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Enhancement the Growth Performance and Photosynthetic Pigments of *Echinacea Purpurea* Plants by Using Some Natural Materials.

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Abstract

Two summer field (2022 and 2023) purpose of this study were conducted to examine the consequences of humic acid soil as addition as well as Extraradicular applying of salicylic acid (200 and 400 mgL^{-1}), alginic acid (250 and 500 mgL^{-1}.) plus chitosan (250 and 500 mgL^{-1}.) on growth performance and chlorophyll concentration of echinacea (*Echinacea purpurea* L. Moench). compared with control plant (Distilled water). The findings demonstrated that every treatment considerably enhanced different studied growth parameters and photosynthetic pigments of echinacea plants compared with control during both seasons. In addition, the foliar spray treatments included salicylic acid at 200 mg L^{-1}, in addition to chitosan at 500 mg L^{-1}. individually or in addition to humic acid drench it significantly improved all the aforementioned growth traits, as well as pigments involved in photosynthetic (carotenoids, chlorophyll a, b, and chl. a + b) compared with the other tretments during both seasons. The most successful treatment in this regard was adding humic acid to the soil together with 200 mgL-1 of salicylic acid. Generally, the foliar spraying treatments with low concentration of salicylic acid and high concentration of chitosan in combination with humic acid as soil addition, were the best treatments for enhancing the growth and higher photosynthesis pigments content of echinacea plants under normal conditions. So this study recommend using it, salicylic acid (200 mgL^{-1-}) plus chitosan (500 mgL^{-1}.) foliar application and humic acid to the soil at the same field conditions.

Keywords: *Echinacea purpurea* L., growth, photosynthesis pigments, natural materials, salicylic acid, alginic acid, chitosan, humic acid.

1. Introduction

Among the most significant and renowned medicinal plants throughout the world is *Echinacea purpurea* L. Moench, the purple coneflower, is a perennial plant belonging to the Asteraceae (Compositae) family. Numerous classes of bioactive chemicals have been linked to its biological characteristics **(Manayi *et al.* 2015)**. *Echinacea purpurea* has gained attention due to its immune-boosting and anti-inflammatory properties, making it a crucial resource in both traditional and modern medicine. Apart from bacterial infections like colds, rheumatic infections and infections of eye, the raw dried root and shoot are utilized as a powder to make a calming tea for body aches, or as extracts in capsules to boost the immunological system of the body **(Kindscher and Wittenberg 2016 and Burlou-Nagy *et al.*, 2022)**. The plant is utilized to treat respiratory, urinary, and common colds as well as the flu. It has demonstrated antibacterial, antiviral, antifungal, and antioxidant qualities **(Oniszczuk *et al.* 2019, Raissy *et al.* 2021)**. Alkamides, polysaccharides, glycoproteins, flavonoids, and phenolic compounds are the most significant constituents of echinacea **(Burlou-Nagy *et al.* 2022)** which provide the genus its therapeutic qualities. However, it should be noted that derivatives of caffeic acid, including echinacoside, cichoric acid, cynarin, chlorogenic acid, and caftaric acid are significant possible active chemicals in purple coneflower. Cichoric acid and echinacoside are two of these chemicals that are important and have important plant pharmacological characteristics.

Salicylic acid (SA), is one of the phenolic substance, it is a significant plant hormone and signaling molecule that regulates the growth and stress tolerance of plants **(Peng *et al.*, 2021)**. SA is found in very small amounts in plant tissues and is essential in controlling several physiological and biochemical processes, overall membrane permeability, ion uptake and transport, stomatal closure, which further prevents ABA's impacts on abscission of leaf, inhibition of ethylene biosynthesis, thermogenesis, photosynthetic rate, raising the content of chlorophyll and carotenoid pigments, flower induction, also, altering the action of some of key enzymatics **(Hayat and Ahmad, 2007 and Emamverdian *et al.*, 2020)**. Previous research on medicinal and aromatic plants has shown that SA enhances plant growth features and boosts plant production (**Nasseralla and Almukhtar, 2023 and El-Naggar *et al.*, 2024**).

Marine plants, including kelp and seaweed, contain alginic acid, a type of naturally occurring polysaccharide polymer (**Liu and Zhang 2015**). Either L-glucuronic acid, β-D-mannuronic acid, or both heterogeneously bound by β-1,4-glycosidic linkages make up alginate. An abundant organic material found in nature, alginate yields 30,000 metric tons annually **(Donati *et al.*, 2009; Szekalska *et al.*, 2016)**. In agricultural applications, alginic acid is frequently employed as a natural stimuli. It can support the development of plants. Additionally, alginic acid can enhance crop quality. Additionally, alginic acid is crucial for boosting the resilience of plants to biotic and abiotic stressors (**Van Oosten *et al.*, 2017**).

Chitosan is a naturally occurring biopolymer that aids in growth of plant, yield also immunity **(Pongprayoon *et al.*, 20I3*;* Sultana *et al.*, 2019)**. Even in chemical fertilizer absence, the use of chitosan in agriculture can significantly boost the population of microorganisms plus convert organic elements into inorganic forms. nutrients that are readily taken up by the roots of plants **(Bolto *et al*., 2004)**. Additionally, Chitosan treatment can create plants less vulnerable to environmental stressors like temperature, salt, and drought **(Lizarraga-Pauli *et al.*, 2011; Jabeen and Ahmad 2013; Pongprayoon *et al.*, 2013)**. It is regarded globally as an environmentally safe, able to break down adaptable polymer that has a variety of uses in addition to being a viable and affordable supplier of flexible and efficient component for crop safety **(Geisberger *et al.*, 20I3; Zhang *et al.*, 2012)**. Therefore, chitosan has a broad range of applications in several agricultural fields, such as crop cultivation and preservation, warehousing and nutritive value of crops.

Humic acid, a macromolecular organic weak acid molecule that is created via the microbial decomposition of animal and botanical residues, soil, water, as well as coal all contain humic acid **(De Melo *et al.*, 20I6; Liang *et al.*, 2O23)**. Its molecules can bind with various soil metals by engage in exchange, adsorption, chelation, and complexation because they usually comprise a range of functional groups like carboxyl, carbonyl, and quinone **(Lee *et al.*, 2023)**. Humic acid has ability to increase crop resistance and boost crop growth. **(Guo *et al.*, 2019).** Because humic acid has a large exchange capacity for positive ions, it is the most significant component of humus **(Chen *et al.*,2020).** Micronutrients and humic acid can combine to produce stable, insoluble complexes **(Vikram *et al.*, 2022**). Additionally, it restores soil health and improves the physical, biological, and chemical properties of soil. By generating proline and decreasing the uptake of alkaline ions, humic substances can lessen the impact of environmental challenges like salinity and drought on plants. They can also boost photosynthesis and enzymatic activity in plants **(Yang *et al.*, 2023)**. Humic acid's biostimulatory effects on enhancing plant performance have been documented in numerous studies **(Muscolo *et al.*, 2007; Schmidt *et al.*, 2007; Mora *et al.*, 2010, 2014; Olaetxea *et al.*, 2019; Zanin *et al.*, 2019; Souza *et al.*, 2022)**. boosted nutrient use efficiency **(Jannin *et al.*, 2012; Zanin *et al.*, 2018)**, improve produce **(Man-hong *et al.*, 2020; Shen *et al.*, 2020a)**.

This study aimed to:

Study the effect of some natural materials salicylic acid, alginic acid, chitosan with and without humic acid as drench on growth performance, physiological plus metabolic features as well as improves the growth, physical and chemical compounds properties of echinacea (Echinacea purpurea) plants.

2. Materials and Methods

Through the two summer grown seasons of 2022 plus 2023, undertaken in the Experimental Farm Station - Faculty of Agriculture Moshtohor, Benha Univ., Qalubia Governorate, Egypt, to investigate the effects salicylic acid at 200 and 400 mgL^{-1}., alginic acid at 250and 500 mgL^{-1}. and chitosan at 250 and 500 mgL^{-1}. with and without humic acid as soil addition compared with control plant (Distilled water). on growth characteristics and photosynthetic pigments concentration as (carotenoids, chlorophyll a and b) of echinacea plants.

Sigma Company provided *Echinacea purpurea* seedlings that were 8–10 cm tall and had four–five leaves. In both seasons, the seedlings were transplanted into clay loam soils in the middle of April **Table (1)** To give the right amount of moisture for growth, the soil was immediately watered. As advised in this area, all traditional cultural methods for cultivating echinacea plants were adhered to

The study treatments were as follows:

This study contain 14 treatments, that were a mix of humic acid soil addition 3 kg/feddan and six treatments of salicylic acid, alginic acid and chitosan as follows:

Control (Distilled water), SA at 200 mgl^{-1}., SA at 400 mgl^{-1}., AA at 250 mgl^{-1}., AA at 500 mgl^{-1}., Chit. at 250 mgl^{-1}., Chit. at 500 mgl^{-1}., Humic acid as soil application 3 kg/fadden, SA at 200 mgl^{-1} + HA as soil application., SA at 400 mgl^{-1} + HA as soil application., AA at 250 mgl^{-1} + HA as soil application., AA at 500 mgl^{-1} + HA as soil application., Chit. at 250 mgl^{-1} + HA as soil application., Chit. at 500 mgl^{-1} + HA as soil application.

Table 1. Physical and chemical features of the research soil in the middle of April and 2022 as well as 2023 seasons at the Faculty of Agri., Moshtohor, Benha Univ., Qalubia Governorate.

Soil examination	Seasons	
	2022	2023
	Prior to planting	Prior to planting
Soluble cations plus anions (mmolec L^{-1})		
Ca^{++}	23.6	25.0
Mg^{++}	15.0	18.0
K^{+}	3.4	3.9
Na^{+}	11.8	14.6
Cl^{-}	21.5	23.0
CO_3^{2-}	-	-
HCO_3^{-}	5.0	6.0
So_4^{2-}	22.6	27.4
Chemical evaluation		
E.C* (dSm^{-1})	6.0	5.6
PH	7.3	7.2
Soluble salits Conc. (PPM)	4800	4480
O.M (gKg^{-1})	1.55	1.69
$Caco_3$ (gKg^{-1})	1.42	1.55
Accessible N (mg/kg^{-1})	22.9	25
P Accessible (mg/kg^{-1})	9.52	11
Accessible K (mg/kg^{-1})	126	124
Particle size variations (Physical study)		
Course sand %	5.95	3.12
Find Sand %	23.55	22.85
Silt %	14.10	24.97
Clay %	51.25	45.10
Soil texture	Heavy Clay	Heavy Clay

Three replicates and a split plot design were used for this investigation. Humic acid was applied to the soil in the main plot. On the other hand, the subplot was dedicated to treatment sprays, which included SA at 200 plus 400 mgL^{-1}, alginic acid at 250 and 500 mgL^{-1}, chitosan at 250 and 500 mgL^{-1}, in addition to control (dis. water). Three different allocated treatments were sprayed on the plants during their growth and development. The first spray was applied 60 days following implantation and it was reiterated every fifteen days. The volume of the spraying solution was applied till the plants out of stock the solution. Every cultural practice was carried out as advised.

Sampling and collecting data:

1. Vegetative growth Aspects:

Ninety days following transplanting, 3 echinacea plants from all treatment were selected at random to measure plant growth features (i.e., height of plant, stem thickness, branches No., suckers No./plant, leaves number/plant, total leaf area, stems D.W, leaves D.W, in addition to shoots dry mass g/plant). The dry weight per plant was determined after samples of the vegetative portions above ground were sun-dried over 72 hours to a consistent weight.

2. Determination of Photosynthetic pigments:

A- Colorimetric measurements of chlorophyll a, b, and carotenoids (mg/ g DW) were made in the foliage of echinacea plants 75 and 90 days after transplanting throughout both seasons using the techniques outlined by **Wettstein (1957)** and calculated as mg/g fresh weight.

Statistical analysis:

The study's data were statistically examined using the techniques outlined by **Snedecor and Cochran (1989)**. Employing the statistical software program MSTAT-C **(Michigan state university, 1983).**

3. Results and discussion

1. Growth parameters of echinacea plants:

Data in **Tables (2, 3 and 4)** cleared that there were significant differences between applied soil treatments with and without humic acid in every vegetative growth trait of echinacea plants examined during the course of the two growth seasons. In this context, soil application with humic acid yielded the most elevated values of all the morphological traits of echinacea plants that were evaluated. Conversely, soil without humic acid gave lower values in every vegetative growth measurement over the duration of the both study seasons. These variations between the assessed soil treatments with and without humic applied may be due to the different roles and benefits of humic acid to soil and plants.

In this respect **Gheware *et al.*, (2025)** announced that humic acid as soil application significantly affected vegetative growth characteristics on Dahlia (*Dahlia variabilis* L.). **El-Nashar (2021)** disclosed that humic acid has significantly effect on calendula plant vegetative growth parameters (i.e. height of plant (cm), branches No. /plant, leaves No./plant, leaf area/plant (cm2) plus dry mass of shoot /plant (g).

As for growth stimulants (Foliar spray) Data in **Tables (2, 3 and 4**) illustrated that all attributes of growth (such as plant height, stem diameter, branches No., Suckers No./plant, leaves No./plant, total leaf area/plant, dry weight of stems, leaves dry weigh plus shoots dry weight g/plant). were greatly enhanced by several applied treatments (i.e., salicylic acid 200 and 400 mgL^{-1}., alginic acid at 250 and 500 mgL^{-1}.and chitosan at 250 and 500 mgL^{-1}.). As show in **Tab1e (2**) height of plant, stem thickness and branches number/plants were gave maximum returns with salicylic acid at 200 mgL^{-1}. Meanwhile, the lowest value was the control at 75 & 90 days post transplanting during 2022 plus 2023 growing seasons respectively.

Data in **Table (3)** showed that the suckers number/plant, No. of leaves/plant also total leaf area/plant show a clear increase with various utilized treatments (such as salicylic acid 200 & 400 mg L^{-1}, alginic acid at 250 and 500 mg L^{-1}, and chitosan at 250 & 500 mg L^{-1}) at 75 and 90 days after transplanting in both seasons. The highest increase was with salicylic acid at 200 mg/L. Meanwhile, control treatments at 75 and 90 days after transplanting during both seasons, in that sequence.

Data in **Table (4)** showed that stems dry weight/plant (g), leaves D.W./plant (g) and shoots D.W./plant(g) were enhanced by the use of salicylic acid 200 & 400 mg L^{-1}., alginic acid @ 250 & 500 mg L^{-1}.and chitosan at 250 & 500 mg L^{-1}.) compared with the control at 75 and 90 days after transplanting during 2022 and 2023 seasons. salicylic acid at 200 mgL^{-1}. had the highest increase in these traits during both seasons. Meanwhile, control treatment gave the lowest value for these treats at 75 and 90 days during 2022 and 2023 seasons.

The usage of growth stimulants, which are crucial and play a major role in improving plant metabolism and, consequently, plant development, is responsible for these increases in vegetative growth features of echinacea plants. Similar outcomes were obtained in this regard by **Dastyar *et al.*, (2019) and Saeed and Zafar-ul-hye (2024).**

Interaction effect of treatments between humic acid (soil addition) and leaf spraying by several bio-stimulants includes several substances that enhance growth performance expressed as height of plant, stem thickness (cm), number of branches No., suckers/ plant, leaves number, leaves D.W./plant (g), Stems D.W./plant(g) and Shoots D.W./plant(g) as indicated via **(Tables 2, 3 and 4)** the greatest results in all studied growth attributes results from spraying echinacea plants with salicylic acid at 200 mg L^{-1}.+ HA(as drench) followed by chitosan at 500 mg L^{-1}.+ HA(as drench), alginic acid at 500 mg L^{-1}.+ HA(as drench), chitosan at 250 mg L^{-1}.+ HA(as drench)in descending order.

As shown in **Table (3)** total leaf area /plant (cm^2) was considerably elevated with various applied usage @ 75 & 90 days after transplanting within the two growing seasons. The exception was that high significant increase in leaf area/plant with the applied concentration of salicylic acid at 200 mgL^{-1}. + HA(as drench) followed by chitosan @ 500 mgL^{-1}. + HA(as drench), alginic acid at 500 mgL^{-1}. + HA(as drench) and chitosan @ 250 mg L^{-1}. + HA(as drench) gave the maximum value with these traits when compared to the control throughout the growth seasons of 2022 &2023.

In this context, the obtained maximize in the morphological performance it might be linked by the advantages of using bio-stimulants material like as (SA, AA, chit. & HA soil addition on cell division, elongation, cell differentiation, plant performance of different parts **Raheem *et al.*, (2018) and Gheware *et al.*, (2025).** Moreover, Salicylic acid treatment enhances and affects the growth, development and cells and tissues differentiation, subsequently improving growth parameters according to **(Helgi and Rolfe 2005)**. Chitosan, as a plant growth promoter, increases the rate of photosynthesis during development, thereby contributing to the elongation of the stem. The rise of the diameter of the stem is a result of the plant's relatively healthy growth, which happens because of the sufficient availability of nutrients. An increased rate of photosynthesis signifies favorable growth. Increased carbohydrates are transported into the phloem and utilized to promote secondary growth, resulting in the enlargement of stem cells and the stem's thickness **(Mondal *et al.*, 2012)**. Additionally, Humic acid is crucial for the growth of leaf area by lowering pH and enhancing iron absorption **(Hanafy Ahmad *et al.*, 2010).**

Typically, use of bio-stimulating material treatments (SA @ 200 & 400 mgL^{-1}, alginic acid at 250 and 500 mgL^{-1}, chitosan at 250 and 500 mgL^{-1}, & HA as drench) could contribute positively to the effects of these various bio-stimulating materials on growth. It provided the most significant positive impact on all measured growth aspects by enhancing growth promoters, serving as a good indicator for improving all other measurements in echinacea plants. Our findings regarding humic acid align with those presented by **Gheware *et al.* (2025)** concerning Dahlia plants. For salicylic acid, it was reported that salicylic acid notably enhanced the vegetative growth features of various plants. **Ghatas (2020)** focused on the Coriander plant, while **Abdelsadek *et al.;* (2021)** on *Dendrantheman grandiflorum*. As for alginic acid; **Aly *et al.*, (2024)** on lettuce plant, for chitosan **Aghjedarbandi *et al.*, (2018)** on coneflower plant.

.2. Photosynthesis pigments of echinacea plants:

As for the effect of humic acid soil addition treatments, Data presented in Tables (5 and 6) showed notable differences in the content of photosynthesis pigments, including chlorophyll a, chlorophyll b, chlorophyll (a+b), and carotenoids, in echinacea plants between those treated with humic acid soil addition and those untreated without humic acid during both experimental seasons of 2022 and 2023. In this regard, treating soil with humic acid demonstrated a significant increase in Ch a, Chl.b, Ch (a+b), carotenoids, and Chl. (a+b)/carot. in echinacea plants. Conversely, untreated plants exhibited the lowest values for these traits in both the 2022 and 2023 seasons

The variations in the treatments examined could be attributed to the differences and active functions of humic acid for plants. These findings align with those of **Talebi and Jabbarzadeh (2018)**, who reported that applying humic acid (HA) to the soil could enhance both the photosynthesis rate and the chlorophyll index (SPAD) of the china rose plant in comparison to the control.

Regarding the impact of the treatments applied, the data in Tables 5 and 6 indicate that the various applied treatments led to a significant rise in the concentrations of chlorophyll a, b, and carotenoids at 75 and 90 days post-transplanting in both the first and second seasons. Additionally, it was observed that the highest enhancement of all these pigments in the leaves occurred with salicylic acid at 200 mgL^{-1}, followed by chitosan at 500 mgL-1, at 75 and 90 days post-transplanting during the 2022 and 2023 seasons. In the same periods, the control produced the minimum values for the same traits at 75 and 90 days in the 2022 and 2023 seasons, respectively.

Our findings align with numerous earlier studies that discovered that usage of salicylic acid (SA) notably maximized chl-a levels, chl-b levels, total chlorophyll pigments, and carotenoid levels in marigold plants. Thus, it was proposed that salicylic acid directly modifies the functions of specific enzymes, while defensive control genes also trigger specific alterations in chloroplast structure and leaf quantity, which are crucial for the energy status of plants **(Basit *et al.*, 2018)**. Moreover, **Dastyar *et al.* (2019)** demonstrated that applying salicylic acid as foliar at both 1 and 2 mM levels considerably enhanced most physiological traits, including total chlorophyll and carotenoids, *of Echinacea purpurea* L. plant

Regarding the impact of interaction, the data in (Tables 5 and 6) distinctly shows that all treatments involving humic acid as a soil addition and foliar applications of certain growth stimulant compounds enhanced the levels of photosynthetic pigments, indicated by chlorophyll a, chlorophyll b, total chlorophyll a+b, carotenoids, and the ratio of chlorophyll a+b to carotenoids in the leaves of echinacea plants at 75 and 90 days post-transplanting across both seasons. Additionally, the maximum levels of all assessed photosynthesis pigments were observed in echinacea plants treated with foliar applications of salicylic acid at 200 mgL^{-1}, combined with humic acid (added to the soil), and chitosan at 500 mgL^{-1}, also paired with humic acid (as soil addition) in comparison to untreated specimens.

In this context, the rise in chlorophyll levels may be linked to the stimulating effects and physiological contributions of humic acid, salicylic acid, chitosan, and alginic acid on chloroplasts and photosynthetic pigments. Regarding humic acid **El-Kinany *et al.*, (2020)** demonstrated that the application of humic acid at a rate of 3 Kg/Fadden to Roselle plants resulted in the highest levels of chlorophyll a (17.72 and 18.03 μg/mL), chlorophyll b (8.47 and 8.19 μg/mL), and total carotenoid contents (3.95 and 4.09 μg/mL) during the first and second seasons, respectively, in comparison to the control, which recorded (12.17 and 12.71 μg/mL), (6.21 and 6.51 μg/mL), and (3.71 and 3.75 μg/mL), respectively. **Abdel-Latef *et al.*, (2024)** reported that salicylic acid using on *Celosia argentea* at rats of (0, 300, & 450 ppm) significantly improved the levels of Chlorophyll A, Chlorophyll B, and Carotenoids of leaves when compared to the control plant. **Moreover, Abdelsadek *et al*.; (2021)** on chrysanthemum plant. For chitosan many researchers found that spraying chitosan improved chlorophyll content **Aghjedarbandi *et al.*, (2018) and Abdul-Hafeez and Ibrahim (2021)**.

Table 2. Impact of various applied treatments on specific morphological traits (plant height, stem diameter plus branches number for echinacea plant at 75 and 90days post transplanting within 2022 & 2023 seasons**.**

Features		Plant height(cm)/plant				Stem diameter (cm)/plant				Branches number/plant			
		2022		2023		2022		2023		2022		2023	
Treatments		75DAYs	90DAYs	75DAYs	90DAYs	75DAYs	90DAYs	75DAYs	90DAYs	75DAYs	90DAYs	75DAYs	90DAYs
A-soil application													
Without Humic acid		15.500^{A}	46.500^{B}	12.976^{B}	42.810^{B}	0.690^{A}	0.852^{A}	0.586^{A}	0.719^{A}	4.810^{A}	14.762^{A}	4.143^{A}	13.476^{B}
With humic acid		16.881^{A}	50.619^{A}	15.810^{A}	49.190^{A}	0.790^{A}	0.910^{A}	0.705^{A}	0.810^{A}	5.667^{A}	18.429^{A}	4.381^{A}	16.000^{A}
B – foliar spraying													
Control		10.750^{E}	39.333^{D}	12.976^{C}	36.583^{D}	0.483^{E}	0.667^{C}	0.433^{D}	0.617^{C}	2.833^{D}	10.000^{B}	2.333^{C}	8.667^{C}
Salicylic acid at 200 mgL^{-1}.		20.417^{A}	57.417^{A}	15.810^{A}	52.583^{A}	0.917^{A}	0.967^{A}	0.800^{A}	0.833^{AB}	7.667^{A}	21.000^{A}	5.833^{A}	18.833^{A}
Salicylic acid at 400 mgL^{-1}.		15.333^{CD}	46.250^{C}	9.750^{B}	43.167^{C}	0.700^{CD}	0.833^{B}	0.617^{C}	0.750^{ABC}	4.500^{CD}	15.333^{AB}	4.000^{ABC}	14.167^{AB}
Alginic acid at 250 mgL^{-1}.		14.500^{D}	45.083^{CD}	18.750^{B}	46.750^{ABC}	0.667^{D}	0.900^{AB}	0.583^{C}	0.733^{BC}	4.000^{CD}	15.667^{AB}	3.333^{BC}	13.167^{BC}
Alginic acid at 500 mgL^{-1}.		17.417^{BC}	49.833^{BC}	14.083^{B}	47.833^{ABC}	0.800^{BC}	0.917^{AB}	0.683^{ABC}	0.783^{AB}	5.667^{BC}	18.000^{A}	5.000^{AB}	15.500^{AB}
Chitosan at 250 mgL^{-1}.		15.750^{CD}	48.333^{BC}	13.083^{B}	45.083^{BC}	0.733^{CD}	0.900^{AB}	0.650^{BC}	0.750^{ABC}	5.000^{C}	16.333^{AB}	4.167^{ABC}	14.833^{AB}
Chitosan at 500 mgL^{-1}.		19.167^{AB}	53.667^{AB}	14.833^{A}	50.000^{AB}	0.883^{AB}	0.983^{A}	0.750^{AS}	0.883^{A}	7.000^{AB}	19.833^{A}	5.167^{AB}	18.000^{A}
C-Interaction (A X B) (Soil application X Foliar spraying)													
Without Humic	**Control**	9.667^{G}	36.833^{F}	8.500^{F}	34.167^{G}	0.433^{H}	0.567^{D}	0.367^{F}	0.533^{C}	2.333^{G}	6.333^{B}	2.000^{D}	4.000^{D}
	Salicylic acid at 200 mgL^{-1}.	19.500^{ABC}	55.333^{AB}	17.000^{ABC}	48.833^{ABCDE}	0.900^{AB}	0.933^{ABC}	0.733^{ABC}	0.800^{AB}	7.000^{ABC}	19.667^{A}	5.667^{AB}	18.333^{AB}
	Salicylic acid at 400 mgL^{-1}.	15.000^{DEF}	43.000^{DEF}	11.833^{E}	41.333^{EFG}	0.633^{FG}	0.800^{BC}	0.567^{CDE}	0.733^{ABC}	4.333^{DEFG}	14.333^{AB}	3.667^{ABCD}	12.667^{BC}
	Alginic acid at 250 mgL^{-1}.	14.333^{EF}	43.167^{DEF}	11.500^{E}	40.000^{FG}	0.633^{FG}	0.900^{ABC}	0.533^{DE}	0.700^{BC}	3.667^{EFG}	14.000^{AB}	3.000^{BCD}	11.667^{C}
	Alginic acid at 500 mgL^{-1}.	16.500^{BCDE}	48.500^{BCDE}	13.167^{DE}	45.167^{CDEF}	0.733^{CDEF}	0.900^{ABC}	0.633^{BCDE}	0.733^{ABC}	5.333^{BCDEF}	16.000^{AB}	5.000^{ABC}	15.333^{ABC}
	Chitosan at 250 mgL^{-1}.	15.167^{DEF}	46.833^{CDE}	12.167^{E}	43.833^{DEF}	0.667^{EFG}	0.900^{ABC}	0.567^{CDE}	0.700^{BC}	4.667^{CDEFG}	15.000^{AB}	4.333^{ABC}	14.667^{ABC}
	Chitosan at 500 mgL^{-1}.	18.333^{ABCD}	51.833^{ABC}	16.667^{BCD}	46.333^{BCDEF}	0.833^{ABCD}	0.967^{AB}	0.700^{ABCD}	0.833 ^{AB}	6.333^{ABCD}	18.000^{A}	5.333^{ABC}	17.667^{ABC}
Humic acid	**Control**	11.833^{FG}	41.833^{EF}	11.000^{E}	39.000^{FG}	0.533^{GH}	0.767^{C}	0.500^{E}	0.700^{BC}	3.333^{FG}	13.667^{AB}	2.667^{CD}	13.333^{ABC}
	Salicylic acid at 200 mgL^{-1}.	21.333^{A}	59.500^{A}	20.500^{A}	56.333^{A}	0.933^{A}	1.000^{A}	0.867^{A}	0.867^{AB}	8.333^{A}	22.333^{A}	6.000^{A}	19.333^{A}
	Salicylic acid at 400 mgL^{-1}.	15.667^{DE}	49.500^{BCDE}	16.333^{BCD}	45.000^{DEF}	0.767^{BCDEF}	0.867^{ABC}	0.667^{BCDE}	0.767^{AB}	4.667^{CDEFG}	16.333^{AB}	4.333^{ABC}	15.667^{ABC}
	Alginic acid at 250 mgL^{-1}.	14.667^{EF}	47.000^{CDE}	14.667^{BCDE}	53.500^{ABC}	0.700^{DEF}	0.900^{ABC}	0.633^{BCDE}	0.767^{AB}	4.333^{DEFG}	17.333^{A}	3.667^{ABCD}	14.667^{ABC}
	Alginic acid at 500 mgL^{-1}.	18.333^{ABCD}	51.167^{BCD}	16.500^{BCD}	50.500^{ABCD}	0.867^{ABC}	0.933^{ABC}	0.733^{ABC}	0.833^{AB}	6.000^{ABCDE}	20.000^{A}	5.000^{ABC}	15.667^{ABC}
	Chitosan at 250 mgL^{-1}.	16.333^{CDE}	49.833^{BCDE}	13.333^{CDE}	46.333^{BCDEF}	0.800^{ABCDE}	0.900^{ABC}	0.733^{ABC}	0.800^{AB}	5.333^{BCDEF}	17.667^{A}	4.000^{ABC}	15.000^{ABC}
	Chitosan at 500 mgL^{-1}.	20.000^{AB}	55.500^{AB}	18.333^{AB}	53.667^{AB}	0.933^{A}	1.000^{A}	0.800^{AB}	0.933^{A}	7.667^{AB}	21.667^{A}	5.000^{ABC}	18.333^{AB}

Table 3: Impact of various applied treatments on specific morphological traits (Suckers number/plant, leaves number/plant & total Leaf area (cm2)/plant of echinacea plant at 75 & 90days after transplanting during 2022 & 2023 seasons.

Characteristics		Suckers number/plant				Leaves number/plant				Total Leaf area (cm^2)/plant			
Treatments		2022		2023		2022		2023		2022		2023	
		75Days	90Days	75Days	90Days	75Days	90Days	75Days	90Days	75Days	90Days	75Days	90Days
A-soil application													
Without humic		4.190^{A}	7.667^{A}	3.619^{A}	6.762^{A}	36.571^{B}	154.333^{A}	33.952^{A}	142.333^{B}	1417.947^{A}	3758.017^{A}	1228.651^{A}	3560.602^{A}
Humic acid		4.762^{A}	8.143^{A}	4.619^{A}	7.905^{A}	40.429^{A}	175.667^{A}	38.333^{A}	161.143^{A}	1683.399^{A}	4306.105^{A}	1550.599^{A}	3972.952^{A}
B – foliar spraying													
Control		2.500^{B}	4.167^{B}	2.333^{B}	3.833^{B}	27.333^{C}	102.833^{B}	24.000^{D}	96.167^{C}	949.520^{E}	2719.147^{A}	820.782^{D}	2448.990^{C}
Salicylic acid at 200 mg/l		5.833^{A}	9.667^{A}	5.333^{A}	9.167^{A}	47.167^{A}	194.667^{A}	44.167^{A}	178.667^{A}	1991.090^{A}	4872.848^{A}	1737.858^{A}	4501.140^{A}
Salicylic acid at 400 mg/l		4.500^{AB}	8.000^{A}	3.833^{AB}	6.667^{A}	36.667^{ABC}	165.000^{A}	33.833^{BC}	152.667^{AB}	1471.477^{CD}	3952.622^{A}	1313.552^{C}	3741.575^{AB}
Alginic acid at 250 mg/l		3.833^{AB}	7.167^{AB}	3.667^{AB}	6.667^{A}	35.167^{BC}	155.000^{A}	30.333^{CD}	142.833^{B}	1328.000^{D}	3698.480^{A}	1263.557^{C}	3398.640^{BC}
Alginic acid at 500 mg/l		4.833^{A}	8.833^{A}	4.500^{AB}	8.333^{A}	38.833^{AB}	177.833^{A}	40.167^{AB}	163.167^{AB}	1656.357^{BC}	4324.722^{A}	1538.137^{ABC}	4008.997^{AB}
Chitosan at 250 mg/l		4.333^{AB}	8.333^{A}	4.167^{AB}	7.667^{A}	40.500^{AB}	170.833^{A}	38.167^{ABC}	155.833^{AB}	1623.155^{BC}	4029.568^{A}	1369.012^{BC}	3919.162^{AB}
Chitosan at 500 mg/l		5.500^{A}	9.167^{A}	5.000^{A}	9.000^{A}	43.833^{AB}	188.833^{A}	42.333^{AB}	172.833^{AB}	1835.113^{AB}	4627.040^{A}	1684.477^{AB}	4348.938^{AB}
C-Interaction (A X B) (Soil application X Foliar spraying)													
Humic acid	**Control**	2.000^{B}	3.667^{C}	1.667^{B}	2.333^{C}	24.333^{C}	74.000^{C}	20.000^{D}	63.667^{C}	760.087^{H}	1957.107^{C}	674.727^{F}	1680.053^{B}
	Salicylic acid at 200 mg/l	5.667^{A}	9.333^{AB}	5.000^{A}	8.667^{AB}	46.333^{A}	184.333^{AB}	42.667^{AB}	174.667^{AB}	1824.570^{BC}	4621.963^{AB}	1590.477^{ABC}	4402.190^{A}
	Salicylic acid at 400 mg/l	4.000^{AB}	7.667^{ABC}	3.333^{AB}	6.333^{AB}	35.667^{ABC}	159.667^{AB}	32.667^{BC}	148.333^{AB}	1320.187^{EFG}	3758.240^{AB}	1172.550^{CDE}	3542.377^{A}
	Alginic acid at 250 mg/l	3.667^{AB}	7.000^{ABC}	3.333^{AB}	6.000^{ABC}	33.000^{ABC}	150.333^{AB}	29.667^{C}	131.000^{B}	1238.423^{FG}	3555.133^{AB}	1054.073^{DE}	3355.413^{A}
	Alginic acid at 500 mg/l	4.333^{AB}	8.667^{ABC}	4.000^{AB}	8.000^{AB}	38.333^{ABC}	169.000^{AB}	37.000^{ABC}	157.000^{AB}	1522.253^{CDEF}	4153.513^{AB}	1372.267^{ABCDE}	3935.043^{A}
	Chitosan at 250 mg/l	4.333^{AB}	8.333^{ABC}	3.667^{AB}	7.333^{AB}	37.333^{ABC}	164.667^{AB}	36.333^{ABC}	151.667^{AB}	1464.447^{DEF}	3750.167^{AB}	1243.113^{BCDE}	3673.350^{A}
	Chitosan at 500 mg/l	5.333^{A}	9.000^{AB}	4.333^{AB}	8.667^{AB}	41.000^{AB}	178.333^{AB}	39.333^{ABC}	170.000^{AB}	1795.663^{BC}	4509.993^{AB}	1493.350^{ABCD}	4335.790^{A}
Without Humic	**Control**	3.000^{AB}	4.667^{BC}	3.000^{AB}	5.333^{BC}	30.333^{BC}	131.667^{BC}	28.000^{C}	128.667^{B}	1138.953^{G}	3481.187^{BC}	966.837^{E}	3217.927^{AB}
	Salicylic acid at 200 mg/l	6.000^{A}	10.000^{A}	5.667^{A}	9.667^{A}	48.000^{A}	205.000^{A}	45.667^{A}	182.667^{A}	2157.610^{A}	5123.733^{A}	1885.240^{A}	4600.090^{A}
	Salicylic acid at 400 mg/l	5.000^{AB}	8.333^{ABC}	4.333^{AB}	7.000^{AB}	37.667^{ABC}	170.333^{AB}	35.000^{ABC}	157.000^{AB}	1622.767^{BCDE}	4147.003^{AB}	1454.553^{ABCDE}	3940.773^{A}
	Alginic acid at 250 mg/l	4.000^{AB}	7.333^{ABC}	4.000^{AB}	7.333^{AB}	37.333^{ABC}	159.667^{AB}	31.000^{BC}	154.667^{AB}	1417.577^{EFG}	3841.827^{AB}	1473.040^{ABCDE}	3441.867^{A}
	Alginic acid at 500 mg/l	5.333^{A}	9.000^{AB}	5.000^{A}	8.667^{AB}	39.333^{ABC}	186.667^{AB}	43.333^{AB}	169.333^{AB}	1790.460^{BC}	4495.930^{AB}	1704.007^{AB}	4082.950^{A}
	Chitosan at 250 mg/l	4.333^{AB}	8.333^{ABC}	4.667^{A}	8.000^{AB}	43.667^{AB}	177.000^{AB}	40.000^{ABC}	160.000^{AB}	1781.863^{BCD}	4308.970^{AB}	1494.910^{ABCD}	4164.973^{A}
	Chitosan at 500 mg/l	5.667^{A}	9.333^{AB}	5.667^{A}	9.333^{A}	46.667^{A}	199.333^{A}	45.333^{A}	175.667^{AB}	1874.563^{AB}	4744.087^{AB}	1875.603^{A}	4362.087^{A}

Table 4: Impact of various applied treatments on specific morphological traits (Stems DW(g)/plant, leaves DW (g)/plant & shoots DW(g)/plant) of echinacea plant @ 75 and 90days after transplanting within 2022 and 2023 seasons**.**

features / Treatments		Stems DW(g)/plant.				Leaves DW (g) /plant.				Shoots DW(g)/plant.			
		1 st		2nd		1 st		2nd		1 st		2nd	
		75Days	90Days	75Days	90Days	75Days	90Days	75Days	90Days	75Days	90Days	75Days	90Days
A-soil application													
Without Humic		4.179^{B}	23.760^{A}	3.684^{A}	22.154^{A}	18.151^{A}	48.108^{A}	15.676^{A}	45.580^{A}	22.330^{B}	97.839^{A}	19.360^{A}	91.055^{B}
Humic acid		5.107^{A}	27.141^{A}	4.357^{A}	25.220^{A}	21.550^{A}	55.123^{A}	19.850^{A}	50.858^{A}	26.656^{A}	114.493^{A}	24.206^{A}	104.914^{A}
B – foliar spraying													
Control		3.228^{D}	32.727^{D}	2.497^{C}	15.028^{E}	12.155^{E}	34.810^{C}	10.328^{D}	31.350^{C}	15.383^{E}	61.908^{C}	12.825^{C}	55.762^{C}
Salicylic acid at 200 mg/l		6.923^{A}	24.577^{A}	5.588^{A}	29.438^{A}	25.488^{A}	62.378^{A}	22.242^{A}	57.620^{A}	32.412^{A}	131.495^{A}	27.830^{A}	121.235^{A}
Salicylic acid at 400 mg/l		3.960^{CD}	21.967^{BC}	3.712^{B}	21.997^{CD}	18.837^{CD}	50.598^{AB}	16.815^{C}	47.897^{AB}	22.797^{CD}	104.328^{B}	20.527^{B}	95.312^{B}
Alginic acid at 250 mg/l		3.927^{CD}	27.092^{CD}	3.477^{B}	20.850^{D}	17.000^{D}	47.345^{BC}	16.175^{C}	43.503^{BC}	20.927^{D}	93.525^{B}	19.652^{B}	88.048^{B}
Alginic acid at 500 mg/l		4.678^{C}	25.490^{ABC}	3.882^{B}	26.375^{ABC}	21.203^{BC}	55.362^{AB}	19.690^{ABC}	51.320^{AB}	25.882^{BC}	114.263^{AB}	23.572^{AB}	103.662^{AB}
Chitosan at 250 mg/l		4.215^{C}	29.817^{BC}	3.918^{B}	24.100^{BCD}	20.778^{BC}	51.583^{AB}	17.525^{BC}	50.170^{AB}	24.993^{C}	109.970^{AB}	21.443^{B}	101.677^{AB}
Chitosan at 500 mg/l		5.567^{B}	32.727^{AB}	5.068^{A}	28.018^{AB}	23.492^{A}	59.232^{AB}	21.563^{AB}	55.672^{AB}	29.058^{AB}	127.670^{A}	26.632^{A}	120.198^{A}
C-Interaction (A X B) (Soil application X Foliar spraying)													
Without Humic	**Control**	2.703^{D}	13.423^{D}	1.913^{H}	12.540^{F}	9.730^{H}	25.057^{C}	8.280^{G}	21.507^{B}	12.433^{I}	42.737^{F}	10.193^{G}	37.993^{F}
	Salicylic acid at 200 mg/l	6.653^{A}	30.020^{AB}	5.013^{BC}	28.660^{AB}	23.357^{BC}	59.167^{AB}	20.350^{ABCD}	56.353^{A}	30.010^{ABC}	123.887^{ABC}	25.363^{ABCD}	116.897^{ABC}
	Salicylic acid at 400 mg/l	3.703^{CD}	23.523^{BC}	3.423^{FG}	20.553^{CDE}	16.900^{EFG}	48.110^{AB}	15.010^{DEF}	45.347^{A}	20.603^{FGH}	98.490^{CDE}	18.433^{DEF}	88.463^{CDE}
	Alginic acid at 250 mg/l	3.510^{CD}	20.083^{CD}	3.337^{FG}	18.607^{DEF}	15.853^{FG}	45.510^{AB}	13.493^{EF}	42.953^{A}	19.363^{GH}	86.927^{DE}	16.830^{EF}	81.877^{DE}
	Alginic acid at 500 mg/l	4.243^{BC}	26.087^{BC}	3.780^{EFG}	24.910^{ABCD}	19.487^{CDEF}	53.170^{AB}	17.567^{BCDEF}	50.373^{A}	23.730^{DEFG}	107.387^{BCDE}	21.347^{CDEF}	100.153^{ABCDE}
	Chitosan at 250 mg/l	3.923^{C}	25.020^{BC}	3.507^{EFG}	22.237^{BCDE}	18.747^{DEF}	48.007^{AB}	15.913^{CDEF}	47.023^{A}	22.670^{EFGH}	104.077^{BCDE}	19.420^{CDEF}	94.607^{BCDE}
	Chitosan at 500 mg/l	4.513^{BC}	28.163^{ABC}	4.813^{BCD}	27.570^{AB}	22.987^{BC}	57.733^{AB}	19.117^{ABCDE}	55.503^{A}	27.500^{BCDE}	121.367^{ABC}	23.930^{ABCD}	117.397^{ABC}
Humic acid	**Control**	3.753^{CD}	19.550^{CD}	3.080^{G}	17.517^{EF}	14.580^{G}	44.563^{BC}	12.377^{F}	41.193^{AB}	18.333^{H}	81.080^{E}	15.457^{F}	73.530^{E}
	Salicylic acid at 200 mg/l	7.193^{A}	35.433^{A}	6.163^{A}	30.217^{A}	27.620^{A}	65.590^{A}	24.133^{A}	58.887^{A}	34.813^{A}	139.103^{A}	30.297^{A}	125.573^{A}
	Salicylic acid at 400 mg/l	4.217^{BC}	25.630^{BC}	4.000^{DEF}	23.440^{ABCDE}	20.773^{BCDE}	53.087^{AB}	18.620^{ABCDEF}	50.447^{A}	24.990^{CDEF}	110.167^{ABCDE}	22.620^{BCDE}	102.160^{ABCDE}
	Alginic acid at 250 mg/l	4.343^{BC}	23.850^{BC}	3.617^{EFG}	23.093^{BCDE}	18.147^{EFG}	49.180^{AB}	18.857^{ABCDEF}	44.053^{A}	22.490^{EFGH}	100.123^{CDE}	22.473^{BCDEF}	94.220^{BCDE}
	Alginic acid at 500 mg/l	5.113^{B}	28.097^{ABC}	3.983^{DEF}	27.840^{AB}	22.920^{BC}	57.553^{AB}	21.810^{ABC}	52.267^{A}	28.033^{BCD}	121.140^{ABC}	25.797^{ABC}	107.170^{ABCD}
	Chitosan at 250 mg/l	4.507^{BC}	25.960^{BC}	4.330^{CDE}	25.963^{ABC}	22.810^{BCD}	55.160^{AB}	19.137^{ABCDE}	53.317^{A}	27.317^{BCDE}	115.863^{ABCD}	23.467^{ABCDE}	108.747^{ABCD}
	Chitosan at 500 mg/l	6.620^{A}	31.470^{AB}	5.323^{AB}	28.467^{AB}	23.997^{AB}	60.730^{AB}	24.010^{AB}	55.840^{A}	30.617^{AB}	133.973^{AB}	29.333^{AB}	123.000^{AB}

Table 5. Effect of different applied treatments on pigments of photosynthetic concentration (mg/g F.W.) in leaves of echinacea (*Echinacea purpurea*) @ 75days post transplanting through 2022 & 2023 seasons.

Treatments	Features	Chlorophyll (a) (mg/g F.W.)		Chlorophyll (b) (mg/g F.W.)		Chlorophyll (a + b) (mg/g F.W.)		Carotenoids (mg/g F.W.)		Chl.a+b/cart.	
		2022 75Days	2023 75Days	2022 75Days	2023 75Days	2022 75Days	2023 75Days	2022 75Days	2023 75Days	2022 75Days	2023 75Days
						A-soil application					
	Without Humic	0.466^{B}	0.359^{B}	0.160^{B}	0.201^{B}	0.627^{B}	0.561^{B}	0.336^{A}	0.273^{B}	1.919^{A}	2.084^{A}
	Humic acid	0.494^{A}	0.442^{A}	0.192^{A}	0.225^{A}	0.687^{A}	0.667^{A}	0.363^{A}	0.307^{A}	1.902^{A}	2.190^{A}
						B – foliar spraying					
	Control	0.411^{B}	0.339^{D}	0.141^{C}	0.160^{C}	0.552^{C}	0.498^{D}	0.308^{B}	0.254^{C}	1.853^{A}	1.995^{A}
	Salicylic acid at 200 mgL^{-1}.	**0.508^{A}**	**0.472^{A}**	**0.210^{A}**	**0.257^{A}**	**0.718^{A}**	**0.729^{A}**	**0.398^{A}**	**0.361^{A}**	1.807^{A}	2.026^{A}
	Salicylic acid at 400 mgL^{-1}.	0.489^{A}	0.397^{BCD}	0.178^{ABC}	0.214^{AB}	0.667^{AB}	0.610^{BC}	0.345^{AB}	0.280^{BC}	1.977^{A}	2.182^{A}
	Alginic acid at 250 mgL^{-1}.	0.471^{A}	0.346^{D}	0.157^{BC}	0.200^{BC}	0.628^{B}	0.546^{CD}	0.328^{B}	0.265^{BC}	1.970^{A}	2.093^{A}
	Alginic acid at 500 mgL^{-1}.	0.499^{A}	0.409^{BC}	0.174^{ABC}	0.221^{AB}	0.673^{AB}	0.631^{BC}	0.345^{AB}	0.288^{BC}	1.969^{A}	2.213^{A}
	Chitosan at 250 mgL^{-1}.	0.482^{A}	0.391^{CD}	0.173^{ABC}	0.207^{B}	0.656^{AB}	0.597^{C}	0.348^{AB}	0.275^{BC}	1.903^{A}	2.199^{A}
	Chitosan at 500 mgL^{-1}.	**0.501^{A}**	**0.452^{AB}**	**0.201^{AB}**	**0.234^{AB}**	**0.702^{A}**	**0.686^{AB}**	**0.374^{AB}**	**0.305^{B}**	1.893^{A}	2.254^{A}
						C-Interaction (A X B) (Soil application X Foliar spraying)					
Without Humic	**Control**	0.338^{B}	0.307^{E}	0.126^{C}	0.119^{C}	0.464^{D}	0.426^{F}	0.253^{B}	0.235^{E}	1.940^{A}	1.875^{A}
	Salicylic acid at 200 mgL^{-1}.	0.505^{A}	0.457^{AB}	0.189^{ABC}	0.256^{AB}	0.694^{ABC}	0.713^{AB}	0.401^{A}	0.353^{AB}	1.735^{A}	2.020^{A}
	Salicylic acid at 400 mgL^{-1}.	0.482^{A}	0.354^{CDE}	0.157^{BC}	0.214^{AB}	0.639^{BC}	0.568^{CDE}	0.323^{AB}	0.272^{CDE}	2.045^{A}	2.076^{A}
	Alginic acid at 250 mgL^{-1}.	0.464^{A}	0.291^{E}	0.153^{BC}	0.187^{B}	0.617^{C}	0.478^{EF}	0.316^{AB}	0.242^{DE}	2.066^{A}	2.049^{A}
	Alginic acid at 500 mgL^{-1}.	0.497^{A}	0.361^{CDE}	0.161^{ABC}	0.223^{AB}	0.658^{ABC}	0.584^{BCDE}	0.337^{AB}	0.264^{CDE}	1.970^{A}	2.256^{A}
	Chitosan at 250 mgL^{-1}.	0.479^{A}	0.320^{DE}	0.150^{BC}	0.189^{AB}	0.629^{BC}	0.509^{DEF}	0.331^{AB}	0.231^{E}	1.923^{A}	2.232^{A}
	Chitosan at 500 mgL^{-1}.	0.497^{A}	0.424^{ABC}	0.187^{ABC}	0.222^{AB}	0.684^{ABC}	0.646^{ABC}	0.391^{A}	0.311^{ABC}	1.753^{A}	2.084^{A}
Humic acid	**Control**	0.484^{A}	0.370^{ABCD}	0.155^{BC}	0.200^{AB}	0.639^{BC}	0.571^{CDE}	0.362^{A}	0.273^{CDE}	1.767^{A}	2.115^{A}
	Salicylic acid at 200 mgL^{-1}.	0.512^{A}	0.486^{A}	0.230^{A}	0.258^{A}	0.742^{A}	0.744^{A}	0.395^{A}	0.368^{A}	1.880^{A}	2.032^{A}
	Salicylic acid at 400 mgL^{-1}.	0.496^{A}	0.440^{ABC}	0.200^{AB}	0.213^{AB}	0.695^{ABC}	0.653^{ABC}	0.367^{A}	0.287^{CDE}	1.910^{A}	2.288^{A}
	Alginic acid at 250 mgL^{-1}.	0.477^{A}	0.400^{ABCD}	0.162^{ABC}	0.213^{AB}	0.639^{BC}	0.613^{ABCD}	0.341^{AB}	0.287^{CDE}	1.875^{A}	2.137^{A}
	Alginic acid at 500 mgL^{-1}.	0.501^{A}	0.458^{AB}	0.187^{ABC}	0.220^{AB}	0.688^{ABC}	0.678^{ABC}	0.353^{A}	0.313^{ABC}	1.967^{A}	2.169^{A}
	Chitosan at 250 mgL^{-1}.	0.486^{A}	0.461^{AB}	0.196^{ABC}	0.224^{AB}	0.682^{ABC}	0.685^{ABC}	0.365^{A}	0.320^{ABC}	1.883^{A}	2.165^{A}
	Chitosan at 500 mgL^{-1}.	0.505^{A}	0.480^{A}	0.216^{AB}	0.246^{AB}	0.721^{AB}	0.725^{A}	0.356^{A}	0.299^{BCD}	2.033^{A}	2.424^{A}

Table 6. Effect of different applied treatments on pigments of photosynthetic concentration (mg/g FW) in leaves of echinacea (*Echinacea purpurea*) @ 90days following transplanting within 2022 & 2023 seasons.

Treatments	Characteristics	Chlorophyll (a) (mg/g F.W.)		Chlorophyll (b) (mg/g F.W.)		Chlorophyll (a + b) (mg/g F.W.)		Carotenoids (mg/g F.W.)		Chl.a+b/cart.	
		2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
		90 days	90 days	90 days	90 days	90 days	90 days	90 days	90 days	90 days	90 days
A-soil application											
Without Humic		0.690^{B}	0.654^{B}	0.389^{A}	0.327^{B}	1.07881^{A}	0.980^{B}	0.561^{B}	0.531^{B}	1.928^{A}	1.848^{A}
Humic acid		0.741^{A}	0.709^{A}	0.416^{A}	0.395^{A}	1.15605^{A}	1.104^{A}	0.606^{A}	0.571^{A}	1.909^{A}	1.933^{A}
B – foliar spraying											
Control		0.594^{D}	0.559^{C}	0.338^{A}	0.278^{B}	0.933^{B}	0.837^{B}	0.471^{C}	0.458^{D}	1.993^{A}	1.842^{A}
Salicylic acid at 200 mgL^{-1}.		0.767^{A}	0.732^{A}	0.451^{A}	0.407^{A}	1.217^{A}	1.139^{A}	0.643^{A}	0.610^{A}	1.889^{A}	1.863^{A}
Salicylic acid at 400 mgL^{-1}.		0.724^{BC}	0.686^{AB}	0.384^{A}	0.366^{AB}	1.107^{A}	1.052^{A}	0.595^{AB}	0.548^{BC}	1.859^{A}	1.916^{A}
Alginic acid at 250 mgL^{-1}.		0.699^{C}	0.665^{B}	0.365^{A}	0.326^{AB}	1.064^{AB}	0.990^{A}	0.556^{B}	0.537^{C}	1.923^{A}	1.845^{A}
Alginic acid at 500 mgL^{-1}.		0.739^{ABC}	0.705^{AB}	0.421^{A}	0.374^{AB}	1.160^{A}	1.079^{A}	0.602^{AB}	0.553^{BC}	1.925^{A}	1.956^{A}
Chitosan at 250 mgL^{-1}.		0.726^{ABC}	0.697^{AB}	0.412^{A}	0.377^{AB}	1.138^{A}	1.074^{A}	0.579^{B}	0.553^{BC}	1.959^{A}	1.936^{A}
Chitosan at 500 mgL^{-1}.		0.759^{AB}	0.727^{A}	0.445^{A}	0.398^{A}	1.204^{A}	1.126^{A}	0.638^{A}	0.598^{AB}	1.883^{A}	1.877^{A}
C-Interaction (A X B) (Soil application X Foliar spraying)											
Without Humic	**Control**	0.546^{F}	0.507^{E}	0.309^{A}	0.219^{B}	0.855^{B}	0.727^{C}	0.415^{D}	0.391^{D}	2.051^{A}	1.868^{A}
	Salicylic acid at 200 mgL^{-1}.	0.745^{ABC}	0.709^{ABC}	0.440^{A}	0.374^{AB}	1.186^{A}	1.083^{AB}	0.623^{AB}	0.596^{ABC}	1.900^{A}	1.818^{A}
	Salicylic acid at 400 mgL^{-1}.	0.703^{CDE}	0.659^{BCD}	0.375^{A}	0.345^{AB}	1.078^{AB}	1.003^{AB}	0.571^{BC}	0.528^{BC}	1.882^{A}	1.896^{A}
	Alginic acid at 250 mgL^{-1}.	0.681^{DE}	0.643^{CD}	0.344^{A}	0.292^{AB}	1.024^{AB}	0.935^{BC}	0.518^{C}	0.516^{C}	1.985^{A}	1.809^{A}
	Alginic acid at 500 mgL^{-1}.	0.719^{BCD}	0.686^{ABC}	0.425^{A}	0.349^{AB}	1.144^{A}	1.034^{AB}	0.603^{ABC}	0.554^{ABC}	1.892^{A}	1.870^{A}
	Chitosan at 250 mgL^{-1}.	0.697^{CDE}	0.668^{BCD}	0.394^{A}	0.346^{AB}	1.092^{AB}	1.014^{AB}	0.577^{ABC}	0.543^{ABC}	1.889^{A}	1.864^{A}
	Chitosan at 500 mgL^{-1}.	0.739^{ABCD}	0.703^{ABC}	0.435^{A}	0.362^{AB}	1.173^{A}	1.065^{AB}	0.617^{AB}	0.587^{ABC}	1.898^{A}	1.812^{A}
Humic acid	**Control**	0.643^{E}	0.610^{D}	0.367^{A}	0.337^{AB}	1.010^{AB}	0.947^{ABC}	0.527^{C}	0.526^{BC}	1.935^{A}	1.817^{A}
	Salicylic acid at 200 mgL^{-1}.	0.788^{A}	0.754^{A}	0.461^{A}	0.440^{A}	1.249^{A}	1.194^{A}	0.664^{A}	0.625^{A}	1.877^{A}	1.907^{A}
	Salicylic acid at 400 mgL^{-1}.	0.744^{ABCD}	0.714^{ABC}	0.393^{A}	0.386^{AB}	1.137^{A}	1.100^{AB}	0.618^{AB}	0.568^{ABC}	1.835^{A}	1.935^{A}
	Alginic acid at 250 mgL^{-1}.	0.717^{BCD}	0.686^{ABC}	0.386^{A}	0.359^{AB}	1.103^{AB}	1.045^{AB}	0.594^{ABC}	0.557^{ABC}	1.860^{A}	1.880^{A}
	Alginic acid at 500 mgL^{-1}.	0.758^{ABC}	0.724^{AB}	0.418^{A}	0.399^{AB}	1.176^{A}	1.123^{AB}	0.601^{ABC}	0.552^{ABC}	1.958^{A}	2.041^{A}
	Chitosan at 250 mgL^{-1}.	0.755^{ABC}	0.726^{AB}	0.429^{A}	0.407^{A}	1.184^{A}	1.133^{AB}	0.582^{ABC}	0.562^{ABC}	2.028^{A}	2.007^{A}
	Chitosan at 500 mgL^{-1}.	0.779^{AB}	0.752^{A}	0.454^{A}	0.435^{A}	1.234^{A}	1.186^{A}	0.659^{A}	0.610^{AB}	1.869^{A}	1.942^{A}

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تحسين أداء النمو و صبغات البناء الضوئي لنبات الاخناسيا بإستخدام بعض مواد النمو الطبيعية.

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أجريت تجربتان حقليتان في صيف موسمي نمو (٢٠٢٢ و ٢٠٢٣) علي نبات الإخناسيا(*Echinacea purpurea* L.) لدراسة تأثير الرش الورقي بكل من حمض السالسليك بتركيز (٢٠٠ ، ٤٠٠ ملجم/لتر)،حمض الالجينك بتركيز (٢٥٠، ٥٠٠ ملجم/لتر) و الشيتوزان بتركيز (٢٥٠ ، ٥٠٠ملجم/لتر) منفردا أو مع الإضافه الارضية لحمض الهيوميك ٣كجرام/فدان مقارنه بالكنترول رشا بالماء المقطر فقط علي صفات النمو للنبات ومحتوي صبغات البناء الضوئي ومن النتائج المتحصل عليها:-

١- أدي الرش الورقي بكل المعاملات والتركيزات الي حدوث زيادة معنوية في كلاً من صفات النمو الخضري (ارتفاع النبات، عدد الأفرع، عدد الخلفات، عدد الأوراق، مساحة الورقة، الوزن الجاف للسيقان والأوراق) في الموسمين بالمقارنه بالنباتات الغير معاملة (الكنترول).

٢- أدي الرش الورقي بكل من حمض السالسليك بتركيز (٢٠٠ ملجم/لتر) و الشيتوزان بتركيز (٥٠٠ ملجم/لتر) منفردا أو مع الاضافة الارضية لحمض الهيوميك إلي زياده معنويه في صفات النمو الخضري وتحسين محتوي صبغات البناء الضوئي مقارنه بالمعاملات الاخري في كلا موسمي النمو ٢٠٢٢ – ٢٠٢٣.

عموماً أظهرت النتائج أن معاملات الرش الورقي بالتركيز المنخفض من حمض السالسليك او التركيز العالي من الشيتوزان مع الاضافة الارضية لحمض الهيوميك أفضل المعاملات لتحسين صفات النمو ومحتوي صبغات البناء الضوئي لنبات الاخناسيا تحت الظروف الطبيعيه .لذلك توصي الدراسه باستخدام الرش الورقي بهما (٢٠٠ ملجم/لتر) حمض السالسليك و (٥٠٠ ملجم/لتر) الشيتوزان مع الاضافة الارضية لحمض الهيوميك لتحقيق احسن صفات النمو و اعلي محتوي صبغات البناء الضوئي للنبات تحت نفس ظروف الدراسه.