formation of lateral buds [61]. Tryptophan is found as one of the amino acids that is used to activate the plasma membrane-based enzyme H^+-ATPase, which is considered essential for food absorption and translocation across xylem and phloem [21]. By increasing enzyme activity, improving root respiration, and providing the energy required for active nutrient absorption, greater root growth is promoted and, eventually, increased nutrient accumulation within the plant is achieved [62]. Tryptophan applied topically also is found to increase the availability of macro- and micronutrients, increasing the efficiency of photosynthesis in leaves. By triggering important photosynthetic enzymes, nutrients are found to affect carbon dioxide fixation in green plant cells, promoting plant growth and the development of new cells and tissues [63]. The main structural elements of plant tissues are made from the monosaccharides produced during photosynthesis [64]. Additionally, applying amino acids topically often is used to make plants more resilient to a range of biotic and abiotic stressors. Additionally, amino acids are used to aid in the synthesis and activation of a wide variety of enzymes and their cofactors, which is used to improve the uptake of vital nutrients from the growth media by plants [65].

Conclusions

A positive response was exhibited by the fig seedlings of the Aswad Diyala cultivar to the addition of sugarcane biochar, particularly at the higher concentration B2 (4%), which was resulted in the best values for all studied traits, except for leaf calcium content. It was also demonstrated by the experiment that all measured traits were significantly influenced by foliar application of the amino acid tryptophan, with the T3 concentration (150 mg L^{-1}) being yielded the highest values for most studied parameters. Furthermore, a significant increase in all measured traits, except for leaf area and chlorophyll content, was led by the interaction between the two experimental factors. The most favorable results were produced by the interaction treatment (B2T3), depending on the specific trait studied. Based on these findings, the application of sugarcane biochar and foliar spraying with tryptophan on fig seedlings Aswad Diyala cv., particularly at their higher concentrations, is recommended to enhance growth and physiological performance.

- ## Disclosure Data

  Ethics approval and consent to participate: The authors confirm that they respect the publication's ethics and consent to their work's publication
- **Consent for publication:** The authors consent to the publication of this work.
- **Author's contribution:** AFZA was responsible for creating the initial research idea and collecting the literature review to achieve the final idea for this research, as well as performing statistical analysis after collected data to investigate the effect of individual factors solely or interaction between them, moreover comprehensive reading for the final manuscript. AYMA carried out the experiment, data collection, and interpretation of results; moreover, the initial writing of the manuscript also compared the findings with the literature and made the conclusions built into the output of this research.
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