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The Complementary Effects of Salicylic Acid, Alginic Acid, Chitosan and Humic Acid to Improve the Yield and Bioactive Component of Echinacea Plants

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Abstract

The present research sought to evaluate the impacts of various treatments via foliar application with some bio-stimulants(i.e. salicylic acid (200 & 400 mg/L.), alginic acid (250 and 500 mgL^{-1}) as well as chitosan (250 & 500 mgL^{-1}.) and humic acid at 3kg/Fadden soil addition compared with control (Distilled water) on flowering parameters (start of inflorescence anthesis (days), inflorescences number/ plant, dry weight of inflorescences, main inflorescence height, main inflorescence diameter and dry weight of main inflorescence /plant) also, some bio-active compounds content (caffeic acid derivatives plus total alkamides) of (*Echinacea purpurea*) plants grown in normal conditions. The results clearly show that all treatments significantly enhanced all studied flowering parameters and some bio-active compounds in echinacea plants compared with control in both seasons. In addition, foliar application treatments of SA at 200 mg L^{-1} also, chitosan at 500 mgL^{-1} either alone or in conjunction with humic acid soil addition considerably boosted all the above mentioned flowering parameters. As for some bio-active compound content (caffeic acid derivatives and total alkamides) compared with the other treatments in both seasons, salicylic acid at 200 mg L^{-1} with humic acid as soil addition was the best successful treatment in this respect. Generally, the foliar spraying treatments by 200mgL^{-1} of salicylic acid and chitosan (500 mgL^{-1}) in combination with humic acid soil addition were the best influential treatments for enhancing flowering traits and some bio-active substances contant of echinacea plants in normal environment, as well as we recommended used of these treatments.at the same field condition.

Keywords: *Echinacea purpurea* L., flowering parameters, caffeic acid derivatives, total alkamides, growth bio-stimulants, salicylic acid, alginic acid, chitosan, humic acid.

1. Introduction

Purple coneflower (*Echinacea purpurea* L.) (EP) is a herbaceous perennial plant belong to the Asteraceae family. EP is highly appreciated for its therapeutic, economic as well as ecological importance. It has drawn notice because its immune-boosting so anti-inflammatory Anti-inflammatory features, making it a crucial resource in both traditional and modern medicine. **(Gupta *et al.*, 2012 and Salgado-Salazar *et al.*, 2023)**. *Echinacea purpurea* is renowned for its immunomodulatory effects, containing active materials as alkylamides, glycoproteins, polysaccharides as well as derivatives of caffeic acid, which enhance immune system activity and aid in the prevention and therapy of illnesses like viral rhinitis so influeinza **(Coelho *et al.*, 2020 and Burlou-Nagy *et al.*, 2022)**. Recent studies confirm the plant's safety and effi-cacy, with research showing a favorable safety profile and effective pharma-cokinetics of its active ingredient, chicoric acid **(Jeong *et al.*, 2024)**. Additionally, clinical trials have demonstrated its immune-enhancing effects in adults, supporting its use as a dietary supplement **(Lee *et al.*, 2024)**. Its adaptability to various soil types and climates further underscores its agricultural value **(Mistríková and Vaverková, 2007).**

A phenolic chemical, salicylic acid (SA), is an essential plant hormone and transmitter agent that controls plant development & stresse tolerance **(Peng *et al.*, 202I)**. SA, which is found naturally in very small amounts in plant tissues, is crucial for controlling several physiological and biochemical activities, including membrane permeability, ion absorption and transport, and stomatal closure. Additionally, SA is responsible for reversing the effects of ABA on leaf abscission, inhibiting ethylene production, thermogenesis, photosynthetic rate, increasing the quantity of carotenoid and chlorophyll pigments, inducing flowers, and altering the activity of some significant enzymes **(Hayat & 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 (**Es-sbihi *et al.*, 2020; Gahory *et al.*, 2022; Nasseralla and Almukhtar, 2023 and El-Naggar *et al.*, 2024**). Numerous studies have generally demonstrated that the usage of SA exogenously increased the effective ingredients for different varieties of aromatic & medicinal plants under unfavorable ambient conditions **(Khorasani *et al.* 2023, Danesh-Shahraki *et al.* 2023, Güneri and Dalkılıç 2023).**

A type of naturally occurring polysaccharide polymer found in many marine plants, including kelp and seaweed, is alginic acid (AA). (**Liu and Zhang 2015**). Alginate (ALG) is made up of heterogeneous β-1,4-glycosidic linkages connecting varying amounts of (M-blocks) D-mannuronic acid, (G-blocks) L-glucuronic acid, or both. An abundant organic material found in nature, 30,000 tons of alginate are produced annually **(Donati *et al.*, 2009; Szekalska *et al*, 2016)**. ALG is widely utilized in industries of food, medical, and agricultural among else sectors, as the most plentiful and inexpensive marine biomass. However, because of its large weight of molecule and poor bioavailability, alginate's uses have been severely restricted **(Xing *et al.*, 2020)**. The novel botanical preparation has a wide range of potential uses and is decomposable, non-polluting, and comparatively safe. **(Khan *et al.*, (2009)**. In agricultural applications, AA is frequently employed as a bioeffectors. It has the ability to stimulate plant growth. Additionally, alginic acid can enhance crop quality. Additionally, alginic acid is crucial for boosting a plant's capability to withstand biotic and abiotic stressors (**Van Oosten *et al.*, 2017**).

Chitosan (Ch)is a naturally occurring natural polymers, that boosts plant growing, yield, & immunity. **(Pongprayoon *et al.*, 2013*;* Sultana *et al.*, 2019)**. Even in the absence of chemical fertilizer, the use of chitosan in agriculture can greatly boost the microbial population and so convert bio-nutrients into synthetic ones that are readily taken up by the roots of plants **(Bolto *et al.*, 2004)**. Additionally, Ch.-treated plants may be less vulnerable to ambient stressors like temperature, salt, and drought **(LizarragaPauli *et al.*, 2011; Jabeen and Ahmad 2013; Pongprayoon *et al.*, 2013)**. Ch. is regarded globally as an environmentally safe & compatible polymer with a variety of uses in addition to a viable and affordable supplier of adaptable and efficient crop safety materials **(Geisberger *et al.*, 2013; Zhang *et al.*, 2012)**. Ch. Hence, has a broad range of applications in several agricultural fields, such as producing crops and preservation, storage, nutritional value and so on.

One natural substitute for traditional farming methods is humic acid (HA) **(Baltazar *et al.*, 2021)**. HA is a commonly used crop enhancer in the humic product business because it breaks down clay, buffers pH, improves holding of water and increases accessible soil nutrients (**Pukalchik *et al.*, 2019, Hu *et al.*, 2021)**. HA It has been demonstrated that HA improves seed germination, enhances the growth of roots, leaves, and shoots, and stimulates blooming, all of which increase plant yield **(Braziene *et al.*, 2021, Najarian *et al.*, 2022)**. HA Increased nutrient absorption, including organic matter and certain macronutrients and micronutrients, is the main cause of HA-enhanced growth. Furthermore, enhanced basis oil concentration and quality in plants like thyme, fennel, and dragonhead demonstrate how HA could profoundly alter on secondary metabolism **(Noroozisharaf and Kaviani 2018; Machiani *et al.*, 2019)**.

This study aimed to:

Assess the effects of salicylic acid, alginic acid, and chitosan, either alone or in conjunction with humic acid as soil application on flowering parameters and some yield, yield components and bioactive compounds to improve these characteristics in purple coneflower *Echinacea.purpurea* plant.

Methodology :-

During the two summer seasons of 2022 and 2023, two studies were conducted in the Experimental Farm Station of the Faculty of Agriculture Moshtohor, Benha Univ., Qalubia Gavernorate, Egypt, to study foliar application effects by salicylic acid at 200 & 400 mgL^{-1} alginic acid at 250and 500 mgL^{-1} in addition to chitosan at 250 & 500 mgL^{-1} with and without humic acid soil addition compared with control (Distilled water) at flowering parameters(i.e. Number of inflorescences/plant, inflorescences FW(g)/plant. and inflorescences DW(g)/plant,and Main inflorescence height /plant, main inflorescence diameter(cm)/plant, inflorescence head FW & DW(g)/plant.), and some bio-active compounds content(i.e. (Total derivatives of caffeic acid content (mg/ g DW)) on roots, herb and flowering heads and Total alkamides content (mg/ g DW)) in roots and areal parts),of *Echinacea purpurea* 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 (**Table 1**) in the middle of April. 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 purpurea* plants were adhered to.

The experiment treatments were as follows:

There were fourteen treatments in this study, which were the combination between humic acid soil addition 3 kg/fadden 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 mg L^{-1}., AA at 500 mg L^{-1}., Chit. at 250 mg L^{-1}., Chit. at 500 mg L^{-1}., Humic acid as soil application 3 kg/fadden, SA at 200 mgl^{-1} + HA as soil application., SA at 400 mg L^{-1}+ HA as soil application., AA at 250 mg L^{-1}+ HA as soil application., AA at 500 mg L^{-1}+ HA as soil application., Chit. at 250 mg L^{-1}+ HA as soil application., Chit. at 500 mg L^{-1}+ HA as soil application.

Table 1. Physical and chemical features of the research soil throughout the 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 added to the soil in the main plot. On the other hand, the subplot was used for treatments sprays i.e. control (Distilled water) salicylic acid at 200 and 400 mgL^{-1}., alginic acid at 250 and 500 mgL^{-1}. and chitosan at 250 and 500 mgL^{-1} Through plant maturation, plants were splashed three times with various allocated solutions. The first treatment was performed 60 days following transplantation, and it continued every fifteen days. The volume of the spraying solution was administered till plants ran off the spray solution.

Every cultural norms were carried out according advised.

Sampling and collecting data:

1. Flowering characteristics:

Three plants of echinacea from each replicates were randomly taken at 150 days after transplanting to measure plant flowering features (inflorescences number/ plant, fresh & dry weight of inflorescences, main inflorescence height, main inflorescence diameter & DW of main inflorescence/plant). The plant dry weight was determined after samples of the vegetative portions above ground sun-dried for 72 hours to a consistent weight.

2. Determination of some bio-active compounds content:

A- The total amount of caffeic acid derivatives in varied parts of echinacea (roots, herb and inflorescences) were measured by utilizing a spectrophotometer in accordance with **A.O.A.C (1990).**

B- Utilizing (HPLC) High Performance Liquid Chromatography in compliance with **Bauer and Remiger (1989)**, The aerial portions of *Echinacea purpurea* (inflorescences, leaves, and stems) were used to quantify total alkamides during both seasons (2022-2023).

Statistical analysis:

The procedures were used for statistically evaluating the study's data. outlined by **Snedecor and Cochran (1989)**. Using the statistical software program MSTAT-C **(Michigan state university, 1983).**

3. Results and discussion

1. Flowering parameters of echinacea plants:

Tables 2 and 3's data revealed that substantial differences existed between humic acid (soil addition) and without HA (soil addition) in all measurements at total flowering stage including (No. of inflorescences / plant, FW of inflorescences (g)/ plant, DW of flowering heads (g)/ plant, main inflorescence height, main inflorescence diameter, and fresh and DW of main flowering head (g)/plant) of echinacea plants across the two experimental growing seasons. In this context, applying humic acid to the soil demonstrated a notably enhanced improvement in all the traits mentioned. Conversely, soil lacking the addition of humic acid exhibited reduced values in all flowering traits across both seasons. The variations observed in the treatments analyzed could stem from the vital roles and essential functions of humic acid

These findings align with the conclusions from **Memon *et al.* (2014)** regarding zinnia (Zinnia elegans), which showed that humic acid, either alone or combined with iron sulfate, significantly enhanced the flowers number per plant, flower size (cm), Mean flower lifespan (days), and overall blooming duration (days). At the same time, the days until the first flower appeared were fewer in contrast to the control. Also, **Ahmad *et al*.,(2019)** demonstrated that the quantity, length, and width of blooms on a plant of calendula plants increased significantly with various doses of humic acid when compared to the control.

According to Table (2), all treatments applied to the foliage (namely, salicylic acid at 200 and 400 mgL^{-1}, alginic acid at 250 and 500 mgL^{-1}, and chitosan at 250 and 500 mg L^{-1}) caused in improving all measured parameters (number of flowering heads per plant, fresh weight of flowering heads (g) per plant) to considerably rise in all measured traits (No. of inflorescences/plant, FW of inflorescences (g)/plant, DW of inflorescences (g)/plant, height of main flowering head, diameter of main flowering head, and main flowering head both fresh & dry weight(g)/plant) in contrast to the control plant. The most efficient treatment in this regard was salicylic acid at 200 mg L^{-1}, followed by chitosan acid at 500 mg L^{-}, alginic acid at 500 mg L^{-1}, and chitosan at 250 mgL^{-1}, observed 150 days next transplanting within 2022 & 2023 seasons contrasted to untreated controls. In relation to the quantity of flowering heads per plant, there was a significant increase with most treatments applied across the two growing seasons. The only exception was a negligible increase observed with each SA @ 200 mg L^{-1} and chitosan @ 500 $mgL^{-1}$when compared to the control at 150 days post-transplanting during the 2022 and 2023 seasons, respectively. Each plant's fresh weight of inflorescences as well as its dry weight per plant displayed the highest values with chitosan at 500 mgL^{-1}, which showed the maximum values, followed by salicylic acid at 200 mgL^{-1}. In comparison with other treatments and control that yielded the minimum value within the both seasons.

Contents in Table (3) investigated that the main flowering head height/ plant and main inflorescence diameter, main inflorescence fresh and dry weight(g)/plant were recorded a significant increase with all different foliar applied treatments. Therefore, the greatest values were observed with salicylic acid & 200 mg L^{-1} succeeded by chitosan at 500 mg L^{-1}, regarding the main inflorescence height in comparison to control during the 2022 and 2023 seasons, respectively. Conversely, the main inflorescence diameter recorded the highest values with chitosan at 500 mg L^{-1} inflorescences salicylic acid at 200 mg L^{-1}. In contrast, the control treatment gave the lowest value during the 2022 and 2023 seasons, respectively. So, FW and DW(g) of inflorescence/ plant gave the greatest value with chitosan at 500 mg L^{-1} as well as salicylic acid at 200 mg L^{-1}. contrasted to control through the two seasons, respectively.

Generally, it could be concluded that enhancements in inflorescences number/ plant, inflorescences weight as fresh/ plant and dry weight of inflorescences/ plant, main inflorescence height per plant, main inflorescence diameter and both the FW and DW of the main inflorescence achieved with salicylic acid at 200 mg L^{-1}. and chitosan at 500 mg/L treatments. could result from an increase in photosynthesis, leading to higher total carbohydrates and proteins in the leaves (source), as well as an increase in endogenous auxins and other photosynthetic products, particularly during the full blooming and setting phases **Khandaker *et al.;* (2011) Basit *et al.,* (2018).**

In this regard, the acquired enhancement in various growth characteristics may be ascribed to the positive impact of (Salicylic acid at 200 & 400 mgL^{-1}, Alginic acid at 250 & 500 mgL^{-1}, and chitosan at 250 & 500 mgL^{-1}) on the absorption of various minerals and additional growth substances in various plant tissues. Moreover, bio-stimulant applications lead to a rise in the number of flowers and the rate of assimilation, as well as playing crucial roles in the control of diverse vital plant processes and enhance the compounds that are involved in free radical scavenging, replacing these radicals with advantageous substances to safeguard the membranes and all organelles within the plant cell. The previously noted rise in flower quantity and the traits of flowering heads is also consistent with **Abdul Kareem and Saeed (2020) and Abdelsadek *et al*. (2021).** Instead of aiding in the development of flowers, salicylic acid is involved in their commencement. SA controls floral changes during both stressful and normal circumstances by utilizing autonomous pathways and photoperiod (**Martinez *et* al.,2004).** offered further molecular proof of the efficacy of chitosan, which has numerous beneficial impacts on plant performance. The beneficial effects noted during the reproductive phase, like increased flowering, can also be linked to advantageous shifts in hormonal levels, improved nutrient mobilization, enhanced photosynthetic efficiency, and postponed senescence, all of which are believed to be triggered by chitosan application **(El-Sayed *et al.,* 2020** and **Abdul-Hafeez and Ibrahim 2021).**

Regarding the impact of the combination between of humic acid soil application & foliar sprays with various bio-stimulating substances, the findings submitted in the same (Tables 2 & 3) proved that the combination between HA (as drench) with SA at 200 mg L^{-1}, and HA (as drench) with Ch.at 500 mg L^{-1} resulted in the greatest readings of each flowering traits of echinacea plants. This was [1]succeeded by the combination treatment involving humic acid (as drench) and foliar spray with alginic acid at 500 mg L^{-1}, chitosan at 250 mg L^{-1}, salicylic acid at 400 mg L^{-1}, and alginic acid at 250 mg L^{-1} when compared to other treatments lacking humic acid soil addition and the control in both seasons. For humic acid **Ahmed *et al.,* (2022)** cleared that humic acid effected positively on inflorescences number/ plant, inflorescence diameter and weight as fresh and dry of inflorescences of german chamomile. As salicylic acid **Abdelsadek *et al.,* (2021)** discovered that chrysanthemum plants sprayed with SA @ a 300 ppm resulted in early blooming (118.83 and 119.17 days post-planting). Simultaneously, applying 300 ppm SA resulted in the highest count of flower heads /plant in addition to, the inflorescence longest stalk plus thickness offlower head in chrysanthemum plant contrasted to the other applied plus control. As for chitosan **Abdul-Hafeez and Ibrahim (2021)** established that 40 ppm of chitosan yeilded the best results for various characteristics, including the flowers number for each plant FW and DW of flower heads and productivitt of dry flowers per fed compared to the untreated plants in the two seasons of the German chamomile plant. Moreover, **Moghith (2024)** reveal that chitosan foliar spray at (3 cm/L) influenced the flowering heads no. per plant, along with the FW and DW of inflorescences per plant of *Echinacea purpurea* L. in comparison to control plants.

2. Some bio-active compounds in echinacea plants:

Data presented in Tables 4 and 5 indicated that the addition of HA to soil resulted in significant differences in all chemical plant quality represented as organic components (i.e., caffeic acid derivatives and total alkamides) across both seasons. In this context, the applied of HA to the soil showed the greatest levels in roots, herbs, as well as inflorescences contents of caffeic acid derivatives, as well as total alkamides in roots and aerial parts during both seasons, in comparison to untreated soil (lacking humic acid). The variations in the examined treatments of humic acid influenced genetic factors that impacted plant quality characteristics.

In this sense, **Khorasaninejad *et al.* (2018)** established that the amount of derivatives of caffeic acid in the root (Cichoric acid, Chlorogenic acid, as wll as caffeic acid) significantly rose with HA soil drench compared to control on purple coneflower.

Tables 4 and 5's data revealed that chemical properties of the echinacea plant (specifically, caffeic acid derivatives and total alkamides) were significantly elevated with the applied safe agents (like SA at 200 & 400 mg L^{-1}, alginic acid at 250 & 500 mg L^{-1}, and chitosan at 250 & 500 mg L^{-1}) throughout both seasons. Echinacea plants were sprayed using SA @ 200 mg L^{-1}. revealed the largest concentration of caffeic acid compounds in the herb, roots, and inflorescences, followed by chitosan at 500 mg L^{-1}. in roots and herb. The highest value was in the inflorescences with chitosan at 250 mg L^{-1}. in comparison to control, that gave the lowest readings in caffeic acid derivatives content in root, herb and flowering heads at 150 days after transplanting during 2022 and 2023 seasons respectively as shown in **Table (4).**

As for alkamides content in Table (5) echinacea plants sprayed with SA at 200 mg L^{-1} exhibited the maximizing concentration in roots and aerial parts, while the control group showed the lowest levels for the 2022 and 2023 seasons, respectively.

In this aspect, **Mohebby *et al.*, (2021)** discovered that SA enhanced the levels of caffeic acid derivatives in (*Echinacea purpurea* L. Moench) when compared to the control. As for chitosan **Strzemski *et al.*, (2025)** found that using chitosan influences the content of secondary metabolites on Carlina leaves, specifically phenolic acids (chlorogenic acids), in comparison to the control. Also, **Moghith (2024)** on *Echinacea purpurea* L.

As for the interaction between humic acid (drench) and spraying with some bio-stimulants materials on chemical echinacea plant quality expressed as organic constituents (i.e., derivatives of caffeic acid, as well as total alkylamides). Findings in Tables (4 and 5) cleared that the greatest concentration in caffeic acid derivatives in root, herb and floweing heads. Total alkamides in root and areal parts gave maximum content as owing to the combination of humic acid (drench) and SA at 200 mg L^{-1}foliar spraying. during the two seasons of growth succeeded by humic acid (drench) with with chitosan at 500 mg L^{-1} as spray. These true findings throughout two experimental seasons.

These findings are in agreement with **Khorasaninejad *et al.*, (2018)** disclosed that humic acid addition to the soil substantially raised total phenolic level in the shoots and the levels of derivatives of caffeic acid in the roots compared to a control of purple coneflower. As for salicylic acid **Mehrpooya *et al.*, (2021)** indicated that the influence of varying salicylic acid concentrations and exposure durations, along with the 1% probability level, their interaction had an extremely substantial impact on the generation of caffeic acid derivatives in coneflowers. For chitosan **Moghith (2024)** studied that applied chitosan at (3 cm/L) had positive enhanced on Caffeic acid derivatives (8.13 and 8.28 mg/g dry weight) of *Echinacea purpurea* L. compared with control plants which gave (7.84 and 8.02 mg/g dry weight) during both seasons in succession and total alkamides in dry aerial parts (mg/g D.W) compared with control plants.

Table 2. Impact of various applied treatments on specific floral traits (Number of inflorescences/plant, inflorescences FW(g)/plant. and inflorescences DW(g)/plant) of the echinacea plant at 150days after transplanting during the 2022 and 2023 seasons**.**

features		Number of inflorescences/plant.		Inflorescences fresh weight(g)/plant.		Inflorescences dry weight(g)/plant.	
Treatments		**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
		150Days	**150Days**	**150Days**	**150Days**	**150Days**	**150Days**
A-soil application							
Without Humic		41.714^{A}	35.095^{A}	382.239^{A}	332.053^{A}	87.975^{B}	75.864^{B}
Humic acid		45.476^{A}	40.952^{A}	430.568^{A}	386.420^{A}	101.131^{A}	87.059^{A}
B – foliar spraying							
Control		21.333$^{\mathbf{D}}$	17.833^{E}	155.908^{D}	135.332^{D}	27.673^{D}	24.447^{D}
Salicylic acid @ 200 mg L^{-1}		53.000^{A}	48.167^{A}	505.845^{AB}	457.618^{AB}	120.607^{A}	99.590^{A}
Salicylic acid @ 400 mg L^{-1}		43.333^{BC}	38.167^{CD}	412.515^{BC}	359.457^{C}	93.618^{C}	84.415^{B}
Alginic acid @ 250 mg L^{-1}		40.000^{C}	35.333^{D}	364.323^{C}	322.392^{C}	88.198^{C}	75.795^{C}
Alginic acid @ 500 mg L^{-1}		48.667^{AB}	42.667^{ABC}	456.143^{ABC}	405.493^{ABC}	106.378^{B}	98.120^{A}
Chitosan @ 250 mg L^{-1}		46.833^{ABC}	39.667^{BCD}	433.718^{ABC}	373.515^{BC}	97.663^{BC}	86.650^{B}
Chitosan @ 500 mg L^{-1}		52.000^{A}	44.333^{AB}	516.370^{A}	460.850^{A}	127.735^{A}	101.215^{A}
C-Interaction (A X B) (Soil application X Foliar spraying)							
Without Humic	control	17.333^{D}	12.667^{G}	122.380^{D}	109.303^{E}	17.050^{H}	14.917^{H}
	Salicylic acid @ 200 mg L^{-1}	52.667^{A}	46.000^{ABC}	497.590^{A}	425.243^{AB}	117.200^{ABC}	97.010^{ABC}
	Salicylic acid @ 400 mg L^{-1}	41.333^{BC}	35.667^{DE}	393.040^{AB}	338.650^{BC}	86.517^{EF}	77.067^{EF}
	Alginic acid @ 250 mg L^{-1}	36.333^{C}	31.667^{E}	313.093^{BC}	279.920^{CD}	77.623^{F}	65.443^{F}
	Alginic acid @ 500 mg L^{-1}	47.667^{AB}	40.000^{BCDE}	434.643^{AB}	383.663^{ABC}	102.360^{CDE}	95.703^{ABC}
	Chitosan @ 250 mg L^{-1}	45.667^{ABC}	38.333^{CDE}	410.647^{AB}	357.527^{BC}	91.267^{EF}	82.087^{DE}
	Chitosan @ 500 mg L^{-1}	51.000^{AB}	41.333^{BCD}	504.280^{A}	430.067^{AB}	123.810^{AB}	98.823^{AB}
Humic acid	control	25.333^{D}	23.000^{F}	189.437^{CD}	161.360^{DE}	38.297^{G}	33.977^{G}
	Salicylic acid @ 200 mg L^{-1}	53.333^{A}	50.333^{A}	514.100^{A}	489.993^{A}	124.013^{AB}	102.170^{AB}
	Salicylic acid @ 400 mg L^{-1}	45.333^{ABC}	40.667^{BCD}	431.990^{AB}	380.263^{ABC}	100.720^{CDE}	91.763^{ABCD}
	Alginic acid @ 250 mg L^{-1}	43.667^{ABC}	39.000^{BCDE}	415.553^{AB}	364.863^{BC}	98.773^{DE}	86.147^{CDE}
	Alginic acid @ 500 mg L^{-1}	49.667^{AB}	45.333^{ABC}	477.643^{A}	427.323^{AB}	110.397^{BCD}	100.537^{AB}
	Chitosan @ 250 mg L^{-1}	48.000^{AB}	41.000^{BCD}	456.790^{A}	389.503^{ABC}	104.060^{CDE}	91.213^{BCD}
	Chitosan @ 500 mg L^{-1}	53.000^{A}	47.333^{AB}	528.460^{A}	491.633^{A}	131.660^{A}	103.607^{A}

Table 3. Impact of various applied treatments on specific traits flowering characteristics (Main inflorescence height /plant, main inflorescence diameter(cm)/plant, inflorescence head FW & DW(g)/plant.) of echinacea plant at 150 days after transplanting during 2022 & 2023 seasons**.**

Treatments	Features	Main Flowering head/ plant							
		Height(cm)/plant.		**Diameter(cm)/plant.**		**Fresh weight(g)/plant.**		**Dry weight(g)/plant.**	
		2022	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
		150Days	**150Days**	**150Days**	**150Days**	**150Days**	**150Days**	**150Days**	**150Days**
A-soil application									
	Without Humic	62.476^{A}	56.952^{A}	4.543^{B}	4.424^{B}	20.626^{B}	19.552^{B}	4.707^{B}	4.308^{B}
	Humic acid	69.167^{A}	64.762^{A}	4.895^{A}	4.743^{A}	22.326^{A}	20.930^{A}	5.264^{A}	5.022^{A}
B – foliar spraying									
	Control	51.083^{C}	49.333^{C}	3.617^{C}	3.267^{D}	14.965^{D}	14.342^{D}	2.888^{C}	2.712^{C}
	Salicylic acid @ 200 mg L^{-1}	73.750^{A}	68.167^{A}	4.983^{A}	4.900^{AB}	24.035^{A}	22.075^{AB}	5.762^{A}	5.533^{A}
	Salicylic acid @ 400 mg L^{-1}	66.333^{AB}	62.250^{AB}	4.900^{AB}	4.750^{BC}	22.467^{B}	20.108^{C}	5.102^{B}	4.798^{B}
	Alginic acid @ 250 mg L^{-1}	60.250^{B}	58.667^{B}	4.683^{B}	4.667^{C}	20.632^{C}	20.080^{C}	5.033^{B}	4.565^{B}
	Alginic acid @ 500 mg L^{-1}	68.500^{A}	61.750^{AB}	4.900^{AB}	4.750^{BC}	22.115^{B}	21.610^{ABC}	5.098^{B}	4.792^{B}
	Chitosan @ 250 mg L^{-1}	69.500^{A}	60.167^{AB}	4.883^{AB}	4.800^{ABC}	21.673^{BC}	20.572^{BC}	5.087^{B}	4.675^{B}
	Chitosan @ 500 mg L^{-1}	71.333^{A}	65.667^{AB}	5.067^{A}	4.950^{A}	24.445^{A}	22.900^{A}	5.927^{A}	5.580^{A}
C-Interaction (A X B) (Soil application X Foliar spraying)									
Without Humic acid	Control	45.500^{G}	42.667^{D}	2.933^{E}	2.667^{F}	13.357^{G}	12.683^{E}	2.203^{F}	2.017^{F}
	Salicylic acid @ 200 mg L^{-1}	70.000^{ABCD}	63.167^{ABC}	4.900^{ABC}	4.833^{ABC}	23.307^{ABC}	21.940^{AB}	5.340^{BC}	5.093^{BC}
	Salicylic acid @ 400 mg L^{-1}	63.667^{CDEF}	59.500^{BC}	4.800^{ABC}	4.700^{BCD}	21.767^{CDE}	19.267^{C}	5.000^{CD}	4.590^{BCD}
	Alginic acid @ 250 mg L^{-1}	58.500^{EF}	56.167^{C}	4.567^{CD}	4.500^{D}	19.937^{E}	19.060^{C}	4.993^{CD}	4.477^{CD}
	Alginic acid @ 500 mg L^{-1}	66.667^{ABCDEF}	59.500^{BC}	4.867^{ABC}	4.733^{BCD}	22.020^{BCD}	21.220^{ABC}	5.047^{BCD}	4.617^{BCD}
	Chitosan @ 250 mg L^{-1}	65.833^{BCDEF}	54.833^{C}	4.767^{BC}	4.667^{CD}	20.060^{DE}	20.000^{BC}	4.890^{D}	4.207^{D}
	Chitosan @ 500 mg L^{-1}	67.167^{ABCDEF}	62.833^{ABC}	4.967^{AB}	4.867^{ABC}	23.937^{AB}	22.697^{A}	5.473^{B}	5.157^{B}
With Humic acid	Control	56.667^{F}	56.000^{C}	4.300^{D}	3.867^{E}	16.573^{F}	16.000^{D}	3.573^{E}	3.407^{E}
	Salicylic acid @ 200 mg L^{-1}	77.500^{A}	73.167^{A}	5.067^{AB}	4.967^{AB}	24.763^{A}	22.210^{AB}	6.183^{A}	5.973^{A}
	Salicylic acid @ 400 mg L^{-1}	69.000^{ABCDE}	65.000^{ABC}	5.000^{AB}	4.800^{ABC}	23.167^{ABC}	20.950^{ABC}	5.203^{BCD}	5.007^{BC}
	Alginic acid @ 250 mg L^{-1}	62.000^{DEF}	61.167^{ABC}	4.800^{ABC}	4.833^{ABC}	21.327^{CDE}	21.100^{ABC}	5.073^{BCD}	4.653^{BCD}
	Alginic acid @ 500 mg L^{-1}	70.333^{ABCD}	64.000^{ABC}	4.933^{ABC}	4.767^{ABCD}	22.210^{BC}	22.000^{AB}	5.150^{BCD}	4.967^{BC}
	Chitosan @ 250 mg L^{-1}	73.167^{ABC}	65.500^{ABC}	5.000^{AB}	4.933^{ABC}	23.287^{ABC}	21.143^{ABC}	5.283^{BCD}	5.143^{B}
	Chitosan @ 500 mg L^{-1}	75.500^{AB}	68.500^{AB}	5.167^{A}	5.033^{A}	24.953^{A}	23.103^{A}	6.380^{A}	6.003^{A}

Table 4. Impact of various applied treatments on certain bio active component content (Total derivatives of caffeic acid content (mg/ g DW)) on roots, herb and flowering heads of echinacea (*Echinacea purpurea*)at 150days after transplanting during 2022 and2023 seasons.

Treatments	Characteristics	Total derivatives of caffeic acid content (mg/ g DW)					
		In Root		**In Herb**		**In Flowering heads**	
		2022	**2023**	**2022**	**2023**	**2022**	**2023**
Without humic acid	**Control**	5.133	5.300	7.700	6.800	9.767	8.133
	Salicylic acid @ 200 mg L^{-1}.	12.00	11.967	14.800	13.900	20.700	15.733
	Salicylic acid @ 400 mg L^{-1}.	9.400	9.267	13.800	8.610	18.500	14.233
	Alginic acid @ 250 mg L^{-1}.	7.467	7.533	13.700	9.500	13.033	12.900
	Alginic acid @500 mg L^{-1}.	8.633	8.400	14.200	10.533	18.200	13.033
	Chitosan @ 250 mg L^{-1}.	9.767	9.500	13.700	13.100	20.033	14.800
	Chitosan @ 500 mg L^{-1}.	10.633	11.033	14.500	13.100	18.00	14.100
With humic acid	**Control**	7.200	6.433	9.733	7.200	12.000	9.833
	Salicylic acid @ 200 mg L^{-1}.	14.000	12.900	17.900	17.600	21.267	17.200
	Salicylic acid @ 400 mg L^{-1}.	11.033	12.467	14.833	13.300	18.933	16.800
	Alginic acid @ 250 mg L^{-1}.	8.333	9.000	15.200	13.200	14.400	13.033
	Alginic acid @500 mg L^{-1}.	8.800	8.733	16.233	13.000	20.333	15.300
	Chitosan @ 250 mg L^{-1}.	11.033	10.167	15.800	13.300	21.100	16.867
	Chitosan @ 500 mg L^{-1}.	12.033	12.900	16.433	14.200	20.500	16.800

Table 5. Impact of various applied treatments on certain bio active component content (Total alkamides content (mg/ g DW)) in roots and areal parts of echinacea (*Echinacea purpurea*)at 150 days after transplanting during 2022 and2023 seasons.

Treatments	Characteristics	Total alkamides content (mg/ g dry weight)			
		In Root		**In Areal parts**	
		2022	**2023**	**2022**	**2023**
Without humic acid	**Control**	0.602	0.564	0.212	0.201
	Salicylic acid @ 200 mg L^{-1}.	0.814	0.785	0.41	0.385
	Salicylic acid @ 400 mg L^{-1}.	0.744	0.712	0.297	0.311
	Alginic acid @ 250 mg L^{-1}.	0.69	0.701	0.315	0.288
	Alginic acid @500 mg L^{-1}.	0.792	0.677	0.285	0.263
	Chitosan @ 250 mg L^{-1}.	0.66	0.591	0.333	0.28
	Chitosan @ 500 mg L^{-1}.	0.802	0.773	0.391	0.323
With humic acid	**Control**	0.698	0.69	0.23	0.219
	Salicylic acid @ 200 mg L^{-1}.	0.963	0.904	0.494	0.425
	Salicylic acid @ 400 mg L^{-1}.	0.804	0.823	0.371	0.312
	Alginic acid @ 250 mg L^{-1}.	0.797	0.800	0.398	0.35
	Alginic acid @500 mg L^{-1}.	0.911	0. 872	0.401	0.344
	Chitosan @ 250 mg L^{-1}.	0.886	0.845	0.47	0.351
	Chitosan @ 500 mg L^{-1}.	0.919	0.897	0.475	0.398

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التأثير التكاملي بين حمض السالسيليك، حمض الالجينيك ، الشيتوزان و حمض الهيوميك لتحسين المحصول و المواد الفعالة لنبات الاخناسيا.

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أجريت تجربتان في موسمي (٢٠٢٢ و ٢٠٢٣) علي نبات الإخناسيا(.*Echinacea purpurea* L) لدراسة تأثير الرش الورقي ببعض مستحثات النمو الطبيعييه التاليه:– حمض السالسليك بتركيز (٢٠٠ ، ٢٥٠ ملجم/لتر) وحمض الالجينك بتركيز (٢٥٠، ٥٠٠ ملجم/لتر) و الشيتوزان بتركيز (٢٥٠ ، ٥٠٠ملجم/لتر) منفردا او مع الإضافة الأرضية لحمض الهيوميك مقارنه بالكنترول رشا بالماء المقطر فقط .. علي الصفاتت االتزهير (بداية التزهير، عدد النورات، الوزن الجاف للنورات، طول النورة الرئيسية، قطر النورة الرئيسية، الوزن الجاف للنورة الرئيسية) ومحتوي بعض المواد الفعالة للنبات (الألكاميدات و مشتقات حمض الكافيك).

ومن النتائج المتحصل عليها امكن التوصل الي :––

١– ان الرش الورقي بجميع المعاملات والتركيزات ادي الي زيادة معنوية في كلاً من صفات التزهير(بداية التزهير، عدد النورات، الوزن الجاف للنورات، طول النورة الرئيسية، قطر النورة الرئيسية، الوزن الجاف للنورة الرئيسية) وأيضاً محتوي بعض المواد الفعالة (الألكاميدات و مشتقات حمض الكافيك) في الموسمين لمقارنه بالنباتات الغير معاملة (الكنترول).

٢–اظهر الرش الورقي بكل من حمض السالسيليك بتركيز (٢٠٠ ملجم/لتر) والشيتوزان بتركيز (٥٠٠ ملجم/لتر) منفردا أو مع الاضافة الارضية لحمض الهيوميك زياده معنويه في صفات التزهير ومحتوي بعض المواد الفعالة للنبات في الموسمين متفوقا علي التركيزات الاخري.

عموماً اكدت النتائج أن الرش الورقي بالتركيز المنخفض من حمض السالسيليك (٢٠٠ ملجم/لتر) والشيتوزان بتركيز (٥٠٠ ملجم/لتر) منفردا أو مع الاضافة الارضية لحمض الهيوميك كان أفضل المعاملات في تحسين صفات التزهير ومحتوي بعض المواد الفعالة لنباتالاخناسيا تحت ظروف الحقل وهذا ما توصي به الدراسه تحت نفس الظروف.