*Plant Archives* Vol. 21, Supplement 1, 2021 pp. 2240-2252 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
doi link : https://doi.org/10.51470/PLANTARCHIVES.2021.v21.S1.370

# THE IMPACT OF HUMIC ACID SOLUTIONS AND TYPES OF GROWING MEDIA ON SOME MORPHOPHYSIOLOGICAL AND BIOCHEMICAL FEATURES OF SYNGONIUM SP. AND POTHOS SP. PLANTS IN INTERIOR GREEN WALL CONDITIONS

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**ABSTRACT**

With the expansion of urbanization and reducing the green space areas in cities, various strategies have been suggested to increase human contact with nature in cities. Some of them are vertical gardens and green wall systems. Apart from increasing human contact with nature in interior and exterior spaces, green wall systems have other advantages, including pollution control and energy conservation in the buildings. Also, with the increase in environmental issues, the use of organic acids enhances plant growth and prevents environmental pollutions. It seems that Syngonium and Pothos are suitable to be used in green wall systems since they possess favorable qualities such as fast climbing and coverage potentials. Therefore, in the present study considering the growth of the plants in an interior green wall condition, two separate factorial experiments were performed base on a completely randomized design with three replications.
Two growing media types (cocopeat, vermicompost and zeolite (CVZ), and cocopeat, vermicompost and perlite (CVP) with ratios of 40v:10v:50v) were investigated under the influence of foliar application of humic acid with four concentration levels (0, 2, 4, and 6 mg/L). Based on the analysis of variance, there were significant differences ($p \leq 0.01$) in all the measured morphophysiological and biochemical factors between the treatments. Findings showed that in most cases, due to the application of perlite, CVP growing medium showed better results than CVZ. Also, by changing the concentration of humic acid to 4mg/L, root mass, stomata concentration, index, and length showed the highest amounts.
***Keywords*:** Pothos, Syngonium, Cocopeat, Vermicompost, Zeolite, Soilless culture, Humic acid.

## Introduction

With increasing environmental issues, the use of various organic acids to improve the quality of crops and plants is increasing. Considering their hormonal compounds, utilizing organic acids have considerable effects on the chemical and physical properties of soil, which results in more crop production [1]. The use of chemical fertilizers (e.g. humic acid) improves their function and causes no harm to the environment. Humic materials are a mixture of organic materials, which are plants' and animals' residues [2]. Humic with molecular weights of 3000 to 300000 Da and folic acid with molecular weights less than 30000 Da provide stable insoluble and soluble complexes with micro-elements, respectively. Humic acids have some advantages that lead to the chelation of necessary elements of nutrition for plants, including sodium, potassium, magnesium, zinc, etc. to overcome the nutritional deficiency. It also increases the length and weight of the root systems [3].

Syngonium belongs to Araceae family and with more than 105 genera and 3300 species has been distributed in warm and mild regions of the world. This species is native to Central America. Syngonium is a weed in banana farms, could grow by the fast growth of concentrated colonies that cover the local vegetation and move native species by changing plant community structures. This species could propagate by seeds and cuttings and spread by birds and mammals. Also, this species has financial benefits in herbal use, decoration, and elimination of pollutants from houses [4]. The young Syngonium plants could be planted as indoor plants.

Another plant from Araceae family called pothos is native to warm and semi-arid regions of South East Asia. It is also known as money plant, devil's ivy, silver grape and golden grape with 3800 reported species in both wild and farm species. It is an evergreen plant, which grows upwards. Young leaves are sharp and the older leaves are heart-shaped. This plant's color varies from green to variegated green, which is sometimes a mixture of yellow and creamy white [5]. Pothos is a suitable plant for hanging flower baskets [6].

Vertical green systems are often divided into two categories, green roof, and green wall systems. They are considered as green infrastructures in the buildings [7] that makes the cities appealing, reduces environmental pollutions, enhances urban environment [9], and the latter system makes the façades more eye-catching [10], improves the thermal function of the building [11], etc. In this study, based on their climbing feature, Syngonium and Pothos are suggested to create a green wall system for the residential places. Hence, their growth speed should be evaluated. In the present study, the morphophysiological and biochemical effects of two mixed growing media containing vermicompost and cocopeat with zeolite, and also vermicompost and cocopeat with perlite under different humic acid concentration levels on two indoor plants in an interior green wall system was examined.

**Humic acid**

Di Leariu *et al*. (2019) investigated the effect of iron oxide and humic acid on cucumber. In this study, four concentrations of humic acid in the presence of iron and under the influence of oxygen and two types of goethite containing a high amount of iron were applied on plants as nanocrystal compound phases and goethite. The results of the study indicated that cucumber had a higher growth rate at the presence of iron, than the control group without iron. Plants treated with goethite and iron had higher iron in their leaves, but leaf concentration was higher in magnetite and humic acid compound [12].

Zandonadi *et al*. (2019) examined the effect of humic acid on the biological activities of corn. N-isopropyldecanamide synthesis and corn sapling were treated with different concentrations for 7 and 15 days. Findings of the study showed that N-isopropyldecanamide synthesis had limited levels with high functionality and was 86% effective. Concentration of six to eight mg/L extended the root in 7 to 15 days. Also, humic acid increased nitric oxide concentration in the lateral roots [13].

Iken (2019) assessed the influence of humic acid on potato and rhizobacteria growth. Seeds of this plant were studied after acid humic treatments (200, 400, and 600 mg/L). The results of the study demonstrate that the amount, weight, specific weight, dry material, starch, protein, minerals (except copper) were improved with plant-booster rhizobacteria treatments and increased when using humic acids [14].

Zhang *et al*. (2019) assessed the effects of magnetic liquid hydroxide $Fe_3O_4$ with humic acid on plant growth. To enhance the soil function in the mineral regions an investigation including mixing magnetic materials with humic acid was conducted at concentrations of 1%, 3%, 5%, and 7%. The findings of the study demonstrated that a mixture of these materials could effectively reduce considerable biological problems of heavy metals (e.g. lead, chrome, nickel, cadmium, zinc) in mining soils and enhance enzyme activities of β-glucosidase, urease, and phosphatase.

**Syngonium**

Zolfaghar *et al*. used coal and farm waste compost for a 20% increase in Syngonium volume. These two types of acids increase pH and electrical conductivity in the formulation of the growing media and plant growth. Nitrogen, phosphorus, potassium, and chlorophyll concentration in leaves, along with the amount of plant photosynthesis in a mixture of these materials increased significantly. Furthermore, there was a significant increase in the amount of plant photosynthesis in the mixture of these materials, compared to the control group. Finally, the results of the study showed that this mixture could be applied at 20% to replace Sphagnum Peat Moss volume. This replacement led to an increase in Syngonium growth [16].

In a study, Khomami *et al*. examined the effect of vermicompost extract at four concentration levels (0, 250, 500, 1000 ppm), as well as sawdust on the growth rate of Syngonium. According to the findings of this study, vermicompost extract enhanced mineral nutrients in the plant. Also, this extract does not have any negative effects on sprouting. Height, leaf surface, chlorophyll, plant's fresh weight, and stem's fresh weight increased compared to the control group. In general, vermicompost extract and sawdust had a positive effect on the growth of Syngonium [17].

Salehi *et al*. considered Syngonium growth by applying Gibberellic acid and Benzyladenin. In this study, the above-mentioned materials were used in concentrations of 100, 200, 400, and 800 mg/L and the control group. The results of the study showed that at a concentration of 800 mg/L, a mixture of these materials improved Syngonium growth by 262% to 270% [18].

Jing *et al*. examined the growth and heavy metal concentration in Syngonium using sewage sludge compost. It was found that increase in bush growth and biomass concentration improved by 30%. When this compost was only used for plant growth, the amount of copper, zinc, lead, and cadmium increased significantly [19].

Dinavarman *et al*. investigated the influence of coal and post-hydrogel on growth and hydrogen of Syngonium. The results of this study indicated that vase (75%) + Sphagnum Peat Moss (25%) + hydrogel/kilogram (3 g) mixture of vases is regarded as an optimal environment for the branch and leaf of the plants of Syngonium vase [20].

**Pothos**

Alhanafi studied the impact of estrogenic animal hormones (Ethinyl estradiol at 0.1, 0.15 and 0.2 ppm) and prognosis (lynestrenol at 1 and 1.5 ppm) on morphologic and chemical structure of pothos. Statistical analysis showed that an obvious response to the hormones significantly increased the height of the plants, along with their leaf and stem parameters. A limited number of parameters were recorded for the roots. Also, an increase in the nitrogen and phosphorus percentage was recorded in the dry leaves [21].

Saffari *et al*. investigated the influence of three different fertilizers (i.e. vermicompost, compost from grains enriched with sulfur and compost waste) at four soil levels of 5, 10, 15, 20% on the growth and function of pothos. It was found that considering leaf surface index, vermicompost treated plants (8/31) had a better performance than the plants treated with other fertilizers. This increase could be due to more absorption of nutrients, better diet followed by better performance of the plants in the presence of vermicompost [22].

In their study, Bidarnamani *et al*. evaluated the influence of growing media on pothos growth. These treatments include perlite+leaf compost, perlite+rice husk, perlite+cocopeat, perlite+mushroom compost. The results of the study show that the shrub height, number of leaves, and the amount of chlorophyll had a better response in perlite, leaf compost, and perlite+mushroom compost [23].

## Materials and Method

To investigate the influence of different concentrations of humic acid and two types of growing media on morphophysiological and biochemical properties of Syngonium and Pothos, a study that lasted for 6 months was conducted. Temperature, humidity, and light at the study setting were controlled automatically using the equipment and EHTC-DC sensor available in that place (Temperature and humidity on the balcony covered were 12±28 C and 20%-60%, respectively). The green wall structure was constructed in the form of a modular system, designed by Skale Company. In this structure, each pot had 16cm depth and 12cm width. For the drainage, in each pot, a piece of felt was placed to prevent the soil from entering the drain and clogging the drain. Two punches were made under each pot. Green wall contained 24 pots for each plant. For each plant, a separate structure with dimensions of 80 by 120 was considered. The plants were cultivated in June and the experiment continued for 6 months afterward. The study was conducted as two separate factorial arrangements (one for Syngonium and one for Pothos) in a completely randomized design with three replications. In the first experiment, Syngonium performance on the green wall was examined based on changing two factors. The first factor was the foliar application of different humic acid concentrations (0, 2, 4, 6 mg/L containing 70% humic acid, 17% folic acid, and 13% potassium) once per week during the experiment. The second factor was two growing media types, a) cocopeat and vermicompost and zeolite (powder) b) cocopeat and vermicompost and crushed perlite (50v:10v:40v, respectively). Table 1 shows the chemical characteristics of the used vermicompost. In the second study, the same condition was applied for Pothos.

**Table 1:** Some chemical characteristics of the used vermicompost in the experiment

| P | N | K (%) | OM | OC | EC (dS/m) | pH |
|---|---|---|---|---|---|---|
| 2.12 | 2.21 | 1.03 | 31.21 | 18.14 | 3.02 | 8.26 |

### Root mass

Root mass was measured according to water volume (cm$^3$), using Archimedes' law with a graduated cylinder, in comparison with its initial volume [24].

### Leaf surface

To measure the leaf surfaces, they were separated from the plant. Next, they were examined by leaf area meter (Li_COR model) made in Germany inside the laboratory.

### Fresh and dry weight of the aerial parts of the plants

In an attempt to weigh the dry root and aerial parts of the plants, they were weighed using a digital scale (GF-300 model, with an accuracy of 0.001) after collection. Afterward, the samples were placed in an oven at 75 ºC for 48 hours. Then the roots and aerial parts of the plants were weighed [25].

### Stomata characteristics and epidermis cell features

In order to measure Stomata and epidermis cell features, one leaf was cut from each plant and a thin layer was incised from the surface of the leaf and placed on a microscope slide. Then, utilizing a microscope, equipped with a camera, the stomata, and epidermis cell concentrations per surface (mm$^2$), as well as their width and length were measured. Thus, to measure the stomata index, the formula 1 was applied:

$$SI = \left(\frac{S}{S+E}\right) \times 100 \quad ...(1)$$

In the above formula, E is the number of epidermis cells per surface (mm$^2$), S is the number of Stomata per surface (mm$^2$), and SI is the stomata index (%) [26].

The SPAD index or the chlorophyll SPAD number of the plants in each treatment was recorded by SPAD (model 502 made in Japan) equipment.

### Measuring the amount of chlorophyll

To measure the contained chlorophyll, 0.2 g of fresh leaf was chopped and crushed with 10 ml of methanol 99% in a china mortar to obtain a homogeneous matter. This mixture was put in a centrifuge (4000 rpm). The buoyant solution was picked immediately and the rate of light absorption was read at wavelengths of 666, 653, and 470 nm using spectrophotometer Bio Quest, CE 2502, UK. Finally, the amount of chlorophyll a, chlorophyll b and total chlorophyll was calculated based on the following formulas [27].

$$Chl_a \left(\frac{\mu g}{ml}\right) = 15.67A_{666} - 7.34A_{653} \quad ...(2)$$

$$Chl_b \left(\frac{\mu g}{ml}\right) = 27.05A_{653} - 11.21A_{666} \quad ...(3)$$

$$Chl_{total} \left(\frac{\mu g}{ml}\right) = Chl_a + Chl_b \quad ...(4)$$

## Result and Discussion

After data collection, they were evaluated using multivariate analyses of variance in SPSS. Also, the tables were drawn using an Excel software package. Duncan test was administered to compare the means.

### Syngonium

As it was previously mentioned, to examine the effect of growing media types and various concentrations of humic acid on Syngonium in the previously-mentioned required conditions, a number of morphophysiological and biochemical factors were measured.

The findings of the factorial experiments are given in the following. The reason for implementing it was to find significant correlations or effects between different treatments. The results are provided in a number of tables.

**Table 2:** Analysis of variance of different treatments in the Syngonium experiment

| Treatment | df | Number of leaves | Leaf surface | Fresh weight of the syngonium's aerial parts of the plants | Dry weight of the syngonium's aerial parts of the plants | Root mass | Chloro-phyll a | Chloro-phyll b | Total Chlorophyll | SPAD index | Stomata index | stomata concentration | epidermis cells concentration | Length of the stomata | Width of the stomata |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Growing media + humic acid | 7 | $101.43^{**}$ | $500,550.2^{*}$ | $2,154.1^{**}$ | $121.7^{**}$ | $14.87^{**}$ | $13.17^{**}$ | $2.28^{**}$ | $26.07^{**}$ | $0.74^{**}$ | $0.12^{**}$ | $23.7^{**}$ | $664.1^{**}$ | $96.7^{**}$ | $83.7^{**}$ |
| Growing media | 1 | $4.17^{*}$ | 82134** | $253.5^{ns}$ | $7.04^{ns}$ | $1.12^{ns}$ | $15.68^{**}$ | $2.67^{**}$ | $31.28^{**}$ | $1.17^{**}$ | $0.11^{*}$ | $7.04^{ns}$ | $590.04^{**}$ | $77.04^{*}$ | $20.16^{*}$ |
| humic acid | 3 | $232.56^{**}$ | $1136712.5^{**}$ | $4877^{**}$ | $278.49^{**}$ | $34.22^{**}$ | $23.96^{**}$ | $4.26^{**}$ | $47.64^{**}$ | $1.29^{**}$ | $0.24^{**}$ | $52.93^{**}$ | $1350.4^{**}$ | $199.4^{**}$ | $186.9^{**}$ |
| Error | 14 | 0.64 | 3,798.49 | 52.42 | 1.82 | 1.45 | 2.93 | 0.22 | 4.39 | 0.05 | 0.02 | 2.32 | 24.0 | 13.1 | 4.8 |

**=p≤0.01, *=p≤0.05, ns=non-significant.

Table 3: Comparison of the means of the measured factors in different treatments in syngonium

| Growing medium | Concentrations of humic acid | Number of leaves (n) | Leaf surface ($cm^2$) | Fresh weight of the syngonium's aerial parts of the plants (gr) | Dry weight of the syngonium's aerial parts of the plants (gr) | Root mass ($cm^3$) | Chlorophyll a ($mg/g_{wet}$) | Chlorophyll b ($mg/g_{wet}$) | Total Chlorophyll ($mg/g_{wet}$) | SPAD index ($mm^2$) | Stomata index (%) | stomata concentration ($mm^2$) | epidermis cells concentration ($mm^2$) | Length of the stomata (μm) | Width of the stomata (μm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CVZ | 0 | $8.0^{c}$ | $504.3^{b}$ | $61.0^{b}$ | $10.3^{b}$ | $2.7^{b}$ | $8.8^{bcd}$ | $3.5^{abc}$ | $12.3^{bc}$ | $3.63^{cd}$ | $1.1^{c}$ | $9^{d}$ | $81.33^{d}$ | $31.67^{c}$ | $20.33^{ab}$ |
| | 2 | $9.0^{c}$ | $566.7^{b}$ | $68.3^{b}$ | $11.7^{b}$ | $3.0^{ab}$ | $9.7^{abc}$ | $3.9^{abc}$ | $13.6^{abc}$ | $4.3^{ab}$ | $1.2^{bc}$ | $10^{cd}$ | $91^{cd}$ | $35.66^{bc}$ | $23^{a}$ |
| | 4 | $17.0^{b}$ | $1230.0^{a}$ | $108.3^{a}$ | $21.0^{a}$ | $7.3^{ab}$ | $6.9^{cd}$ | $-2.4^{c}$ | $9.3^{c}$ | $3.53^{cd}$ | $1.5^{abc}$ | $14.3^{abc}$ | $111^{ab}$ | $45.33^{ab}$ | $12.6^{c}$ |
| | 6 | $19.0^{ab}$ | $1303.3^{a}$ | $108.0^{a}$ | $22.0^{a}$ | $2.7^{b}$ | $6.5^{d}$ | $2.8^{c}$ | $9.2^{c}$ | $3.2^{d}$ | $1.4^{abc}$ | $14.67^{abc}$ | $110.6^{ab}$ | $36^{bc}$ | $13.3^{c}$ |
| CVP | 0 | $7.7^{c}$ | $602.3^{b}$ | $62.7^{b}$ | $10.3^{b}$ | $3.0^{ab}$ | $11.5^{ab}$ | $4.4^{ab}$ | $15.9^{ab}$ | $4.3^{ab}$ | $1.2^{bc}$ | $10^{cd}$ | $91.67^{cd}$ | $35.67^{bc}$ | $23.3^{a}$ |
| | 2 | $8.7^{c}$ | $661.7^{b}$ | $68.3^{b}$ | $11.3^{b}$ | $3.3^{ab}$ | $12.0^{a}$ | $4.9^{a}$ | $16.8^{a}$ | $4.7^{a}$ | $1.3^{abc}$ | $11^{bcd}$ | $99.33^{bc}$ | $39.6^{abc}$ | $25.33^{a}$ |
| | 4 | $19.0^{ab}$ | $1363.3^{a}$ | $120.3^{s}$ | $23.3^{a}$ | $8.1^{a}$ | $7.6^{cd}$ | $2.7^{c}$ | $10.3^{c}$ | $3.9^{bc}$ | $1.67^{a}$ | $15.3^{ab}$ | $120.6^{a}$ | $49^{a}$ | $13.3^{c}$ |
| | 6 | $21.0^{a}$ | $1445.0^{a}$ | $120.3^{s}$ | $24.3^{a}$ | $3.0^{ab}$ | $7.3^{cd}$ | $3.2^{bc}$ | $10.4^{c}$ | $3.57^{cd}$ | $1.57^{ab}$ | $16^{a}$ | $122^{a}$ | $38.6^{abc}$ | $14.67^{bc}$ |

Means followed by the same letters are not significantly different

Table 3: Comparison of the means of the measured factors in different treatments in syngonium.

| Growing medium | Concentrations of humic acid | Number of leaves (n) | Leaf surface ($cm^2$) | Fresh weight of the syngonium's aerial parts of the plants (gr) | Dry weight of the syngonium's aerial parts of the plants (gr) | Root mass ($cm^3$) | Chlorophyll a ($mg/g_{wet}$) | Chlorophyll b ($mg/g_{wet}$) | Total Chlorophyll ($mg/g_{wet}$) | SPAD index ($mm^2$) | Stomata index (%) | stomata concentration ($mm^2$) | epidermis cells concentration ($mm^2$) | Length of the stomata (μm) | Width of the stomata (μm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CVZ | 0 | $8.0^{c}$ | $504.3^{b}$ | $61.0^{b}$ | $10.3^{b}$ | $2.7^{b}$ | $8.8^{bcd}$ | $3.5^{abc}$ | $12.3^{bc}$ | $3.63^{cd}$ | $1.1^{c}$ | $9^{d}$ | $81.33^{d}$ | $31.67^{c}$ | $20.33^{ab}$ |
| | 2 | $9.0^{c}$ | $566.7^{b}$ | $68.3^{b}$ | $11.7^{b}$ | $3.0^{ab}$ | $9.7^{abc}$ | $3.9^{abc}$ | $13.6^{abc}$ | $4.3^{ab}$ | $1.2^{bc}$ | $10^{cd}$ | $91^{cd}$ | $35.66^{bc}$ | $23^{a}$ |
| | 4 | $17.0^{b}$ | $1230.0^{a}$ | $108.3^{a}$ | $21.0^{a}$ | $7.3^{ab}$ | $6.9^{cd}$ | $-2.4^{c}$ | $9.3^{c}$ | $3.53^{cd}$ | $1.5^{abc}$ | $14.3^{abc}$ | $111^{ab}$ | $45.33^{ab}$ | $12.6^{c}$ |
| | 6 | $19.0^{ab}$ | $1303.3^{a}$ | $108.0^{a}$ | $22.0^{a}$ | $2.7^{b}$ | $6.5^{d}$ | $2.8^{c}$ | $9.2^{c}$ | $3.2^{d}$ | $1.4^{abc}$ | $14.67^{abc}$ | $110.6^{ab}$ | $36^{bc}$ | $13.3^{c}$ |
| CVP | 0 | $7.7^{c}$ | $602.3^{b}$ | $62.7^{b}$ | $10.3^{b}$ | $3.0^{ab}$ | $11.5^{ab}$ | $4.4^{ab}$ | $15.9^{ab}$ | $4.3^{ab}$ | $1.2^{bc}$ | $10^{cd}$ | $91.67^{cd}$ | $35.67^{bc}$ | $23.3^{a}$ |
| | 2 | $8.7^{c}$ | $661.7^{b}$ | $68.3^{b}$ | $11.3^{b}$ | $3.3^{ab}$ | $12.0^{a}$ | $4.9^{a}$ | $16.8^{a}$ | $4.7^{a}$ | $1.3^{abc}$ | $11^{bcd}$ | $99.33^{bc}$ | $39.6^{abc}$ | $25.33^{a}$ |
| | 4 | $19.0^{ab}$ | $1363.3^{a}$ | $120.3^{s}$ | $23.3^{a}$ | $8.1^{a}$ | $7.6^{cd}$ | $2.7^{c}$ | $10.3^{c}$ | $3.9^{bc}$ | $1.67^{a}$ | $15.3^{ab}$ | $120.6^{a}$ | $49^{a}$ | $13.3^{c}$ |
| | 6 | $21.0^{a}$ | $1445.0^{a}$ | $120.3^{s}$ | $24.3^{a}$ | $3.0^{ab}$ | $7.3^{cd}$ | $3.2^{bc}$ | $10.4^{c}$ | $3.57^{cd}$ | $1.57^{ab}$ | $16^{a}$ | $122^{a}$ | $38.6^{abc}$ | $14.67^{bc}$ |

Means followed by the same letters are not significantly different.

According to the Tables 2, there were significant differences in morphophysiological and biochemical characteristics of the Syngonium under different treatments. Therefore, it is clear that the number of leaves in the plants treated with CVZ mixture is higher than that in the other growing media type ($p \leq 0.01$). Therefore, changes in this variable are due to the application of CVP growing medium. In addition, this change in the levels of humic acid usage is significant. At 0 and 2 mg/L concentrations, no considerable changes happened, but with an increase in concentration level to 4 and 6 mg/L the number of leaves in the plants treated with CVP was also increased.

Regarding the leaf area variable, the plants cultivated in CVP covered 12.9% more leaf area. Considering the significance of these changes in this treatment, it could be stated that the changes are the result of the various treatments.

Taking into account the fresh weight of the Syngonium's aerial parts of the plants, CVP growing medium in general (7.5%) and also, in particular, gave more weight to the plants at different concentrations of humic acid. The same applies to the dry weight of the aerial part of the plants. The findings presented at this part for enhancement of CVP use versus CVZ use show a 6.6% improvement. Also, it should be kept in mind that at concentration levels of 0 and 2 mg no considerable changes were observed in the two growing media types. However, with an increase in concentration levels from 4 to 6 ml this weight increase was intensified. This intensification is more obvious in CVP.

After analysis of root mass results, some changes resulting from different treatments were evident. On average, the root mass of the plants on CVP was 10.9% more than that in the CVZ. With an increase in humic acid concentration, this increase in root mass enhances the plants in both growing media types.

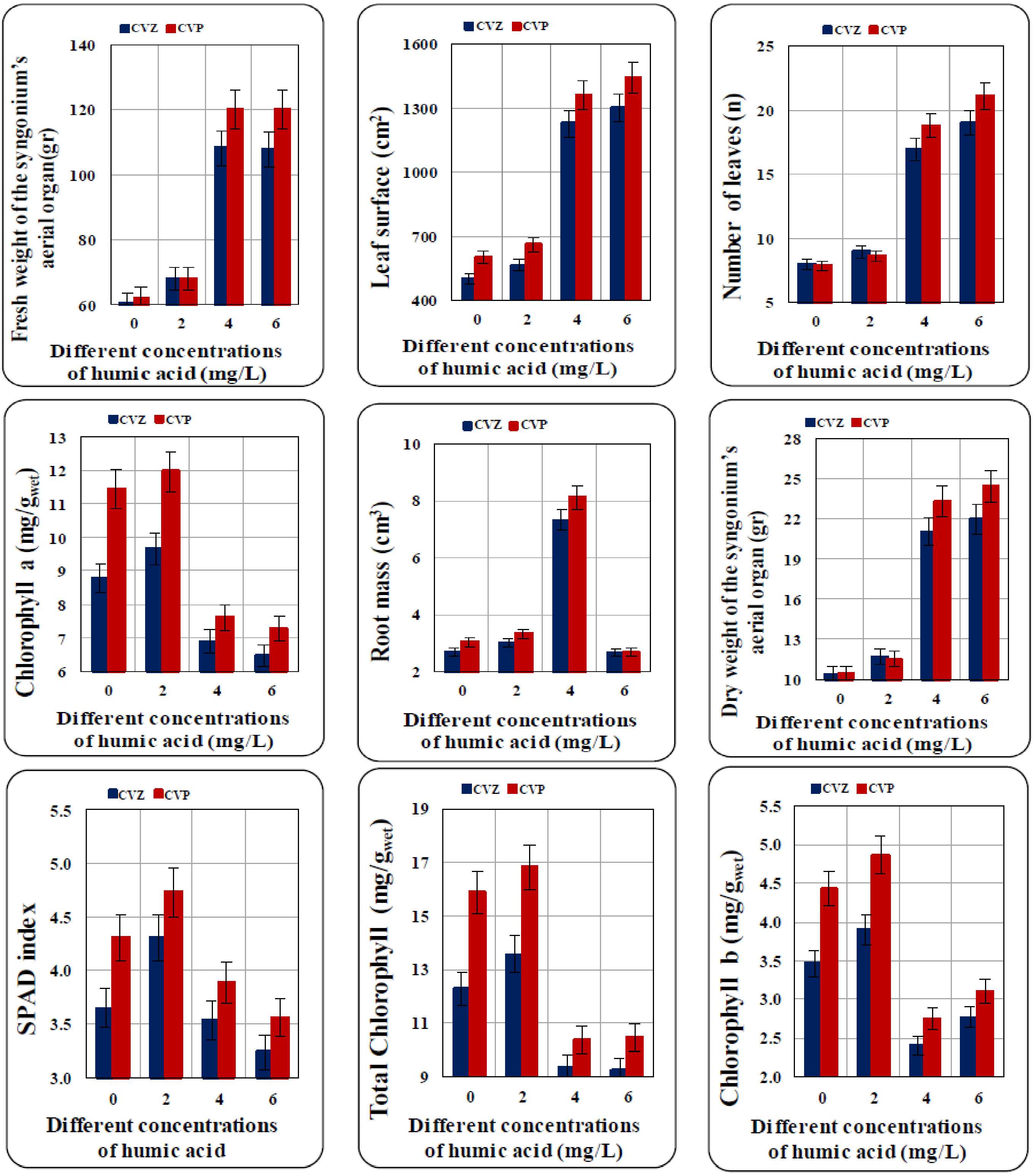
Furthermore, the results showed that both growing media types and humic acid solution concentrations affected chlorophyll a, b and total. The amount of each factor at 2 mg/L concentration reached its maximum level. Moreover, this variable was obtained more at all concentration levels in CVP growing medium. Considering the significance of various treatments for this variable, it could be claimed that the differences in chlorophyll a, b, and total are due to specific treatments on the plants. On average, at CVP, these variables were higher compared to them in the other growing medium (20%, 21%, and 20.56% respectively).

Considering the SPAD index and stomata index, the steps to rely on examination results were taken and in this case, the factorial examination results showed a significant difference between different treatment groups. Therefore, similar to the other cases, in the cultivation of the plants in CVP at 2 mg/L concentration, the highest amounts of SPAD index and stomata index were achieved. In addition, the average increase in these factors in CVP was 12% and 10%, respectively.

Finally, epidermis cell concentration and stomata concentration were evaluated. It was found that as other variables in CVP, there was a 10% and 9.7% increase. In both growing media types, with an increase in humic acid concentration, the range of this oscillation rises as well.

Regarding the length and width of the plants, the required steps to rely on test results were taken. In this factor, the plants in CVP growing medium under 2 and 4 mg/L humic acid treatment showed the highest numbers of these factors. It should be noted that the average increase in the length and width of the plants in CVP was 9.5% and 10.6%.

To investigate the effect of the available solution and the growing media types on Syngonium, tables depicting variable changes have been provided in the following.



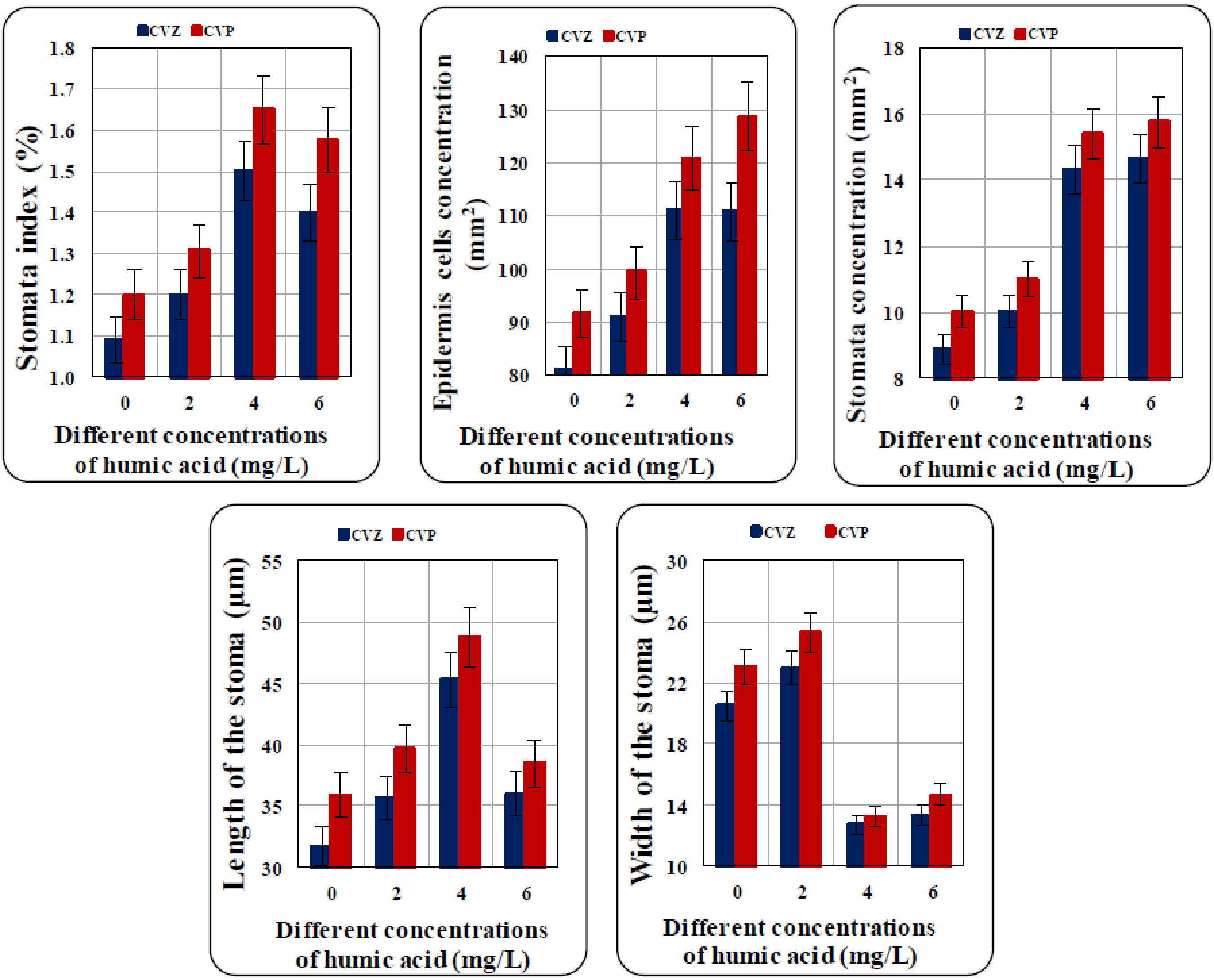



**Fig. 1:** Morphopysiological and biochemical responses of Syngonium to the growing media types and humic acid concentration levels in the green wall system

The Tables 3 and Figure 1 are used to show the effects of humic acid on Syngonium in two growing media of CVZ and CVP. In the first step, there was a control group, which only shows the influence of the type of growing media, in comparison to other parts and simultaneous interaction of the growing media and humic acid. Even at a low concentration level of humic acid (2 mg/L) no considerable changes were observed in the number of the leaves. In this variable, it is clear that at 4 mg/L concentration of humic acid, there was the highest number of leaves. This applies to both growing media types. In CVP, which acted better in pothos, the number of leaves increased.

It should be kept in mind that the leaf area had a similar behavior to the number of leaves. The reason for this is mentioned in the analysis section of pothos leaf area. In CVP, it had a higher amount of leaf area at all the humic acid concentration levels.

By referring to the tables of fresh weight changes of Syngonium's aerial organ, it is clear that an increase in humic acid concentration to 4 mg/L leads to a notable increase in the fresh weight of the aerial organs, followed by a gradual decrease. It should be taken into account that CVP growing medium constantly provides more weight in the aerial parts of the plant.

With a closer look at the relevant table, it is apparent that root mass at concentration level of 4 mg/L humic acid was the highest root mass. For concentrations over 4 mg/L, there was a sharp decrease in root mass.

Similarly, Chlorophyll a, b, and total showed similar reactions. The highest reaction and numbers of these factors happened at 2 mg/L humic acid. Then, by an increase in humic acid level, the reactions were reduced. In this case, the growing media types was very influential, and as it is evident in Figure 1, there is a major difference between two various growing media types of the present study.

By referring to the Figure 1, it could be implied that by adding the lowest level of humic acid (2 mg/L) the SPAD index increased. On the contrary, with an increase in humic acid concentration level up to 6 mg/L, there was a reverse trend and this index was decreased. In the growing media type of CVP, other variables showed better responses in Syngonium. The next examined factors were epidermis cell concentration and stomata concentration that the plants in CVP growing medium showed better responses. Adding humic acid to 4 mg/L, considerably increased the epidermis cell concentration. In concentrations above this level, the growth continued with a slower trend. In the other growing medium (CVP), stomata index and length had a better response and reached their highest level in concentration level of 4 mg/L. likewise, the same trend happened in stomata width in concentration level of 2 mg/L humic acid.

**Pothos**

In this section, the results of the experiment with pothos are provided. In the present study, the effect of two growing media types and four levels of humic acid concentration on 10 variables were examined. Findings and statistical analyses are provided in the following sections.

By implementing a factorial experiment, table of analysis of variance was given in table 4.

**Table 4:** Analysis of variance of different treatments in the pothos experiment

| Treatment | df | Number of leaves | Leaf surface | Fresh weight of the syngonium's aerial parts of the plants | Dry weight of the syngonium's aerial parts of the plants | Root mass | Chloro-phyll a | Chloro-phyll b | Total Chloro-phyll | SPAD index | Stomata index | stomata concentration | epidermis cells concentration | Length of the stomata | Width of the stomata |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Growing media+ humic acid | 7 | 279.6$^{**}$ | 813376.6$^{**}$ | 3888.9$^{**}$ | 65.1$^{**}$ | 5.1$^{**}$ | 3.0$^{**}$ | 0.1$^{**}$ | 3.61$^{**}$ | 0.68$^{**}$ | 0.11$^{**}$ | 24.37$^{**}$ | 734.71$^{**}$ | 113.41$^{**}$ | 77.41$^{**}$ |
| Growing media types | 1 | 22.04$^{**}$ | 30459.38$^{ns}$ | 651.04$^{**}$ | 12.04$^{**}$ | 0.38$^{**}$ | 5.32$^{**}$ | 0.18$^{*}$ | 8.52$^{**}$ | 0.74$^{**}$ | 0.04$^{ns}$ | 9.37$^{**}$ | 513.38$^{**}$ | 73.5$^{*}$ | 9.37$^{ns}$ |
| humic acid | 3 | 643.38$^{**}$ | 1885585.26$^{**}$ | 8829.15$^{**}$ | 147.02$^{**}$ | 11.62$^{**}$ | 4.04$^{**}$ | 0.18$^{**}$ | 4.49$^{**}$ | 1.33$^{**}$ | 0.22$^{**}$ | 52.82$^{**}$ | 1525.38$^{**}$ | 237.39$^{**}$ | 177.82$^{**}$ |
| Error | 14 | 1.1 | 3674.06 | 3.7 | 0.32 | 0.03 | 0.1 | 0.01 | 0 | 0.03 | 0.02 | 1.99 | 22.84 | 13.06 | 3.64 |

**$p\leq0.01$, *$p\leq0.05$, ns=non-significant.

**Table 5:** Comparison of the means of the measured factors in different treatments in pothos

| Growing medium | concentrations of humic acid | Number of leaves (n) | Leaf surface ($cm^2$) | Fresh weight of the syngonium's aerial parts of the plants (gr) | Dry weight of the syngonium's aerial parts of the plants (gr) | Root mass ($cm^3$) | Chloro-phyll a ($mg/g_{wet}$) | Chloro-phyll b ($mg/g_{wet}$) | Total Chlorophyll ($mg/g_{wet}$) | SPAD index ($mm^2$) | Stomata index (%) | stomata concentration ($mm^2$) | epidermis cells concentration ($mm^2$) | Length of the stomata (µm) | Width of the stomata (µm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CVZ | 0 | 9.33$^{d}$ | 501$^{c}$ | 71.7$^{d}$ | 12.7$^{d}$ | 1.9$^{d}$ | 3.0$^{d}$ | 2.1$^{b}$ | 5.1$^{d}$ | 3.9$^{bc}$ | 1.06$^{c}$ | 9.33$^{d}$ | 82.33$^{d}$ | 32.33$^{c}$ | 21.3$^{a}$ |
| | 2 | 10.33$^{d}$ | 556.7$^{c}$ | 79.3$^{cd}$ | 13.7$^{de}$ | 2.1$^{cd}$ | 5.0$^{ab}$ | 2.3$^{ab}$ | 7.3$^{abc}$ | 4.3$^{ab}$ | 1.2$^{bc}$ | 10$^{cd}$ | 91.33$^{cd}$ | 36$^{bc}$ | 23.33$^{a}$ |
| | 4 | 25.00$^{c}$ | 1283.2$^{b}$ | 139.7$^{b}$ | 23.0$^{s}$ | 4.7$^{b}$ | 4.3$^{bcd}$ | 1.9$^{b}$ | 6.3$^{bcd}$ | 3.53$^{cd}$ | 1.5$^{ab}$ | 14$^{abc}$ | 109.6$^{ab}$ | 45.3$^{ab}$ | 13$^{b}$ |
| | 6 | 28.33$^{ab}$ | 1616.7$^{a}$ | 136.3$^{b}$ | 16.3$^{bc}$ | 2.3$^{cd}$ | 3.3$^{cd}$ | 2.3$^{ab}$ | 5.6$^{cd}$ | 3.23$^{d}$ | 1.4$^{abc}$ | 14.67$^{ab}$ | 111.6$^{ab}$ | 35$^{bc}$ | 13.6$^{b}$ |
| CVP | 0 | 10.33$^{d}$ | 538.6$^{c}$ | 77.0$^{d}$ | 13.0$^{de}$ | 2.0$^{d}$ | 5.0$^{ab}$ | 2.2$^{ab}$ | 7.5$^{ab}$ | 4.2$^{ab}$ | 1.2$^{bc}$ | 10$^{cd}$ | 87.33$^{cd}$ | 34.6$^{bc}$ | 22.33$^{a}$ |
| | 2 | 11.33$^{d}$ | 612.3$^{c}$ | 87.7$^{c}$ | 15.0$^{cd}$ | 2.3$^{cd}$ | 6.0$^{a}$ | 2.5$^{a}$ | 8.5$^{a}$ | 4.7$^{a}$ | 1.3$^{abc}$ | 11$^{bcd}$ | 99.33$^{bc}$ | 38.67$^{bc}$ | 25.33$^{a}$ |
| | 4 | 27.67$^{bc}$ | 1408.3$^{ab}$ | 153.7$^{a}$ | 25.0$^{a}$ | 5.2$^{a}$ | 4.8$^{abc}$ | 2.1$^{ab}$ | 6.9$^{abc}$ | 3.9$^{bc}$ | 1.67$^{a}$ | 15.67$^{a}$ | 122.3$^{a}$ | 50.66$^{a}$ | 14$^{b}$ |
| | 6 | 31.33$^{a}$ | 1683.3$^{a}$ | 150.3$^{a}$ | 18.3$^{b}$ | 2.5$^{c}$ | 3.7$^{bcd}$ | 2.5$^{a}$ | 6.1$^{bcd}$ | 3.57$^{cd}$ | 1.33$^{abc}$ | 16.33$^{a}$ | 123$^{a}$ | 38.66$^{bc}$ | 14.67$^{b}$ |

Means followed by the same letters are not significantly different.

Based on the provided Table 4, there was significant interaction effect on all the measured morohophysiological and biochemical characteristics of pothos as the effect of growing media types and humic acid concentrations. Therefore, by replacing the CVZ growing medium with CVP, on average, there was a 9.6% increase in the average leaf numbers. Considering the significance level for this factor ($p\leq0.01$) in Table 5, the reason for this variation is the application of CVP growing medium.

In this study also, it was found that variations caused by different treatments had a significant effect on leaf area. All the two different growing media types and humic acid concentration levels, significantly increased a higher number for leaf area in the plants cultivated in CVP.

Taking into account the fresh weight of the aerial organs in pothos, CVP increased its weight by 9.8%. Since a significant effect was found between the treatments, this variation could be attributed to the CVP growing medium. The same results applies to the dry weight of the aerial parts of the plants. The results of this study showed that by adding CVP as the growing medium the dried part of the aerial organs gained 8.6% more weight compared to that in the other growing medium type.

In the data analysis of the root mass, changes resulting from the treatments were demonstrated. It was found that the root mass of the plants grown in CVP growing medium was higher than the average of this factor in the plants grown in CVZ growing medium. The results indicated a 9.5% higher amount of the plants in this factor when planted in CVZ. Also, at different concentrations of humic acid, significant effects on root masses of the plants were found. The findings signify the higher quality (5.3%, 79%, 10.7%, and 8.7%) of root masses of the plants cultivated in CVP growing medium in all the three concentration levels of humic acid.

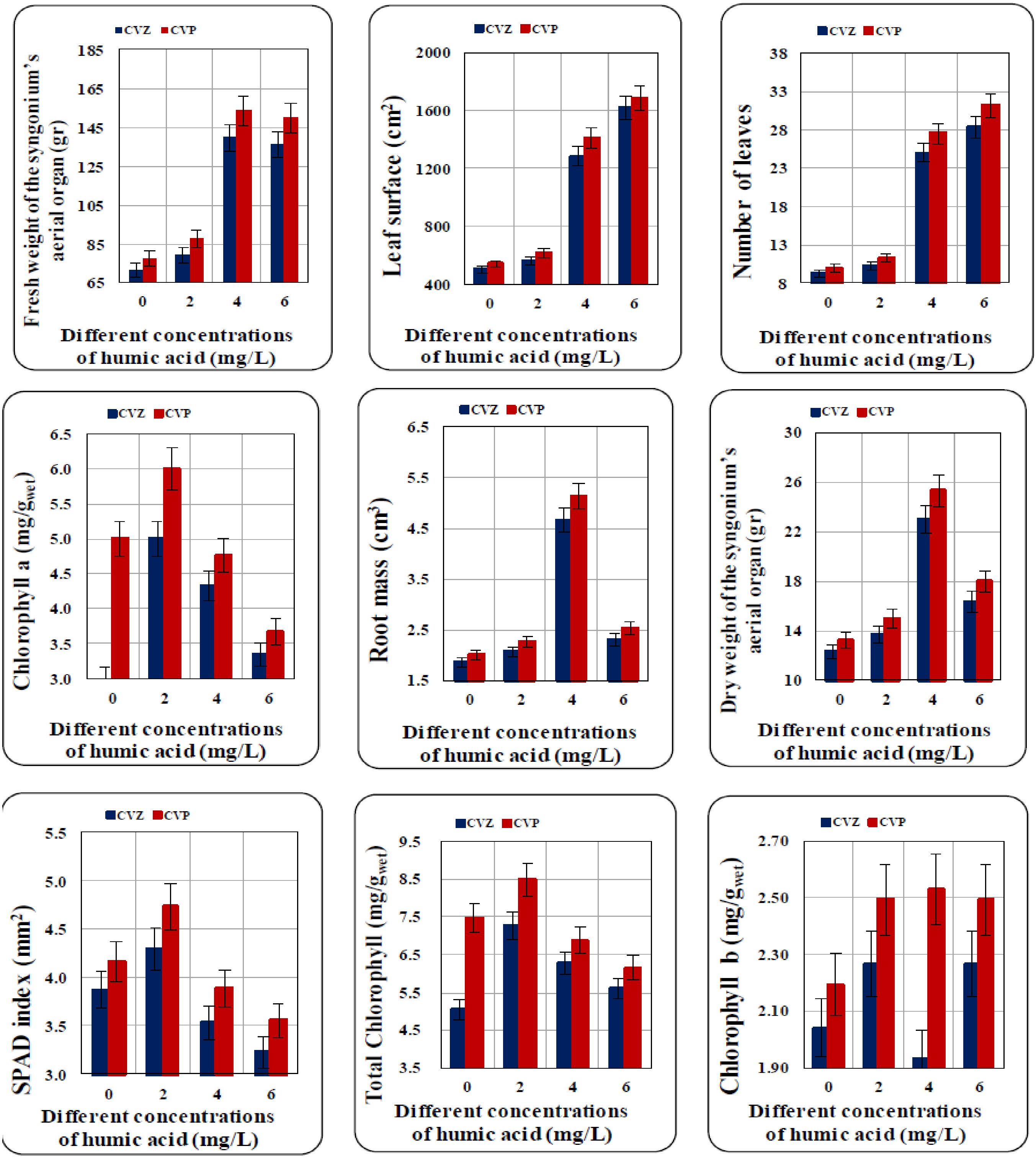
Results of the study showed that changes in humic acid concentrations and growing media types were also significantly effective in chlorophyll a, chlorophyll b, and total chlorophyll. Findings of this study demonstrated that both of the growing media types and humic acid concentration levels affected chlorophyll a, chlorophyll b, and total chlorophyll. These factors reached to their maximum 2 mg/L humic acid treatment. Moreover, the amount of this variable for all the humic acid concentrations in CVP was higher than that in the other growing medium type. Considering the significance of various treatments for these variables, such differences are due to various treatments applied on the variables. On average, chlorophyll a, chlorophyll b, and total chlorophyll of the plants in CVP had a higher amount than these variables in the plants cultivated in the other growing medium (23.9%, 8.4%, and 19.67%, respectively).

In the case of both culture media, the diagram for humic acid shows that only in dose 2 of humic acid, an increase in the number of SPAD compared to the control was observed. But in the other two doses, the reduction in humic acid is evident. But overall, the CVP platform performed better than the other platform. Also, In the case of stomata index, in both culture media, all concentrations of humic acid were able to increase this index compared to control. However, the highest rate of this index is related to the concentration of 4 mgr/l humic acids.

Also, similar results were obtained for epidermis and stomata concentrations. The results of factorial experiment, in table. 4 showed a significant effect between various treatment groups. It showed the significant influence of various treatments of the growing medium and various concentrations of humic acid on this plant type. Therefore, in these variables better results were obtained using the CVP growing medium. The mean of epidermis and stomata concentrations under CVP growing medium was higher than that in CVZ growing medium (Respectively. 12.2% and 10.4%).

Also, for the length and width of the stomata the results showed that cultivation on CVP at 4 and 2 mg/L was related with the highest numbers in these factors. It should be noted that the average increase in length and width of the stomata in CVP growing medium compared with that in CVZ growing medium was 9.3% and 7.2%, respectively.

To investigate the impact of various humic acid concentrations in each growing medium, some tables are given to illustrate the variation and the interaction effect of humic acid and growing media types on pothos



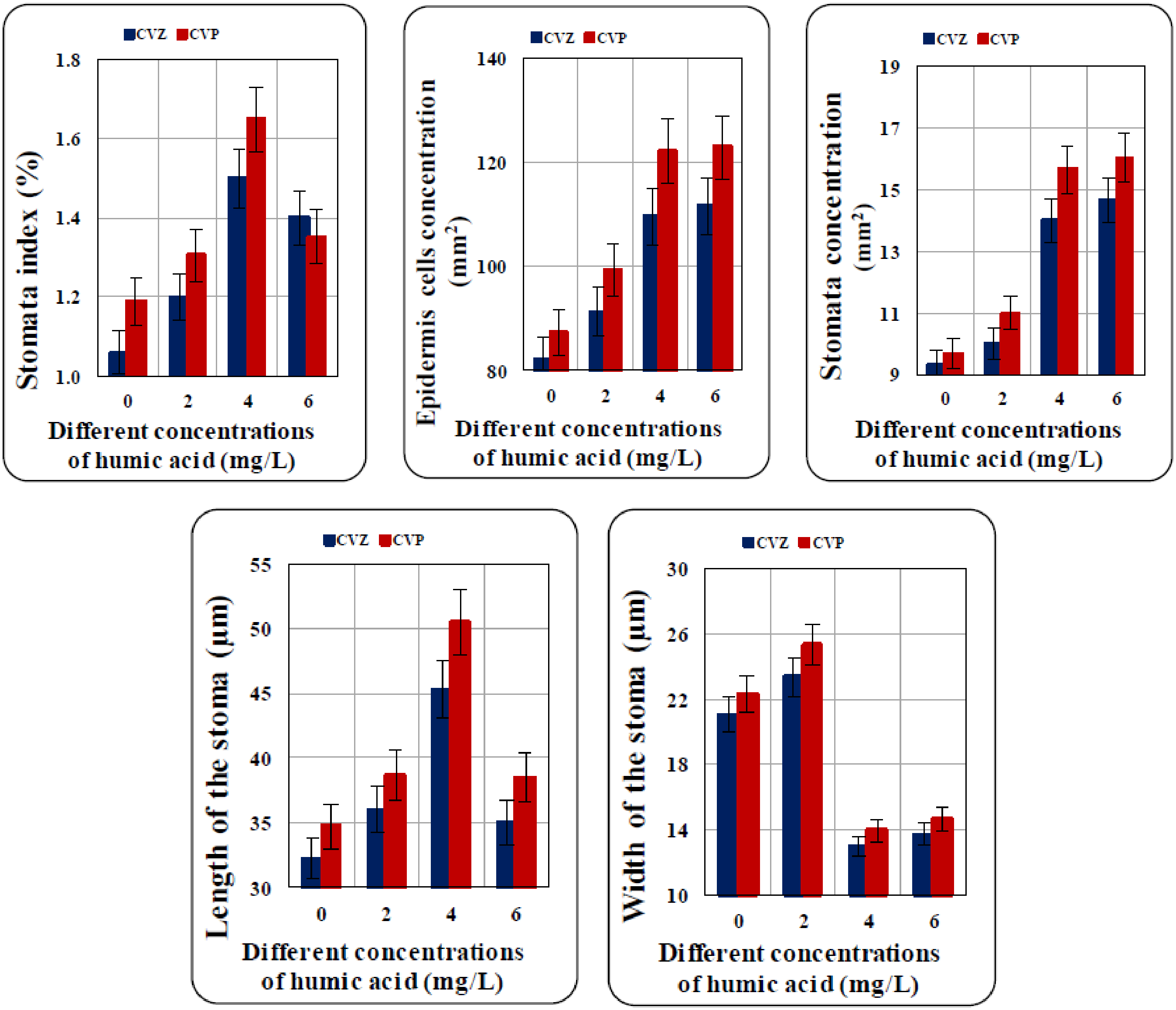



**Fig. 2:** Morphopysiological and biochemical responses of pothos to the growing media types and humic acid concentration levels in the green wall system

The Table 5 and Figure 2 are used to investigate the impact of humic acid on pothos in two different growing media types. They also showed the interaction effect of the growing media type and humic acid concentration levels. The results showed that with regard to the number of leaves, in the control groups that only the effect of the treatments exist much lower differences can be seen compared to the conditions when the interaction effects of the growing media and humic acid concentrations exist. Regarding this variable, the highest number of leaves were found at 4 mg/L concentration of humic acid. This applies to both growing media types but the number of leaves increased higher in CVP compared to the other the CVZ growing medium.

Similar analyses were conducted to investigate the differences on leaf areas under different treatments with humic acid and growing media types. By a closer look at figure 2, it can be illustrated that changes in this variable are similar to the changes on number of the leaves. This appears to be an expected relationship, since in most cases with the increase in the number of leaves, the leaf area would increase.

The next morphophysiological variable, was the fresh weight of the aerial part of the plants. It was shown that with an increase in humic acid concentration, the fresh weight of the aerial parts of the plants increased. This increase could be the influence of humic acid on water absorption or body of the aerial organs, which will be illustrated in dry weight of the aerial organs. By referring to the tables which shows the changes in dry weight of the aerial parts of the plants, it was found that an increase in humic acid concentration in the growing media types led to an increase in the dry weight of the aerial parts of the plants and this trend continued by increasing the concentration level of humic acid up to 4 mg/L. Regarding both factors of fresh and dry weight of the aerial parts of the plants changes in CVP showed a higher increase in the mentioned factors.

The next measured variable was the root mass. The pertinent table shows that root mass at 4 mg/L humic acid had the largest mass in both growing media types.

It should be noted that chlorophyll a increased with adding lower levels of humic acid. However, with higher increase on concentrations of humic acid, chlorophyll a gradually decreased. It should be noted that the levels of chlorophyll a in the plants cultivated in CVZ was always less than that in the plants cultivated in the other growing medium. With an increase in humic acid concentration level, there was less variation in chlorophyll a. The same is applied to total chlorophyll. The only difference was that the decline in total chlorophyll occurred later than the decline in chlorophyll a and this decline was started at 4 mg/L concentration level of humic acid treatment. However, this was not the case for chlorophyll b. The trend for the total chlorophyll in CVZ growing medium followed the same trend as for the CVP growing medium. However, changes from CVP to CVZ did not followed a regular trend. It should be kept in mind that the amount of changes in chlorophyll b after the treatments were also low and the irregularities showed in figure 2 is magnified.

The next examined chemical variables were SPAD and stomata indices. Looking at the given table, it could be implied that with a little increase in humic acid from 2 to 4 mg/L, the SPAD and stomata indices increased. In contrast, with an increase in application of humic acid these indices decreased. Responses of the SPAD index and stomata index of the plants to CVP were in higher level than that in the other growing medium. Other indices in this study were epidermis cell concentrations and stomata concentrations. After a number of experiments, it was shown that CVP could present better responses for these factors in the examined plants. Adding humic acid to 4 mg/L showed a drastic increase in epidermis cell concentration. Over this level of humic acid concentration, a gradual increase in the variables was observed.

The two variables of length and width of the stomata in the plants had a higher response in CVP growing medium. The maximum amounts were obtained in 4 and 2 mg/L concentration levels. Considering the significance of all intervening variables, these could be generalized to the other similar cases.

## Discussion

Humic acid together with calcium enhances nutrients in tomato and increased root growth, stem, number of leaves, fresh weight of the aerial organs, and fresh and dry weight of the root [28]. Furthermore, humic acid at various concentration levels influenced pepper and eggplant growth. It also increased sapling's stem thickness, leaf number, fresh and dry weight of the aerial organs, branches, and dry and fresh weight of the roots [29]. In this study, the results showed that humic acid has an effect on these properties (For the number of leaves, the concentration 6 and for the fresh weight, the concentration of 4 mg / l was the most appropriate). Humic acid in concentrations of 0, 1, 2, and 3 g/L influenced the height of the shrub, number of leaves, and dry and fresh weight of bean. It also accelerated its growth. Also, the amount of chlorophyll, flower's protein and N, P and K increased [30]. In the present study, the results showed that humic acid on both substrates affected chlorophyll a, b, total and wet and dry weight of the plant. In the Syngonium plant, the best responses for chlorophyll a, b, and total occurred at concentrations of 2, 4, and 2 mg / l, respectively, and for the pothos plant at concentrations of 2 mg / l. Humic acid influenced the quality and functionality of apricot and by mixing with branch and leaf compost increased fruit size, resilience and acidity of bio-growth of apricot tree [31]. Humic acid also affected the functionality and quality of mint. Treatment of 2000 mg/L humic acid showed the highest dry weight and height, as well as the highest number of leaves and flowers [32]. Also, in this study, humic acid has affected the weight (wet and dry) of the plant, the number of leaves for both Pothos and Syngonium plants. For dry weight, the best values for Syngonium and Pothos were 6 and 4 mg / L.

*Petunia grandiflora* Juss and *Nicotiana alata* Link & Otto were investigated with mixture of fallow soil (FS), Biolan peat (BP), acid peat (AP) and leaf compost and perlite. It was found that the leaf area, the number of flowers and photosynthesis increased [33]. In this study, it was concluded that perlite substrate has increased leaf area in the both of two plants. In a comparison between zeolite and perlite's role in lettuce growth, it was concluded that use of zeolite leads to an increase in growth, concentration, and N and K concentration in tissue and lower scouring of K [34]. Moreover, strawberry characteristics, namely leaf number, leaf area, root length and fresh weight of strawberry plant in soil mixture and various concentrations of perlite increased [35]. The study also found that in both culture media, the number of leaves, leaf area and wet weight of Pothos and Syngonium plants improved in both media. Adding perlite to the soil results in higher leaf number, stem thickness, height, leaf area, premature function and the number of fruits in cucumber [36]. Adding coco fiber to perlite increases leaf water, NAR, perspiration, along with increase in leaf number and leaf area [37]. In this study, these results were obtained for Pothos and Syngonium plants for CVP substrate.

The same factor has improved the biochemical properties of the plant Pothos and Syngonium. In another study Applying vermicompost with different percentages to tomato sapling reduces total porosity, percentage of air, pH and ammonium concentration in soil. The largest growth happened in treatments of 25% and 50% vermicompost [38]. In addition, vermicompost prevents fast withering of tomato [39]. The results of our study on soil acidity reduction with vermicompost application and better absorption of nutrients were consistent with the results of these researchers.

Using a 5% vermicompost as an alternative mixed growing medium enhances biomass and growth index, as well as the greenery of the ground cover plants [40]. Jozay *et al*. reported that vermicompost containing 17%-36% humic acid and 13-30% folic acid contain Organic materials. With this in mind, the above factors could be considered as the reason for the acidity of the growing media caused by vermicompost. Also, acidity of the growing medium plays an important role in iron and magnesium absorption [41]. A decrease in pH of the around the root leads to higher dissolution of compounds including iron, magnesium and zinc. In addition, it improves absorption of these elements by roots [42]. Due to the use of vermicompost, the pH around the roots is reduced and the organic compounds in the substrate are more easily absorbed.

Cocopeat and perlite mixture prompted growth and germination of *Anthurium anderanum cv. Terra* (from Araceae family) [43]. Mixture of cocopeat and moist gunny bag have also been used for germination and growth of mango. It showed that amount of germination, percentage of germination, mortality percentage, sapling growth characteristics, leaf number, leaf area, stem thickness, root growth, heart length, lung weight, lung capacity, aerial organ mass and fresh weight of the plants had significant effects in a period of ten days [44]. In this study, the results also showed that the variables expressed improved under the influence of different treatments. It should be noted that the other specifications considered in this study were improved under the influence of the changes. In the analysis and results section, it is described in detail. In Kaya *et al*.'s report, the use of humic acid shows an increase in the absorption efficiency through young leaves as well as the porous density in beans [45] the present study also found that the use of humic acid improves the density of the orifice.

In a study of apple trees, Yu *et al*. Strengthened their biochemical and physiological properties by using humic acid. The use of humic acid increased the length and width of the opening and subsequently increased plant photosynthesis [46]. The use of humic acid increases the leaf stomata of the apple tree. Increasing the length and width of the apple leaf stomata prevented the leaf from burning in tropical conditions and increasing photosynthesis operations [47].

In the present study, it was shown that at a concentration of 2 mg / l of humic acid, the maximum stomata width and at a concentration of 4 mg / l, the maximum stomata length was obtained for both plants.

## Conclusion

According to the findings of this study, the cultivation of two plant species, Pothos and Syngonium, was recommended for indoor green wall conditions installed in balcony conditions. Cultivation of these two plant species in the cocopeat, vermicompost and perlite culture bed had the most beauty and greenery and this bed is recommended for use in interior green walls. It is also recommended for supplementary feeding for both plant species of foliar application once a week at a dose of 4 mg / l of humic acid.

To sum up, it was found based on the study on Pothos and Syngonium that the results of different treatments had significant effects in morphophysiological and biochemical factors on these plant types. Using cocopeat, vermicompost and perlite growing medium had better responses on the mentioned plant types on the green wall system. This finding was evident in leaf number, leaf area, dry and fresh weight of the aerial organs, chlorophyll a, chlorophyll b and total chlorophyll, as well as SPAD index and epidermis cell concentration.

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