AMERICAN JOURNAL OF BIODIVERSITY
https://biojournals.us/index.php/AJB
ISSN: 2997-3600

Article

Effect of Humic Adding and Foliar Application with Licorice Extract and Organic Matter on Growth and Yield of *Hibiscus sabdariffa* L.

Moeassar Awad Abdullah
Horticulture and Landscape Engineering Department, College of Agriculture, University of Tikrit, Tikrit, Iraq
Email: Ma.alabedy2017@tu.edu.iq

Citation: Abdullah, M. A. Effect of Humic Adding and Foliar Application with Licorice Extract and Organic Matter on Growth and Yield of *Hibiscus sabdariffa* L. American Journal Of Biodiversity 2026, 3(11), 1-13

Received: 13th Aug 2026
Revised: 28th Sep 2026
Accepted: 15th Oct 2026
Published: 22th Nov 2026

Copyright: © 2026 by the authors. Submitted for open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/)

Abstract: In this research, it explored the impact of humic acid, organic matter, and licorice extract on the growth, yield, and biochemical attributes of Hibiscus sabdariffa L. under controlled conditions. A two-level factor experiment was carried out; the levels of humic acid were 0 and 2 mL/L, foliar licorice extract levels were 0 and 10 g/L, and the level of organic matter was 0 and 10 percent. It was revealed that vegetative characteristics, production of the capsules and chemical content were affected by all treatments and their interactions significantly.The greatest quantity of capsules (308.7) and capsule weight (2019 g/plant) were observed in used combination of 10 per cent organic matter and 10g/L licorice extract. The height of plants also showed a considerably large that ranged to 159cm in certain combinations. The treatments increased macronutrient proportions (N, P, K) in the sepals with nitrogen proportions up to 2.72%. Besides, protein content (up to 17%), glycosides (25.64%), saponins (4.84%), flavonoids (74.4%), and terpenes (16.6 mg/100g) increased significantly.The results also reflect the synergy in the application of natural biostimulants in the development of the roselle plant in terms of growth, yield, and nutritional quality. The researchers advise the incorporation of humic acid, licorice extract, and organic matter among the eco-friendly instead of chemicals to be used to cultivate Hibiscus sabdariffa L.

Keywords: Hibiscus sabdariffa L., humic acid, organic matter, licorice extract, growth, yield, phytochemicals, sustainable agriculture.

Introduction

Hibiscus (Hibiscus sabdariffa L.), is a member of the Malvaceae family, It It is a herbaceous plant that grows all year and is commonly grown in many places, including Central America, Asia, and Africa,. Roselle calyx infusions have been studied for their chemical and antioxidant properties [1]. Roselle beverages also feature in accounts of traditional drinks [2]. The plant has beautiful leaves and the flowers and may grow to a height of two metres. Hibiscus is regarded as an important food crop due to its nutritional value, rich pigment content, and medicinal properties [3]. Many Hibiscus components, including leaves, seeds, fruits, and roots, are used in the medicinal and food industries. The most important economic element of the Hibiscus is its calyx, which is the fleshy, brilliant red cup-like structure of the flower. Hibiscus calyxes are used to make a variety of food products, including wine, jam, ice cream, chocolates, puddings, cakes, and herbal drinks [4]. Extraction of phenolics from roselle calyces has also been investigated [5]. The hibiscus calyx is sold either dry or fresh, and it is recognized

to have therapeutic biological qualities such as antihypertensive, diarrheal, and anticancer effects [6]. Hibiscus leaves have also been utilized to boost overall health and well-being, such as a digestive aid and diuretic [7].

Roselle contains nutrients and bioactive compounds such as flavonoids [8]. Also, calyx includes a high pigment content and is a natural source of food colorants [9].

Given the current awareness of the financial and ecological harm caused by the overuse of chemical fertilizers in agriculture, it is advisable to look into viable alternatives. It is evident that mineral fertilizers increase plant growth, but they also have detrimental effects on the environment, animals, and human health [10].It is possible to increase production by using natural fertilizers, such as humic acid, that do not have detrimental impacts on biological systems. As a result, the new tendency is to partially replace mineral fertilizers with more environmentally friendly compounds like humic acid. Abdou et al. investigated soil media and growth regulators in ryegrass [11]. Maibodi et al. investigated foliar humic acid in the same species [12]. El-Sayed et al. examined humic acid under different irrigation regimes in seashore paspalum [13]. Desoky et al. evaluated humus materials in Sudan grass under salinity stress [14]. Abdou et al. studied compost and humic acid in gazon grass [15]. Sharifiasl et al. examined Bermuda grass under salinity stress [16]. Humic acid application has harmless effects, making it effective and easy for farmers to implement. Humic acids play an important function in the growth and productivity of Hibiscus sabdariffa L. plants, possibly because they aid in rectifying plant chlorosis, increasing the permeability of plant membranes, and intensifying plant enzyme systems [17]. Organic acids are frequently used to increase the quality and quantity of agricultural products because they contain harmonic compounds that have beneficial effects on crop productivity and agricultural product quality. Humic acid, an environmentally friendly fertilizer, is regarded as one of the most essential organic fertilizers since it promotes plant development and boosts nitrogen, potassium, calcium, magnesium, and phosphorus absorption. It is regarded as a great stimulator and carrier for foliar nutrients. It promotes plant growth by absorbing major and minor nutrients, activating enzymes, altering membrane permeability, producing proteins, and initiating biomass production [18].

Humic acid promotes soil organism growth, improves soil physical conditions, and regulates media pH. It also has an enzymatic and hormonal impact on plant development. Humic compounds boost plant resilience to environmental challenges such as drought and salinity, seed germination, and root growth, resulting in increased crop quantity and quality [19].Plant extracts, such as licorice extract, can have similar effects on plant roots and vegetative development qualities. This plant includes various sweet-tasting chemical compounds, including gleserezin, glycyrrhizin, and licorice acid constituents like glabridin and glaring. These substances contain a variety of elements and nutrients and, like growth regulators, boost the vegetative and blooming features of diverse plants. Licorice extract can reduce water loss by slowing transpiration, limiting cellular evaporation, and maintaining cellular fullness [20].

Literature Review

Roselle (Hibiscus sabdariffa L) is a rapidly growing herbaceous plant that is used to produce calyces rich in phytochemicals and nutrients especially in subtropical and tropical areas. The plant is regarded as a source of antioxidant, antihypertensive, and antimicrobial properties because of the abundance of flavonoids, phenolics, tannins, and organic acids [1]. These are some of the compounds that make it have medicinal and nutritional value, mostly in herbal infusions and functional beverages [21]. Nutritional and functional properties have also been reported for roselle seed products [22]. Roselle is rich in both macro- and micronutrients, like calcium, iron, and vitamin C, as well as is famous because of a group of bioactive secondary metabolites [3]. Dhar et al. [6] state that seeds of Hibiscus sabdariffa are as well highly nutritious and industrial value, which are due to the presence of essential fatty acids and bioactive oils in the seeds.

Humic substances, many in form of humic acid, have been identified to be good amendments in the soil and they lead to an improved performance of the plant. A number of studies also indicate that humic acid increases nutrient uptake, chlorophyll concentration, root growth, and crop productivity [18]. The humic acid foliar application improved the most important growth parameters and nutrient accumulation in perennial ryegrass considerably [12]. Likewise, the study also indicated improved turfgrass height and quality with humic acid irrigation [13] also indicating the positive influence on

plants in terms of physiology and stress tolerance. Humic acid also boosts the microbial activity and structure in the soil thus boosting root penetration and availability of nutrients [23]. Rauthan and Schnitzer [24] have suggested that humic acid operates by raising the permeability of cell membranes and provoking plant hormone-like activities, e.g. root extension and shoot biomass development. The physical, chemical, and biological properties of soil are enhanced by organic matter. Applying compost and animal manure improves crop quality and yields by increasing microbial populations, water-holding capacity, and macro- and micronutrient availability [15]. Additionally, organic amendments increase a plant's resistance to abiotic stressors like drought and salinity [16]. The importance of organic fertilization for long-term soil fertility and crop sustainability was highlighted by Raslan [25] and Al-Sahhaf [26]. Additionally, organic matter-derived humic substances function as natural chelating agents, improving the solubility and absorption of vital nutrients such as potassium and phosphorus [19].

Glycyrrhizin, flavonoids, and other phytochemicals found in licorice (Glycyrrhiza glabra) extract function as organic growth promoters [27]. Al-Sahhaf and Al-Marsoumi examined foliar licorice extract in onion seed production [28]. By adjusting endogenous hormone levels, it encourages root development, flowering, and fruiting. In drought conditions, licorice extract has also been demonstrated to decrease transpiration and increase water-use efficiency [20].

Licorice extract's high concentration of bioavailable nutrients and secondary metabolites has been shown to improve vegetative growth in a number of crops when applied topically. As a result, it presents a viable natural substitute for artificial growth regulators [28]. Although the combined effects of humic acid, organic matter, and licorice extract on Hibiscus sabdariffa L. have not been thoroughly investigated, individual applications have yielded encouraging outcomes. For example, Andzi Barhé and Feuya Tchouya [4] reported strong antioxidant activity in Hibiscus calyces linked to the plant's biochemical response to environmental inputs, while Mohammedamin and Kanimarani [17] reported increased growth and productivity of Roselle under humic acid treatments.Combining organic fertilizers with natural stimulants like licorice extract and humic acid may maximize nutrient availability and improve yield and quality. This strategy is in line with sustainable farming methods that reduce the use of synthetic fertilizers and enhance environmental protection [23].

Materials and Methods

Data Collection

Field design and Experimental design

The data was recorded in a controlled field experiment in which the effect of humic acid supplementation, foliar application of licorice extract and organic matter extract on growth and yield of hibiscus sabdariffa L. was to be examined. Experimentation was carried out in the 201718 agricultural season of a privately owned farm in Salah AlDin Governorate in Iraq. The study was based on a factorial experiment under Completely Randomized Block Design (CRBD) using a three replicate per combination of treatments.

The research area was chopped into 24 initiating squares which were 4 m 2 measurements in size composed of three rods with a roving room of 75 cm and an isolate layover of 25 cm. This system had the capacity to hold 576 plants (24 plants on one unit and 24 units). On April 25, 2017, seeds were planted and most standard agricultural activities like irrigation, weeding, and pest control were used during the growing period.

Treatment Combinations

There were three sets of independent variables (factors) and each of them had 2 levels. These variables have been combined in all possible combinations and there was a total of 8 combinations of treatment. The levels and solutions to the treatments are explained in the table below:

Table 1. The levels and solutions to the treatments

Factor	Level 1	Level 2
Humic Acid (H)	H1: 0 mL/L	H2: 2 mL/L via irrigation water
Licorice Extract (G)	G1: 0 g/L	G2: 10 g/L foliar sprayed
Organic Matter (F)	F1: 0% animal manure	F2: 10% organic matter extract

The licorice extract was applied twice in growing season, which means that the first application occurred three months after planting and the second one during one month. The application was applied early in the morning, before the high temperatures to ensure the application was not highly subjected to high temperatures and a wetting agent was added so as to enhance adherence and penetrate the solution.

Observations and Sampling of Five plants were chosen at random from each experimental unit in order to gather data. Several growth and yield metrics, such as plant height, number of capsules per plant, and average capsule weight, were evaluated using these plants. As a result, 120 plants (5 plants × 24 units) were examined for morphological characteristics.

Samples of the calyx and leaves were gathered at harvest and prepared for chemical examination. The samples were ground into a fine powder using a mechanical grinder, oven-dried at 60°C until they reached a constant weight, and then sieved through mesh sizes ranging from 0.15 to 0.50 mm.

Measured variables and lab techniques

The measurement of macronutrients (potassium, phosphorus, and nitrogen) and phytochemical components (protein, glycosides, saponins, flavonoids, tannins, terpenes, and total phenolic content) was the main focus of the chemical analysis. The techniques employed were derived from established protocols found in earlier research:

In accordance with Al-Sahhaf [26], nitrogen (%) was calculated using the Kjeldahl method. In accordance with John [29], phosphorus (%) was calculated colorimetrically using ascorbic acid and ammonium molybdate.

A flame photometer was used to measure the percentage of potassium.

The methods for glycosides, flavonoids, tannins, alkaloids, and terpenes are described below. The nutritional and biochemical status of the plants under various treatment conditions was assessed by measuring these parameters.

Data Processing

Drying and Sample Preparation

Samples were taken of the five plants chosen in each of the 24 experimental units after the plants matured. The gathered plant materials consisted of calyces and leaves and these were handled at once to be subjected to laboratory analysis. Oven-drying was done at 60 o C until constant weight was obtained to ensure uniformity of the plant materials. This drying process was necessary in order to remove differences in moisture on the one hand and to standardize the weight measurements.

After being dried the samples were reduced to fine powder by means of an electric mechanical grinder and sieved with mesh openings of 0.15 mm2 to 0.50 mm2. This gave a consistent particle size needed in order to do consistent digestion and chemical analysis.

Nutrient Analysis Digestion

An analytical grade mixture of concentrated sulfuric acid (H 2 SO 4) and perchloric acid (H Cl O 4) was used to digest the processed plant samples. This digestion procedure was done under this guideline as revised by the Cresser and Parsons [30] when organic matter was allowed to breakdown and the bound nutrients released to be analyzed.

The filtered solutions were then ready to be determined to have the main macronutrients of nitrogen (N), phosphorus (P), and potassium (K).

Nitrogen Analysis

The Kjeldahl method, a typical protocol in plant nutrition research was used in estimating the nitrogen level in the digested samples. This procedure follows three consecutive steps:

The plant sample to be digested in order to convert nitrogen into the ammonium sulfate one.The ammonia so formed was distilled off.Titration to determine the level of nitrogen.The described technique was used according to the procedure which was described by Al-Sahhaf [26].

Phosphorus Analysis

The measurement of phosphorus was performed with Spectronic 205 spectrophotometer in the mode of 620 nm wavelength. The measurement was predicated on the formation of a blue-colored complex in the digested solution as a result of the reaction of ascorbic acid and ammonium molybdate with phosphate. The concentration of phosphorus is directly correlated with the blue color's intensity. This approach was based on the method of John [29].

Potassium Analysis

A flame photometer (Model: DR.) was used in measuring the content of potassium in the samples. Hearing words of love, Lang (60 M) heard. The apparatus uses the intensity of potassium ions emission when the sample under analysis is atomized in a flame. The procedure employed was in line with that done by Al-Sahhaf [26].

Phytochemical Processing

In order to analyze secondary metabolites and biologically active compounds in Hibiscus sabdariffa, a series of phytochemical tests was conducted, the validated methods of the literature were used:

The total Glycosides were measured according to Tofighi et al. [31].

Total phenolics were estimated using the Folin–Ciocalteu colorimetric assay with gallic acid as the standard.

The methodology used to establish flavonoids was the one found in the paper of Baba and Malik [32].

Tannin content was measured.

After the method suggested by Ghorai et al. [33], the analysis of the terpenes was conducted.

The above estimation makes use of the classical measurement of Evans [34] on gravimetric analysis of alkaloid.

Chemical analyses were done under controlled laboratory environments meaning that the results could be reliable and reproducible.

Analysis of Data

The results of field and laboratory measurements were statistically interpreted to clarify the importance of the changes of the three major factors of treatment such as the addition of the humic acid, licorice extract in the foliar spray, and organic matter extract in the Hibiscus sabdariffa L. growth, yield, and biochemical composition.

The design of statistics and structures of experiments

The experiment design was a factorial replica in Completely Randomized Block Design (CRBD) in three replications of the treatment combinations which were eight. In this design, it was possible to evaluate the following:

The individual main effects (F, G, H),

Two-way interactions (F x G, F x H, G xH),

Three-way interaction F x G x H

on every one of the variables measured.

For growth and yield parameters, a sample size of 120 plants was obtained from the analysis of 24 treatment plots (8 treatment combinations × 3 replicates), each of which had five sampled plants.

Data Averaging and Data Compilation

The measurements of the 5 plants in a given treatment unit were averagely used as a representation of that unit, in each parameter, e.g., plant height, number of capsules, quantity of nutrients. These averages were in turn utilized in the analysis so that the effect of individual plant variability did not macroize treatment effect.

Analysis of Variance ANOVA

Analysis of Variance (ANOVA) was performed on the data collected to establish whether or not the treatment effects would be significant at the probability level of 5 percent (p 0.05) or not. The following was taken into consideration in the analysis:

Factorial treatment design (2 x 2 x 2)

Replication as the random block effect

The interaction among the factors of treatment

The importance of the differences between means provided was evaluated with the Least Significant Difference (LSD) test, which is obviously reported in each table in all factors and interactions. For example:

In Table 1 (capsule number) LSD values were:

Main effects (F, G, H) =18.82

F (X G and other two way interactions) = 26.61

The three way interaction (F x G x H) = 37.63

The same strategy was applied to all the traits, morphological (height), yield (capsule weight), chemical (N, P, K, protein, glycosides, etc.).

Interpretation Approach

The importance of the treatment effects was determined with reference to:

1. Whether the levels of the mean differences between treatments were higher than the LSD values thus indicating that there is a statistically significant effect.
2. Any change in the data to determine which combinations gave the greatest number of good results.
3. Influence of individual as compared to interactive effect on complex traits.

With the help of the analysis, we have had an in-depth idea of how the interaction of natural inputs influenced the development and chemical quality of roselle plants, and we could also come to some conclusions regarding the best fertilizing rates.

Results

The experiment assessed how Hibiscus sabdariffa L. growth, yield, and biochemical composition were affected by the application of humic acid, foliar spraying with licorice extract, and the addition of organic matter. The majority of the measured parameters were significantly impacted by all three factors and their interactions, according to the analysis of variance.

The quantity of capsules in each plant

All of the major factors and their interactions had a significant impact on the number of capsules per plant. The treatment combination F2 × H1 × G1 (10% organic matter, 0 mL/L humic acid, and no licorice extract) produced the most capsules (308.7 per plant), while F1 × H2 × G1 produced the fewest, 133.7 capsules per plant.Table 2 summarizes the average number of capsules under each treatment.

Table 2. Impact of Treatments on Plant Capsule Count

Organic Matter (F)	Humic Acid (H)	Licorice Extract (G)	Number of Capsules
F1 (0%)	H1 (0 mL/L)	G1 (0 g/L)	148.3
F1	H1	G2 (10 g/L)	290.0
F1	H2 (2 mL/L)	G1	133.7
F1	H2	G2	166.0
F2 (10%)	H1	G1	**308.7**
F2	H1	G2	199.7
F2	H2	G1	141.0
F2	H2	G2	240.5

In comparison to the control, the application of organic matter increased the number of capsules by 20.6% and the amount of licorice extract by 22.5%. It's interesting to note that humic acid application by itself (H2) did not always increase capsule production, indicating that its impact might rely on how it interacts with other elements. Figure 1 shows the significant variation in the number of capsules per

plant across treatment combinations.

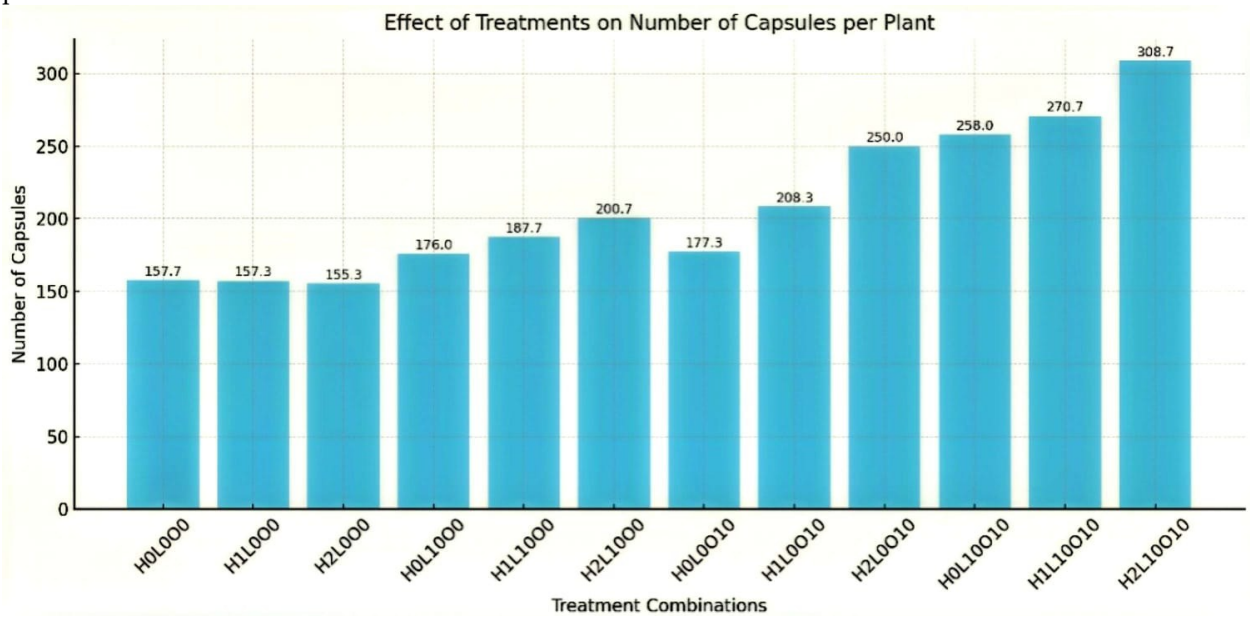

Figure 1. The number of capsules per Hibiscus sabdariffa plant under various combinations of licorice extract (L), humic acid (H), and organic matter (O) is displayed in a bar chart in

Weight of Capsules

The weight of the capsules responded strongly to the treatments that were used. Under F1 × H1 × G2, the lowest capsule weight was 608 g/plant, while the highest was 2019 g/plant. According to the data in Table 3, every factor increased the mass of the fruit.

Table 3. Treatment Impact on Capsule Weight (g)

F	H	G	Capsule Weight (g)
F1	H1	G1	608
F1	H1	G2	**2019**
F1	H2	G1	840
F1	H2	G2	1246
F2	H1	G1	1577
F2	H1	G2	1391
F2	H2	G1	1581
F2	H2	G2	1622

The weight of the capsules increased by 30.9% when organic matter was added, and by 36.2% when licorice extract was applied topically. This parameter was slightly impacted by the humic acid.

Height of Plants

The F2 × H2 × G1 group had the tallest plants (159.0 cm), although plant height varied greatly among treatments. F1 × H2 × G1 had the shortest plants (127.7 cm).

Table 4. Treatment Impact on Plant Height (cm)

F	H	G	Plant Height (cm)
F1	H1	G1	131.5
F1	H1	G2	131.7
F1	H2	G1	127.7
F1	H2	G2	155.0
F2	H1	G1	144.8
F2	H1	G2	141.7
F2	H2	G1	**159.0**

F	H	G	Plant Height (cm)
F2	H2	G2	141.3

The application of organic matter resulted in a 7.5% increase in plant height, followed by a 6.1% increase from humic acid and a smaller but still beneficial effect from licorice extract.

Sepals' Macronutrient Content

The levels of potassium (K), phosphorus (P), and nitrogen (N) in sepal tissues were all considerably impacted by the treatments. Table 5 provides a summary of these findings.

Table 5. Sepals' Macronutrient Content (% or mg/100g)

Nutrient	Minimum Value	Maximum Value	% Increase
Nitrogen (%)	0.735	2.720	+270%
Phosphorus (%)	0.799	1.756	+120%
Potassium (mg/100g)	462.3	607.5	+31.4%

While organic matter and humic acid combinations primarily increased potassium, licorice extract and humic acid together increased N content by more than 100%..

Content of Protein

Certain treatments, especially humic acid, resulted in a significant increase in protein content. F1 × H2 × G1 had the highest protein percentage (17.00%), while F1 × H1 × G2 had the lowest (4.59%). The difference between the minimum and maximum values has increased by 270%.

Compounds of Phytochemistry

The production of bioactive compounds was greatly increased by the treatments. The findings for glycosides, saponins, flavonoids, phenolics, tannins, and terpenes are compiled in Table 6.

Table 6. Sepals' Phytochemical Composition

Compound	Min Value	Max Value	% Increase
Glycosides (%)	13.95	25.64	+83.8%
Saponins (%)	2.24	4.84	+115.2%
Flavonoids (%)	51.0	74.4	+45.9%
Phenolics (mg/100g)	46.12	62.76	+36.1%
Tannins (mg/100g)	33.43	59.28	+77.3%
Terpenes (mg/100g)	5.58	16.60	**+197.5%**

Terpenes showed the most noticeable improvement, almost tripling under combined treatments, indicating a synergistic effect between the organic inputs. Figure 2 illustrates how treatments affect the amounts of phytochemicals like protein, flavonoids, and phenols.

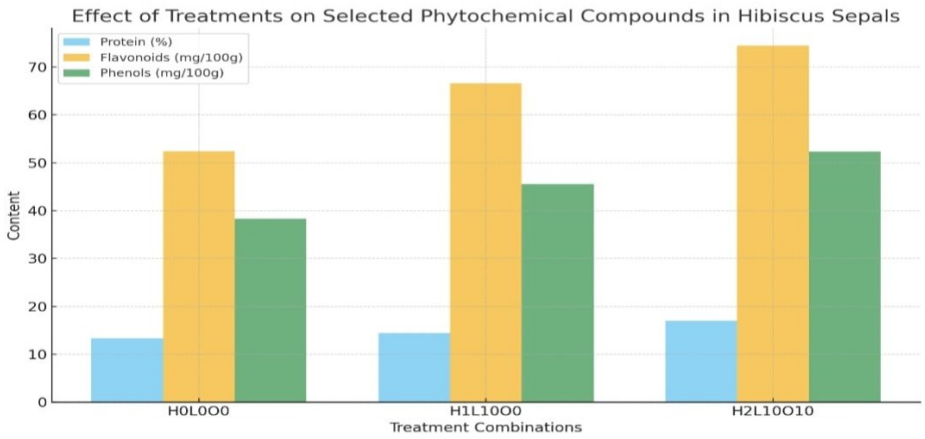

Figure 2. The protein (%), flavonoid (mg/100g), and phenol (mg/100g) concentrations in Hibiscus sabdariffa sepals under specific treatment combinations are shown in a comparative bar chart

Discussion

It was obviously indicated by the results that the joint use of humic acid, licorice extract, and organic matter also had a pronounced effect on the morphological, yield, and phytochemical properties of Hibiscus sabdariffa L.. All these findings are in line with the previous reports which had highlighted the importance of the natural biostimulants and organic amendments in boosting the growth and productivity of the vegetation.

The experimentally obtained increment of plant height, capsules per plant, and weight of the humic acid-treated plants is in tandem with an earlier study made by Khazaie and Kafi [18] that found out that humic substances led to an increment in root and shoot growth of wheat plants. Similarly, Maibodi et al. [12] pointed out that humic acid enhances nutrient availability and the general plant healthiness. This is probably due to the increase in the amount of capsules formed and height of the plant, augmented by the membrane permeability and the activation of enzyme [24], augmentative photosynthesis and movement of nutrients [35].application of humic acid augmented the nitrogen, phosphorus and potassium content in the tissues of sepals. This observation is in line with Cangi et al. [19] who demonstrated that application of humic acid enhanced the uptake of nutrients and fruit traits in the grapevines. Turkmen et al. stated that humic substances increase cation exchange capacity and root utilization of nutrients which in turn increase availability and yield components [36]. The effects of morphological differences were obvious in the given difference between the best performing treatment (H2L10O10) and the control group (H0L0O0) in terms of plant height, leaf area and the number of calyces per plant (Figure 3).

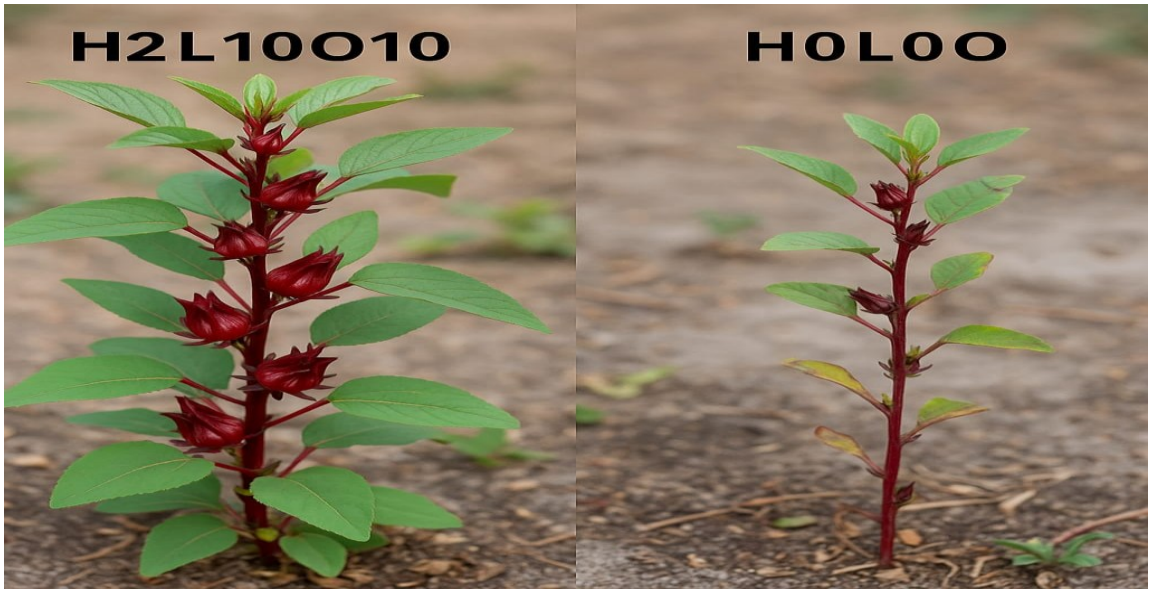

Figure 3. shows a morphological comparison of Hibiscus sabdariffa L. plants treated with H2L10O10 (left) and H0L0O0 (right). The combined application of humic acid, licorice extract, and organic matter resulted in increased growth and calyx formation.

The growth parameters were considerably enhanced by use of organic matter (10% animal manure extract). This may be attributed to the fact that it is slow releasing of nutrients, and enriching of microbial activity in soils thereby improving soil structure and aeration. Pettit [23] explained that humus and organic materials are vital to soil in terms of nutrient retention and capacities to act as buffering. On the same note, Raslan [25] highlighted that organic manure enhances the fertility of the soil and nutrient sustainability of the soil.It is possible that the rise in phytochemical contents upon organic matter treatment, especially the glycosides and terpenes could be attributed to the induction of secondary metabolism through natural organic additions. According to Senn and Kingman [37], the use of organic fertilizers triggers enzyme activities which have direct influence on active compound biosynthesis.

Spraying of licorice extract increased plant height, weight of capsules and biochemical composition. This has been attributed to the bioactive constituents in licorice like glycyrrhizin and glabridin that performs the same way as natural growth regulators [28]. Nasser et al. [20] state that licorice extract has several vegetative growth promoting properties, including water-use efficiency effects, as a result of transpiration reduction and cell turgor maintenance. According to Al-Marsoumi [27] licorice extracts enhance the seed yield and flowering characteristics, which are similar in this study since the number of capsules was increased.

There was augmented take up of nitrogen, phosphorus and potassium with joint application of humic acid and organic matter along with licorice extract. These results agree with the ones made by Cresser and Parsons [30] which highlighted the efficiency of sulfuric-perchloric digestion in the retention of total nutrient content. The trend noted in NPK condition is also congruent with the research conducted by Al-Sahhaf [26] who found out that, both organic and mineral balanced nutrition yields the optimum nutrient absorption. Interaction of these treatments not only enhanced macronutrient component but also caused a higher level of protein which is probably due to a better utilization of nitrogen and de novo protein synthesis.

One of the most important was the build-up of secondary metabolites that included phenol, flavonoids, tannins and terpenes. This can be blamed on the activation of metabolism through bio-based inputs because of stress. Ojulari et al. [8] have provided evidence that Hibiscus sabdariffa will respond to a stimulus of bioactive with a surge of antioxidant-rich metabolites. Further on, Moser et al. [1] and McKay et al. [21] justified the correlation between environmental modulation and higher rates of antioxidant compounds production in hibiscus calyces.In addition to that, the growth of glycosides and saponins corresponds with the research of Abu-Tarboush et al. [22] that identified the high content of nutritional and medicinal compounds of Hibiscus seeds influenced by natural biofertilizers.

Although the present findings concurred with most of the past reports, there were deviations observed. As an example, whereas Babb-Hartman [10] informed that organic turf maintenance always boost all vegetative characteristics, in the current study, humic acid impacts on the number of capsules varied according to organic and licorice blends. This means that dose optimization and the timing should be considered significantly since it has been reported by El-Sayed et al. [13] on turfgrass experiences under various irrigation conditions. Dhar et al. [6] and Andzi Barh Guy & Feuya Tchouya [4] outlined the fact that the expression of bioactive compounds in Hibiscus species can also be modified by elements of the environment, including temperature and intensity of light, which can at least partly underlie the treatment interactions found in the current research.

Conclusion

This experiment will be useful in giving a clear picture on positive impact of humic acid, foliar licorice extract and organic matter on growth, yield and biochemical characteristics of Hibiscus sabdariffa L. A combination of these natural treatments had a considerable effect on increasing the height of the plants, the number and weight of the capsules in addition to nutrient and phytochemical content of the sepals.The application of all these treatments with a combination of 10 percent organic matter and without humic acid in the foliar licorice extract produced the best productivity in preference to the number of capsules and their weight. In the interim, association between humic acid and organic matter contributed significantly towards nutrient absorption and protein levels in the plant tissues. the treated plants showed a significant rise in significant bioactive compounds namely phenolics, flavonoids , glycosides and terpenes. Such modifications do not only help the agronomic efficiencies but also imply better nutritional and therapeutic potential in the plant.

All in all, the addition of humic acid, organic fertilizers and licorice extract in the Hibiscus production is an overall sustainable environmentally sound approach that can maintain not only plant health, quality and yield, but also the value of the products without putting its chemical dependence into play.

REFERENCES

[1] C. Moser Paraíso et al., "Comparative studies on chemical stability, antioxidant and antimicrobial activity from hot and cold hibiscus (Hibiscus sabdariffa L.) calyces tea infusions," *Journal of Food Measurement and Characterization*, vol. 15, no. 4, pp. 3531–3538, 2021, doi: 10.1007/s11694-021-00936-4.

[2] O. Nwaiwu, C. C. Aduba, V. C. Igbokwe, C. E. Sam, and M. U. Ukwuru, "Traditional and artisanal beverages in nigeria: microbial diversity and safety issues," *Beverages*, vol. 6, Art. no. 53, 2020, doi: 10.3390/beverages6030053.

[3] I. C. Akujobi, G. Obicheozo, and C. U. Nwokorie, "Nutrient composition, phytochemical and sensory properties of zobo (Hibiscus sabdariffa) drinks substituted with pineapple (Ananas comosus) and orange (Citrus sinensis) juices," *Journal of Agriculture and Food Science*, vol. 16, no. 2, pp. 1–11, 2019, doi: 10.4314/jafs.v16i2.1.

[4] T. Andzi Barhé and G. R. Feuya Tchouya, "Comparative study of the anti-oxidant activity of the total polyphenols extracted from Hibiscus sabdariffa L., Glycine max L. Merr., yellow tea and red wine through reaction with DPPH free radicals," *Arabian Journal of Chemistry*, vol. 9, no. 1, pp. 1–8, 2016, doi: 10.1016/j.arabjc.2014.11.048.

[5] O. R. Alara and N. H. Abdurahman, "Microwave-assisted extraction of phenolics from Hibiscus sabdariffa calyces: Kinetic modelling and process intensification," *Industrial Crops and Products*, vol. 137, pp. 528–535, 2019, doi: 10.1016/j.indcrop.2019.05.053.

[6] P. Dhar, C. S. Kar, D. Ojha, S. K. Pandey, and J. Mitra, "Chemistry, phytotechnology, pharmacology and nutraceutical functions of kenaf (Hibiscus cannabinus L.) and roselle (Hibiscus sabdariffa L.) seed oil: An overview," *Industrial Crops and Products*, vol. 77, pp. 323–332, 2015, doi: 10.1016/j.indcrop.2015.08.064.

[7] E. Montalvo-Gonzalez et al., "Physiological effects and human health benefits of Hibiscus sabdariffa: A review of clinical trials," *Pharmaceuticals*, vol. 15, no. 4, Art. no. 464, 2022, doi: 10.3390/ph15040464.

[8] O. V. Ojulari, S. G. Lee, and J. O. Nam, "Beneficial effects of natural bioactive compounds from Hibiscus sabdariffa L. on obesity," *Molecules*, vol. 24, no. 1, Art. no. 210, 2019, doi: 10.3390/molecules24010210.

[9] S. Gonzalez-Palomares, M. Estarrón-Espinosa, J. F. Gómez-Leyva, and I. Andrade-González, "Effect of the temperature on the spray drying of Roselle extracts (Hibiscus sabdariffa L.)," *Plant Foods for Human Nutrition*, vol. 64, no. 1, pp. 62–67, 2009, doi: 10.1007/s11130-008-0103-y.

[10] M. E. Babb-Hartman, "Maintenance of warm-season turfgrasses with organic and nonsynthetic pesticides and fertilizers," Ph.D. dissertation, University of Georgia, Athens, GA, USA, 2020.

[11] M. A. H. Abdou, F. S. Badran, R. H. Taha, and H. M. Hussain, "Effect of some soil media types and growth regulators on Lolium perenne," *Annals of Agricultural Science, Moshtohor*, vol. 51, no. 3, pp. 253–262, 2013, doi: 10.21608/assjm.2013.141816.

[12] N. D. H. Maibodi, M. Kafi, A. Nikbakht, and F. Rejali, "Effect of foliar applications of humic acid on growth, visual quality, nutrients content and root parameters of perennial ryegrass (Lolium perenne L.)," *Journal of Plant Nutrition*, vol. 38, no. 2, pp. 224–236, 2015, doi: 10.1080/01904167.2014.939759.

[13] B. A. El-Sayed, S. M. Shahin, T. M. Noor ElDeen, and M. A. El-Ashwah, "Response of seashore paspalum turfgrass to irrigation periods and humic acid," *Scientific Journal of Flowers & Ornamental Plants*, vol. 3, no. 1, pp. 71–78, 2016, doi: 10.21608/sjfop.2016.5124.

[14] E. Desoky, A. R. Merwad, and S. Ibrahim, "Humus materials and moringa (Moringa oleifera Lam.) leaf extract modulate the harmful effect of soil salinity stress in Sudan grass (Sorghum vulgare L.)," *Egyptian Journal of Agronomy*, vol. 41, no. 1, pp. 29–45, 2019, doi: 10.21608/agro.2019.6844.1141.

[15] M. A. H. Abdou, A. A. El-Sayed, R. A. Taha, and M. E. Tolba, "Response of gazon grass plants to compost, humic acid and bio-fertilizer," *Minia Journal of Agricultural Research & Development*, vol. 40, no. 2, pp. 243–255, 2020, doi: 10.21608/SJFOP.2023.298699.

[16] R. Sharifiasl, M. Kafi, M. Saidi, and S. Kalatejari, "The effect of humic acid on growth and some physiological responses in Bermuda grass subjected to salinity stress," *Iranian Journal of Horticultural Sciences*, vol. 51, no. 2, pp. 415–425, 2020.

[17] M. E. Mohammedamin and S. Kanimarani, "Impact of foliar application of humic acid and the measure time on growth and production of roselle Hibiscus sabdariffa L," *Tikrit Journal for Agricultural Sciences*, vol. 20, no. 1, pp. 38–48, 2022, doi: 10.25130/tjas.20.1.4.

[18] H. Khazaie and M. Kafi, "Effect of humic acid on root and shoot growth of two wheat cultivars (Triticum aestivum L.)," *Water and Soil*, vol. 23, no. 2, 2009, doi: 10.22067/jsw.v0i0.1731.

[19] R. Cangi, C. Tarakçıoğlu, and H. Yaşar, "Effect of humic acid applications on yield, fruit characteristics and nutrient uptake in Ercis grape (V. vinifera L.) cultivars," *Asian Journal of Chemistry*, vol. 18, pp. 1493–1499, 2006.

[20] N. S. Nasser, M. W. Mahdi, and S. S. Abdullah, "The effect of spraying with licorice extract and organic fertilization of poultry in the growth of fenugreek plant (Trigonella foenum-graecum L.)," *Swedish J. Sci. Res.*, vol. 1, no. 6, pp. 36–42, 2014.

[21] D. L. McKay, C. Y. Chen, E. Saltzman, and J. B. Blumberg, "Hibiscus sabdariffa L. tea (tisane) lowers blood pressure in prehypertensive and mildly hypertensive adults," *The Journal of nutrition*, vol. 140, no. 2, pp. 298–303, 2010, doi: 10.3945/jn.109.115097.

[22] H. M. Abu-Tarboush, S. A. B. Ahmed, and H. A. Al Kahtani, "Some nutritional and functional properties of Karkade (Hibiscus sabdariffa) seed products," *Cereal Chemistry*, vol. 74, no. 3, pp. 352–355, 1997, doi: 10.1094/CCHEM.1997.74.3.352.

[23] R. E. Pettit, "Organic matter, humus, humates, humic acid, fulvic acid and humin: Their importance in soil fertility and plant health," Texas A&M University, College Station, TX, USA, 2003.

[24] B. S. Rauthan and M. Schnitzer, "Effects of a soil fulvic acid on the growth and nutrient content of cucumber (Cucumis sativus) plants," *Plant and Soil*, vol. 63, no. 3, pp. 491–495, 1981, doi: 10.1007/BF02370049.

[25] A. H. Raslan, *Theoretical Booklet on Soil Fertility and Fertilization*. Agricultural Technical Institute, Abu Ghraib, Iraq, 1974.

[26] F. H. Al-Sahhaf, *Applied Plant Nutrition*. Baghdad, Iraq: House of Wisdom, University of Baghdad, 1989.

[27] H. G. K. Al-Marsoumi, "The effect of some factors on vegetative growth traits and seed yield in three varieties of onion (Allium cepa L.)," Ph.D. dissertation, College of Agriculture, University of Baghdad, Baghdad, Iraq, 1999.

[28] F. H. Al-Sahhaf and H. G. K. Al-Marsoumi, "Effect of spraying gibberellin, licorice extract and nutrients on onion seed production," *Iraqi Journal of Agricultural Sciences*, vol. 34, no. 2, pp. 37–46, 2003.

[29] M. K. John, "Colorimetric determination of phosphorus in soil and plant materials with ascorbic acid," *Soil Science*, vol. 109, no. 4, pp. 214–220, 1970, doi: 10.1097/00010694-197004000-00002.

[30] M. S. Cresser and J. W. Parsons, "Sulphuric–perchloric acid digestion of plant material for the determination of nitrogen, phosphorus, potassium, calcium and magnesium," *Anal. Chim. Acta*, vol. 109, no. 2, pp. 431–436, 1979, doi: 10.1016/S0003-2670(01)84273-2.

[31] Z. Tofighi, A. Ghazi Saeidi, A. Hadjiakhoondi, and N. Yassa, "Determination of cardiac glycosides and total phenols in different generations of Securigera securidaca suspension culture," *Res. J. Pharmacogn.*, vol. 3, no. 2, pp. 25–31, 2016. [Online]. Available: https://doaj.org/article/2bd9370b7b04487abea6d729f78023b7

[32] S. A. Baba and S. A. Malik, "Determination of total phenolic and flavonoid content, antimicrobial and antioxidant activity of a root extract of Arisaema jacquemontii Blume," *J. Taibah Univ. Sci.*, vol. 9, no. 4, pp. 449–454, 2015, doi: 10.1016/j.jtusci.2014.11.001.

[33] N. Ghorai et al., "Estimation of total terpenoids concentration in plant tissues using a monoterpene, linalool as standard reagent," *Protocol Exchange*, 2012, doi: 10.1038/protex.2012.055.

[34] W. C. Evans, *Trease and Evans' Pharmacognosy*, 15th ed. W. B. Saunders, 2002.

[35] Y. P. Sun, Z. P. Zhang, and L. J. Wang, "Promotion of 5-aminolevulinic acid treatment on leaf photosynthesis is related with increase of antioxidant enzyme activity in watermelon seedlings grown under shade condition," *Photosynthetica*, vol. 47, no. 3, pp. 347–354, 2009, doi: 10.1007/s11099-009-0055-y.

[36] O. Turkmen, A. Bozkurt, and K. Mcimin, "Effect of nitrogen and humic acid applications on head weight, nutrient and contents in lettuce," *Adv. Food Sci.*, vol. 26, pp. 1–6, 2004.

[37] T. L. Senn and A. R. Kingman, "A review of humus and humic acid," South Carolina Agricultural Experiment Station, Clemson, SC, USA, Research Series No. 145, 1998.