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Effect of Salinity, Humic Acid, Salicylic Acid and Their Interaction On Growth And Chemical Component Of *Celosia argentea*

Abdel-Latef, M. S.,[1*] El-Sayed, A.A.,[2*] El-Leithy, A. S. [2*] and Bazraa, W. M.[1*]

1- Ornamental Horti., Dept., Agriculture research center, Giza,Egypt.
2- Ornamental Horti., Dept., Fac. of Agric., Cairo Univ., Giza, Egypt.

Abstract

The experiment was conducted throughout two successive seasons (2019 and 2020) in the nursery of Faculty of Agriculture, Cairo University, Giza to ascertain the impact of water salinity at various concentrations (control, 1000, 2000, 4000ppm), humic acid at various concentrations (0.2 and 0.4 g/l), and salicylic acid at various concentrations (300 and 450ppm) on the behavior of growth and blooming as well as the chemical components of *Celosia argentea* plant. The findings highlighted the fact that salinity at higher concentration (4000 ppm) reduced plant height, inflorescences number and flower density per plant and dry weight of vegetative growth. The content of total carotenoids, chlorophyll a and b, as well as total carbohydrates reduced in the dried leaves. Sodium, chlorine, and proline concentrations were increased when plants were exposed to higher salinity levels. Salicylic acid and humic acid, however, markedly decreased all evaluated features content of Na, Cl and proline. It is mostly preferred to use salicylic acid. Spraying salicylic acid could improve growth and flowering parameters and reducing the effects of salt. It can be advised to utilize salicylic acid at 450ppm based on the aforementioned findings.

Keywords: Salinity, Humic acid, Salicylic acid, Chemical component, Celosia argentea.

1- Introduction

Celosia argentea plant a member of the *Amaranthaceae* family is a native of warm Asia and Africa. With a height of 30 to 90 cm, it is an annual flower **[1].** Because of the exceptional quality of its flowers, which come in a variety of colours, this plant is used as a border flower as well as dried flowers **[2].** According to recent reports, the flowers (inflorescences) can thrive and adapt to soils with high copper levels **[3]**. Certain *Amaranthaceae* species contain many secondary metabolites like lipids, amino acids, peptides, phenols, phenolic acids, flavonoids, terpenes, alkaloids, and carbohydrates **[4]**.The *Amaranthaceae* is closely related to the *Chenopodiaceae,* which has several salt-tolerant plants. Celosia was chosen for its potential as a salt tolerant cut flower crop due to its ability to endure exceptionally high salinity stress **[5].**

Water shortage is one of the most pressing issues confronting modern agriculture. When water quality and quantity become restricted, salinity is becoming increasingly important in landscaping, where salty ground waters and wastewaters may provide a beneficial water supply for irrigation of chosen floriculture crops and establishment of crops on saline soils **[1].** Salinity stress affects plant growth in a variety of ways, although it is unknown how much of an impact each of these approaches **[6, 7].** According to **[8, 9]**, among the effects of salinity stress on plants is a decrease in cell membrane stability, a decrease in CMS, enzyme activities, photosynthesis as well as ion uptake. The ability of plant species to counteract the damaging effects of salinity determine show they respond to salinity in soil or water, resulting in a decline in the growth and economic parts of the plant [**10].**

Humic substances are considered more than 60% of the soil's organic carbon, are thought to be stored as humic compounds, which come from the microbial breakdown of plant and animal materials **[11].** Under stressful and non-stressful circumstances, these humic compounds can control plant growth and development **[12]**. Humate application to plants is seen as a potential strategy because it enhances seed germination, root development, shoot and leaf development, nutrition and water intake, and antioxidant enzyme activity [**13**, **14].**A commercial

*Corresponding author e-mail: mahygirl@ymail.com
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product called potassium hamate (KH) is created when potassium salt and humic acid mix to create complex humic compounds [**14,15**]. The structure composition of humic acid molecules as shown in Fig (1)**.**

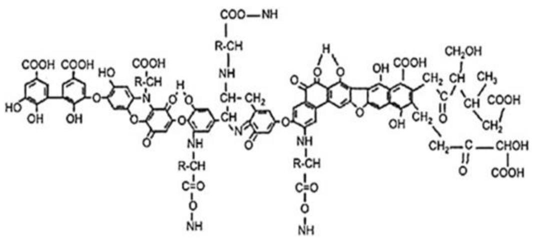


Fig (1): Humic acid strcutre

Salicylic acid (SA) is a hormone (phenolic compound) in plants which exhibit a great role in alleviation several abiotic stresses **[16].** Salicylic acid is a lipophillicmom hydroxybenzoic acid, a type of phenolic acid and beta hydroxyl acid (BHA) with formula$C_7H_6O_3$ Fig (2) **[17].** It is crucial for physiological activities such as plant growth and development, photosynthesis, transpiration, and ion uptake. In addition, it is recognized as a key signal molecule in plants' reactions to environmental stressors **[18].** Under extreme stress, a plant's ability to regulate itself is compromised, and the ineffectiveness of the antioxidant system has a negative impact on the physiology of the plant and leads to oxidative damage. As a result, the use of exogenous SA as a cellular messenger molecule can significantly contribute to the development of tolerance to biotic and abiotic challenges **[19]**. Exogenous SA application acts as a growth and flowering promoter besides its effect on secondary metabolites **[20].**

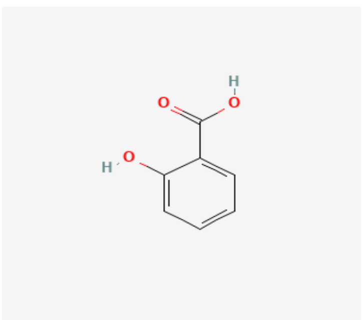


Fig (2): Chemical structure of Salicylic acid

The use of salty water resources for irrigation of floriculture plants is becoming more common in arid and semi-arid locations, although it can limit plant development and cause environmental concerns. Some measures for reducing the negative effects of salty water irrigation, such as the use of humic acid or salicylic acid, can help to minimize the negative effects of salinity **[21]**.

As a result, our study was conducted to assess the effects of saline water treatments on *Celosia argentea* and utilize it for beneficial water supply of irrigation, as well as the potential function of spraying humic and salicylic acids to counteract the negative effects of salt.

2. Materials and Methods

The experimental trial was consummated throughout two successive seasons of (2019 and 2020) at the nursery of Faculty of Agriculture, Cairo University, Giza to find out the effect of salinity at control, 1000, 2000 and 4000 ppm, humic acid at the rates of (0, 0.2 and 0.4 g/l) and salicylic acid at the rates of (0, 300 and 450 ppm) on vegetative growth, flowering and chemical composition of plumed cockscomb (*Celosia argentea*). Seeds were sown on foam trays on 15th February filled with sandy and peat moss (1:1 v/v) mixture, after 45 days rooted seedlings were transferred and planted into 30 cm (diameter) plastic pots filled with a sand +clay soil (1:1, v/v).Physical and chemical properties of the used growing medium were determined according to **[22]** as shown in Table (1).

After transplanting, the seedlings were irrigated with tap water every three days for 30 days before beginning salty water irrigation with NaCl and $CaCl_2$ (1:1w/w).Three times each week, the plants were watered with salty water at concentrations of 0, 1000, 2000, and 4000 ppm. Plants were sprayed three times with salicylic acid at concentrations of 0, 300, or 450 ppm, as well as humic acid at concentrations of 0, 0.2, and 0.4 g/l. The plants were let to grow in an open field and received fertilization treatments throughout their growth cycle. All plants were fertilized with a 19:19:19% N: P: K mixture at 2g/pot/month.

2.1. Experimental design: The layout of the experiment was factorial in a randomized complete block design (RCBD), with three replicates; the first factor was salinity, whereas the second one was the treatment of foliar application of humic acid (potassium humate) and salicylic acid, every experimental unit was represented by 5 plants and every treatment represented by 15 plants. Regular agricultural practices such as weeding and watering etc…were done.

2.2. Data recorded: plant height (cm), number of flowers (inflorescences) /plant and dry weights of vegetative growth (g) were recorded. Chlorophyll a, b and total carotenoids were determined in the fresh leaves according to the method mentioned by **[23]**.Total carbohydrates contents were determined in the dried leaves using colorimetric method described by **[24]**. Proline content was determined in the fresh leaves according to **[25]**.Na^+ content was determined according to**[26]**.Chloride content was determined using the method described by**[27]**.Data were then tabulated and statistically analyzed using SAS computer program (1994) and means of the treatments were compared by L.S.D test at the level 5% according to **[28].**

Table (1). Physical and chemical analysis of the used soil in the experiment

		First season	Second season
Physical analysis		8.94	8.57
	Silt%	9.93	9.78
		25.66	24.27
	Clay %	55.47	52.38
	Soiltexture	Sandy loam	Sandy loam
Chemical analysis	**pH**	8.6	8.5
	EC	1.21	1.10
	Available N (ppm)	165	147
	AvailableP_2O_5 (ppm)	202	200
	Available K_2O (ppm)	0.63	0.60
	Zn (ppm)	4.95	4.53
	Cu (ppm)	0.65	0.61
	B (ppm)	0.51	0.45
	Fe (ppm)	2.17	2.01
	Mn (ppm)	4.46	4.20

3. Results and Discussion:

3.1. Effect of salinity, humic acid and salicylic acid on growth parameters:

3.1.1. Plant height (cm)

It is evident from data in Table(2), irrigation with saline water exhibited harmful impacts on *Celosia argentea* growth parameters and the high levels of salinity- caused a steady decrease in plant height. Salinity concentrations significantly decreased the plant height (cm) compared to the control plants. Salinity at the highest concentration 4000ppm gave the shortest plants (on the other side, tap water treatment gave the tallest plants).

Data in Table (2) indicated that the high rates of humic acid (0.4 g/1) and salicylic acid 450ppm significantly increased the plant height when compared to control plants.

Regarding the interaction, as shown in Table (2), there were significant effects on plant height to alleviate the salinity impacts owing to humic and

Table. (2) Effect of salinity, humic acid, salicylic acid and their interaction on plant height (cm) of *Celosia argentea* during 2019 and 2020 seasons.

Salinity / Treatment	Control	1000ppm	2000ppm	4000ppm	Mean
First season 2019					
Control	59.47a-c	47.53e-g	40.20gh	24.87i	**43.02c**
H1	63.00ab	50.87c-f	44.73fg	28.47i	**46.77bc**
H2	63.40ab	52.33c-f	49.93d-f	29.33i	**48.75b**
SA1	51.87c-f	51.07c-f	50.67c-f	32.93hi	**46.63bc**
SA2	66.40a	58.27a-d	55.13b-e	32.73hi	**53.13a**
Mean Treatment	**60.83a**	**52.01b**	**48.13c**	**29.67 d**	
Second season 2020					
Cont.	63.27b	43.87de	45.20cd	31.47g	**45.95b**
H1	65.87b	46.07cd	46.07cd	34.13g	**48.03b**
H2	75.93a	47.27cd	47.13cd	36.93e-g	**51.82a**
SA1	74.40a	48.87cd	48.87cd	35.73fg	**51.97a**
SA2	76.40a	52.27c	42.90d-f	37.07e-g	**52.16a**
Mean Treatment	**71.17a**	**47.67b**	**46.03b**	**35.07c**	

salicylic acids application, in both seasons. In comparison to the control plants, the highest value of plant height was obtained when tap water irrigation was coupled with the treatments of salicylic acid (450 ppm) and humic acid (0.4g/1). Furthermore, the shortest plant was also recorded in case of salinity at 4000 ppm + control treatment. Similar results were obtained by **[29, 30]** on *Calendula officinalis*, **[31]** on *Dianthus caryophyllus* L., **[32, 33]** on *Tagetes erecta* plants and **[34]** on *Matericaria recutita* L. However height is closely related to growth which is dependent on the osmotic pressure of the root medium, growth depends on the maintenance of turgor while osmotic under adjustment might retard growth until additional absorbed solutes (salts) or synthesized solutes (organic compounds) affect the requisite adjustment. Hence, the reduction in height and growth may be retarded as a consequent of the requirement for osmotic adjustment.

3.1.2. Number of flowers/plant:

Table (3) shows how salinity treatments affected the production of *Celosia argentea* inflorescences (flowers). Different salt concentrations reduced the number of inflorescences (flowers), with the greatest salinity (4000 ppm) producing the fewest inflorescences /plant when compared to control plants (tap water), which generated the highest inflorescences number.

As shown in Table (3), also, raising the rate of humic acid from0.2g/l to 0.4g/l had a significant effect on increasing number of the flowers/plant. The number of flowers was gradually increased as the rate of salicylic acid increased and using the concentration of 450ppm was the most effective in both seasons. The improvement in vegetative growth traits of plants treated with humic acid may be due to humic acid's role in increasing the physiological activities of the plant and its reflection in increasing growth and plant nutrient content, as well as increasing cytokinins and endogenous auxin. Alternatively, humic acid contains plant growth regulators such as indole acetic acid, gibberellin, and cytokinin, which have a substantial influence on plant growth **[35].**

Regarding the interaction between salinity and treatments of (humic acid and salicylic acid) on formation of flowers as shown in Table3, it was clear that the high level of salicylic acid (450ppm) was the most effective in this regard. The highest value of number of flowers/plant was obtained from the treatment of salicylic acid at 450ppm + tap water compared to all combinations treatments in the experiment.

3.1.3. Dry weights of vegetative growth (g/plant):

Data presented in Table (4) showed that dry weight of *Celosia argentea* plants were affected by all salinity concentrations compared to control.

The results indicated that salinity at the high rate (4000ppm) significantly decreased the dry weights/ plant as compared to tap water treatment giving the lowest values, in both seasons; meanwhile the opposite trend was recorded with tap water. The loss in growth caused by salinity treatments can be attributable to either reduced water absorption owing to salty water's low potential or particular ion toxicity (Na+ and Cl-), or both. It has been reported that salinity hinders cell division rather than cell expansion, resulting in a significant drop in photosynthesis. On *Schefflera arboricola*, high salinity causes leaf abscission; a reduction in total volume at a constant cell number, increased reactive

Table. (3) Effect of salinity, humic acid, salicylic acid and their interaction on No. of flower/plant of *Celosia argentea* during 2019 and 2020 seasons.

Salinity / Treatment	Cont.	1000ppm	2000ppm	4000ppm	Mean Salinity
First season 2019					
Cont.	4.93b-e	4.13d-g	3.26g	3.20g	**3.88b**
H1	5.53bc	4.60c-f	3.46fg	3.46fg	**4.26b**
H2	8.40a	5.26b-d	4.46c-f	3.80e-g	**5.48a**
SA1	7.80a	5.33bc	4.53c-f	4.13d-g	**5.45a**
SA2	8.26a	5.93b	5.00b-d	4.60c-f	**5.95a**
Mean Treatment	**6.98a**	**5.05b**	**4.14c**	**3.84c**	
Second season 2020					
Cont.	6.73b-d	5.40d-f	4.73f-h	3.40h	**5.06b**
H1	6.80b-d	5.66d-f	5.13e-g	3.73gh	**5.33b**
H2	7.73a-c	6.33c-e	5.60d-f	4.20f-h	**5.96a**
SA1	7.86ab	6.40c-e	5.46d-f	4.66f-h	**6.10a**
SA2	8.20a	6.80b-d	5.26ef	4.86fg	**6.28a**
Mean Treatment	**7.46a**	**6.12b**	**5.24c**	**4.17d**	

H1: humic acid at 0.2 g/l,H2: humic acid at 0.4 g/l, SA1: salicylic acid at 300 ppm and SA2: salicylic acid at 450 ppm.

oxygen species (ROS) generation, and decreased antioxidant enzyme activity **[36]**.

As shown in Table (4), all rates of humic acid significantly increased dry weights of *Celosia argentea* plants. A gradual increase in the dry weights was recorded depending on humic acid and salicylic acid rates. The highest rate of humic acid (0.4g/l) and SA at 450ppm had great effects on increasing the weights in both seasons, in comparison with the control. The greater effect of HA might be attributed to its role in osmotic adjustment by stimulating proline synthesis, decreasing membrane antioxidant enzymes, and permitting leakage **[37]**.

The interaction between the two factors demonstrated that humic acid at 0.4 g/l and salicylic acid at 450 ppm treatments had a significant effect in increasing the dry weights of *Celosia argentea* to the highest values under salinity conditions compared to the other combinations treatments. These results agreed with **[38]** on *Tagetes sp.* and **[39]** on *Gazania rigens* L.

highest contents in both seasons. This might be due to the harmful and the negative effect of saline water on stroma lamella formation and grana and chlorophyll appearance during the normal growth of the leaves. This effect of salinity on chlorophyll-a, chlorophyll-b and carotonids contents was in agreement with the results reported by **[40]** on *Cortaderia selloana*,**[41]**on *Amaranthus tricolor* L. and **[36]**on *Schefflera arboricola* who reported that raising salinity concentration reduced plant pigments content.

Regarding the effect of humic acid and salicylic acid treatments on chlorophyll a chlorophyll b and carotenoids contents of *Celosia argentea* plant, data presented in Fig (6, 7 and 8) showed that, the different humic acid and salicylic acid treatments increased chlorophyll a, chlorophyll b and carotenoids contents of *Celosia argentea* plants compared to the control. Moreover, humic acid at the rate of 0.4g/l and SA at 450ppm gave the highest chlorophyll-a, chlorophyll-b and carotenoids contents. Furthermore, chlorophyll a, b, and carotenoid levels are signals of leaf photosynthesis, with carotenoids serving as receptors and safeguards for the photosynthetic machinery. Salicylic acid regulates photosynthesis through influencing the structure of leaves and chloroplasts, the closure of stomata, and the amounts of chlorophyll and carotenoids. The use of SA resulted in an increase in growth and photosynthetic rates. Changes in the activity of the Rubisco enzyme and photosystem II

Table (4) Effect of salinity, humic acid, salicylic acid and their interaction on dry weight (g/plant) of vegetative growth of *Celosia argentea* during 2019 and 2020 seasons.

Treatment \ Salinity	Cont.	1000ppm	2000ppm	4000ppm	Mean Salinity
First season 2019					
Cont.	12.60f-h	11.50hi	9.90i	7.83j	**10.46d**
H1	15.40cd	13.93d-f	11.90gh	11.50hi	**13.18c**
H2	16.03c	14.00d-f	13.40e-g	12.70f-h	**14.03b**
SA1	18.27b	14.90c-e	13.80d-f	12.57f-h	**14.88a**
SA2	20.07a	15.37cd	14.20d-f	12.77f-h	**15.60a**
Mean Treatment	**16.47a**	**13.94b**	**12.64c**	**11.47d**	
Second season 2020					
Cont.	10.80e-g	9.90fg	9.40fg	8.60g	**9.67c**
H1	11.20d-f	11.77c-f	10.80e-g	10.03fg	**10.95b**
H2	13.90bc	13.10b-e	11.47c-f	10.17fg	**12.16a**
SA1	15.27ab	13.50b-d	11.80c-f	11.00d-g	**12.89a**
SA2	16.33a	12.77c-e	11.90c-f	11.77c-f	**13.19a**
Mean Treatment	**13.50a**	**12.21b**	**11.07c**	**10.31c**	

H1: humic acid at 0.2 g/l, H2: humic acid at 0.4 g/l, SA1: salicylic acid at 300 ppm and SA2: salicylic acid at 450 ppm.

3.2. Effects of salinity, humic acid, salicylic acid and their interactions on chemical components:

3.2.1. Plant pigments

The results illustrated in Fig (3, 4 and 5) showed that raising salinity concentration resulted in a steady decrease in chlorophyll-a, chlorophyll-b and carotonids contents. Moreover, the highest salinity concentration (4000 ppm) gave the lowest contents in the two seasons compared to control which gave the may be the cause, or ATPase pump activation may facilitate iron absorption. Furthermore, SA increases photosynthesis, chlorophyll formation, and the content of alpha amino levulinic acid (a-ALA), a critical step in chlorophyll synthesis. These results are in agreement with the findings of **[42]** on *Dianthus caryophyllus* and **[43]** on *Acalypha wilkesiana* and **[44]** on *Ocimum basilicum***.**

Concerning the effect of interaction treatments on chlorophyll a, chlorophyll b and carotenoids content, data in Fig (9, 10 and 11) indicated that, the maximum values of chlorophyll-a, chlorophyll-b and carotenoids contents were obtained when using the combined treatment of salicylic acid at the highest rate (450ppm) and the tap water treatment. On the other hand, the minimum values were recorded when plants received only saline water at the highest concentration (4000ppm).These results met those of **[45]** on *Calendula officinalis* L. and **[46]** on *Plectranthus ciliates.*

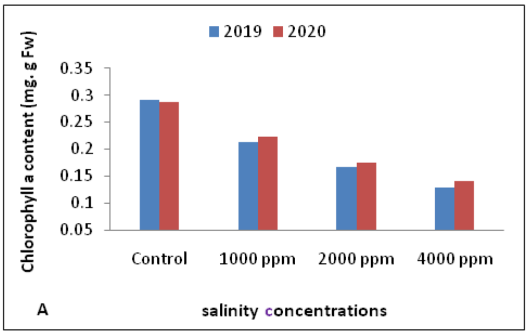
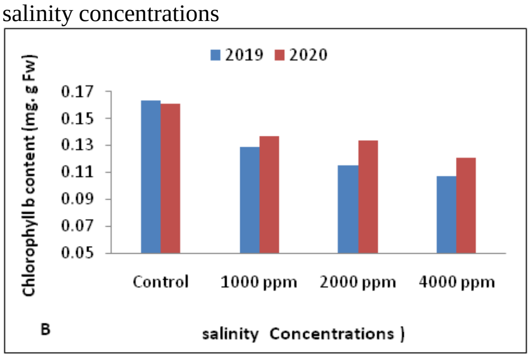


Fig (3). Chlorophyll a content (mg./g.Fw) as influenced by salinity concentrations



Fig(4). Chlorophyll b content (mg./g.F.w) as influenced by salinity concentrations

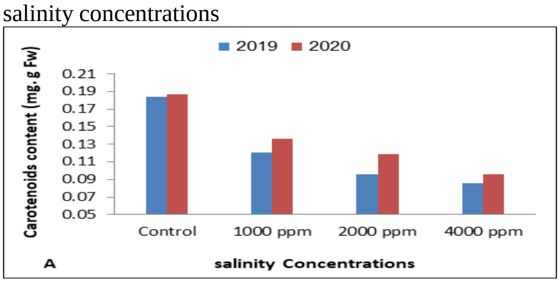


Fig (5). Carotenoids content (mg.g.Fw) as influenced by salinity concentrations

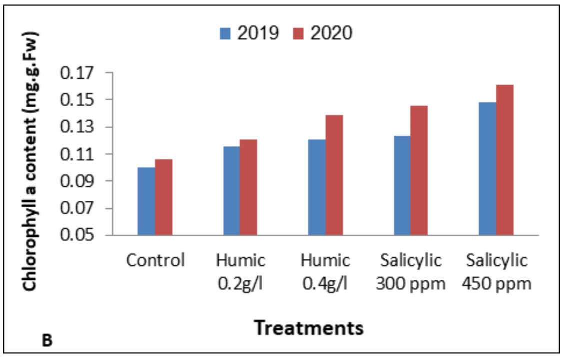


Fig (6). Chlorophyll a content (mg.g.Fw) as influenced by humic and salicylic acid treatments

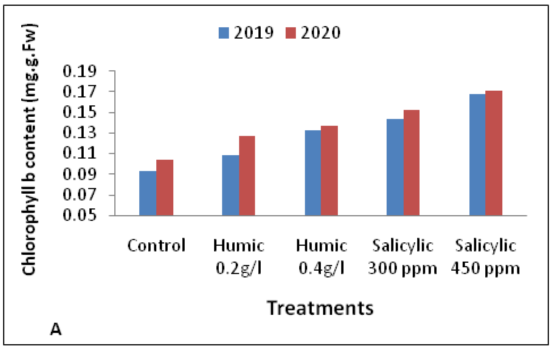


Fig (7). Chlorophyll b content (mg./g.Fw) as influenced by humic and salicylic acid treatments

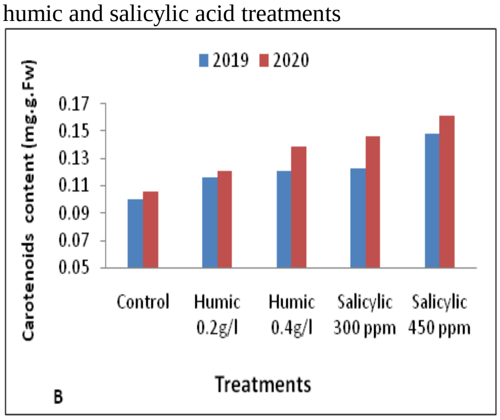
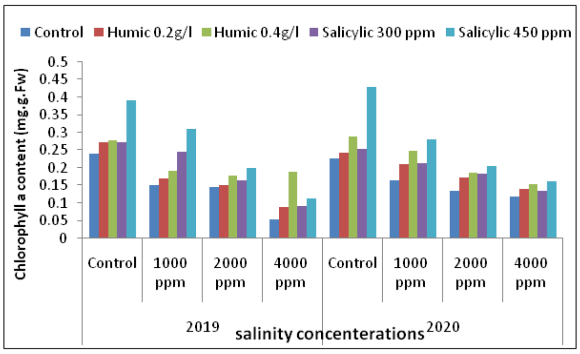
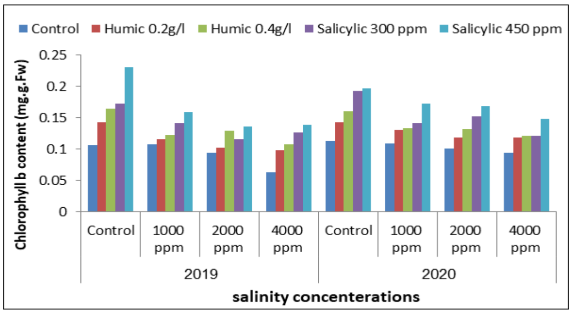


Fig (8). Carotenoids content (mg.g.Fw) as influenced by humic and salicylic acid treatments



Fig(9). Chlorophyll a content (mg.g.F.w) as influenced by the interaction between salinity concentrations, humic and salicylic acid treatments



Fig(10). Chlorophyll b content (mg./g.Fw) as influenced by the interaction between salinity concentrations, humic and salicylic acid treatments

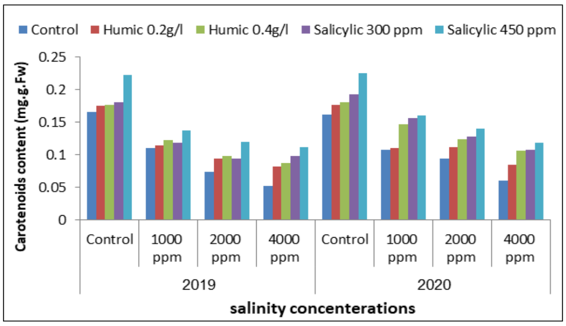


Fig.(11). Carotenoids content (mg.g.Fw) as influenced by the interaction between salinity concentrations, humic and salicylic acid treatments

As demonstrated in Table (5), irrigating plants with saline water significantly reduced carbohydrate accumulation in the leaves in both seasons, and the salt level at 4000 ppm reduced it to the bare minimum, with the control treatment providing the maximum concentration. These results are in agreement with those obtained by **[40]** on *Cortaderia selloana* plant.

Both humic acid and salicylic acid treatments enhanced carbohydrate accumulation compared to the control, with plants treated with salicylic acid at 450 ppm having the greatest concentration Table (5).

The interaction effect revealed that plants watered with tap water and treated with salicylic acid at 450 ppm had the maximum carbohydrate content in both seasons. The lowest was achieved from control plants treated with salinity at 4000ppm. These findings are consistent with previous research **[47]** on *Euphorbia milii* var. longifolia

3.2.2. Carbohydrate content in leaves:

3.2.3. Sodium and chlorine contents (Na% and Cl% DW):

Tables (6) and (7), show that, in both seasons, the contents of Na and Cl% in *Celosia argentea* leaves increased as the salinity levels increased. The highest values were gained from the saline water treatment at 4000ppm.Moreover, there were reductions in these contents in response to the foliar application of humic acid, compared to the control and the highest concentrations of salicylic and humic acids lowered them.

The interactions as shown in Tables (6) and (7) emphasized that plants treated with saline water at 4000 ppm exhibited the highest values of Na and Cl% while the lowest ones were recorded in plants treated with salicylic acid at 450ppm which irrigated with tap water. These results agreed with the results

Table (5). Effect of salinity, humic acid, salicylic acid and their interaction on total charbohydrates percentage in dry leaves of *Celosia argentea* plant during 2019 and 2020 seasons.

Salinity / Treatments	Cont.	1000ppm	2000ppm	4000ppm	Mean salinity
			First season 2019		
Cont.	30.015	26.319	24.819	18.324	**24.869**
H1	31.989	28.278	26.386	19.097	**26.437**
H2	32.381	29.969	28.458	20.216	**27.687**
SA1	35.087	30.458	29.201	22.015	**29.190**
SA2	39.824	30.706	29.969	23.989	**31.053**
MeanTreatment	**33.859**	**29.146**	**27.766**	**20.728**	
			Second season 2020		
Cont.	31.017	28.401	27.050	20.379	**26.711**
H1	31.218	29.102	27.408	20.517	**27.061**
H2	32.303	29.989	27.989	21.030	**27.827**
SA1	33.714	30.075	28.339	21.517	**28.411**
SA2	35.115	31.910	29.009	22.042	**29.269**
Mean Treatment	**33.073**	**29.695**	**27.959**	**22.097**	

H1: humic acid at 0.2 g/l,H2: humic acid at 0.4 g/l, SA1: salicylic acid at 300 ppm and SA2: salicylic acid at 450 ppm.

[40] on *Cortaderia selloana* and **[48]** on *Duranta plumeri*.

Table (6). Effect of salinity, humic acid, salicylic acid and their interaction on sodium percentage in dry leaves of *Celosia argentea* plant during 2019 and 2020 seasons.

Salinity / Treatments	Cont.	1000ppm	2000ppm	4000ppm	Mean
First season 2019					
Cont.	0.178	0.219	0.282	0.601	**0.300**
H1	0.167	0.190	0.260	0.562	**0.294**
H2	0.155	0.196	0.236	0.556	**0.285**
SA1	0.150	0.213	0.230	0.488	**0.270**
SA2	0.144	0.198	0.213	0.477	**0.258**
Mean Treatment	**0.158**	**0.203**	**0.244**	**0.536**	
Second season 2020					
Cont.	0.123	0.190	0.298	0.593	**0.301**
H1	0.100	0.178	0.281	0.512	**0.267**
H2	0.098	0.169	0.278	0.414	**0.239**
SA1	0.081	0.162	0.272	0.418	**0.233**
SA2	0.078	0.157	0.261	0.315	**0.202**
Mean Treatment	**0.096**	**0.171**	**0.278**	**0.450**	

H1: humic acid at 0.2 g/l, H2: humic acid at 0.4 g/l, SA1: salicylic acid at 300 ppm and SA2: salicylic acid at 450 ppm.

Chlorophyll content is an indicator of leaf photosynthesis and the major role of the carotenoids is to act as light receptors and protectors of the photosynthetic apparatus. Recent evidence suggests that SA is an important regulator of photosynthesis because it affects leaf and chloroplast structure, stomata closure, and chlorophyll and carotenoid contents. Also, water salinity condition and chlorine decreased the total chlorophyll and carotenoids content to a larger extent. Decreases in photosynthetic pigments (total chlorophyll and carotenoid content) were due to instability of protein complexes and destruction of chlorophyll by increasing activity of chlorophyll degrading enzyme chlorophyllase under stress condition. The enhancing effects of SA on photosynthetic pigment could be attributed to its stimulatory effects on Rubisco activity and photosynthesis. Salicylic acid induced synthesis of protein kinases, which play an important role in regulating cell division, differentiation and morphogenesis. **[49].**

3.2.4. Proline content:

As demonstrated in Fig (12), proline content in leaves rose linearly as salt levels increased, with the maximum content attained in plants given saline water at 4000ppm and the lowest in control plants. Several investigations on increased proline content as a result of salt stress have shown similar results. They explained proline's involvement in ismotic adjustment, as an energy reserve, and in protecting enzymes and cell membranes from salt stress. It has been demonstrated that proline accumulation under salt stress shields plants against damage brought on by free radicals. Similar results of increasing proline content due to salinity stress were reported by many studies, as **[50,51]** on *Jatropha integerrima*, **[52]** and**[53]**on *Dracaena sanderiana.*

In most cases; treating plants with humic acid and salicylic acid at all concentrations decreased the proline content in leaves and spraying salicylic acid at 450ppm decreased it to the lowest values in both seasons Fig (13).

In terms of the effect of salinity and the treatments of humic acid and salicylic acid on the proline content of *Celosia argentea*, data presented in Fig (14) showed that plants treated with salicylic acid at 450 ppm under non-salinity conditions had the lowest proline content in both seasons. Meanwhile, the highest ones were obtained from saline water treatment at 4000 ppm without humic acid and salicylic acid treatments. Similar results were obtained by **[54]** on *Calendula officinalis* L**.**

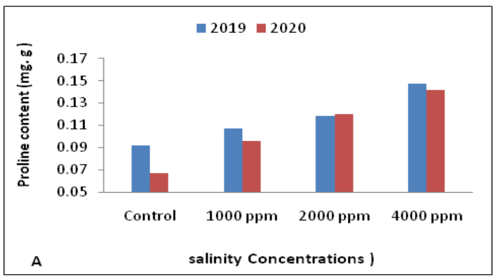


Fig (12) Proline content (mg.g.Fw) as influenced by salinity concentrations

Table (7). Effect of salinity, humic acid, salicylic acid and their interaction on chlorine percentage in dry leaves of Celosia argentea plant during 2019 and 2020 seasons

Salinity / Treatments	Cont.	1000ppm	2000ppm	4000ppm	Mean salinity
First season 2019					
Cont.	0.88	0.177	0.339	0.878	**0.370**
H1	0.076	0.176	0.310	0.801	**0.341**
H2	0.073	0.157	0.293	0.738	**0.315**
SA1	0.069	0.146	0.263	0.585	**0.266**
SA2	0.057	0.122	0.235	0.590	**0.251**
Mean Treatment	**0.073**	**0.156**	**0.288**	**0.718**	
Second season 2020					
Cont.	0.060	0.161	0.301	0.480	**0.251**
H1	0.056	0.160	0.260	0.431	**0.227**
H2	0.054	0.152	0.235	0.422	**0.216**
SA1	0.053	0.150	0.194	0.415	**0.203**
SA2	0.050	0.142	0.184	0.395	**0.193**
Mean Treatment	**0.055**	**0.153**	**0.235**	**0.429**	

H1: humic acid at 0.2 g/l, H2: humic acid at 0.4 g/l, SA1: salicylic acid at 300 ppm and SA2: salicylic acid at 450 ppm.

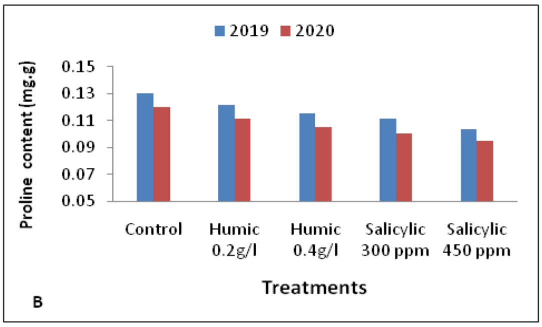


Fig (13) Proline content (mg.g.F.w) as influenced by humic and salicylic acid treatments

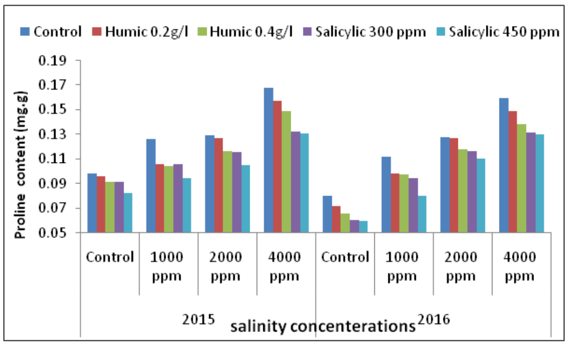


Fig. (14) Proline content (mg.g.F.w) as influenced by the interaction between salinity concentrations, humic and salicylic acid treatments

4. Conclusions

It can be concluded that, under the experimental conditions, *Celosia argentea* plants could tolerate salinity when treated with humic acid and salicylic acid.

Spraying salicylic acid could improve growth and flowering parameters and reducing the effects of salt. *Celosia argentea* plants responded significantly to combined treatments of tap water and different treatments of "humic acid and salicylic acid," which positively improved and enhanced plant vegetative characters, active constituents, and chemical composition. Also, plants treated with salicylic acid (450 ppm) achieved the highest values for most parameters, followed by plants treated with tap water + humic acid (0.4g/l). As a result, this effort may be classified as applied research to increase the production of *Celosia argentea* plants.

5. Conflicts of interest

There is no conflict of interest

List of abbreviations:

Abbreviation	**Meaning**
Ca	Calcium
Cl	Chlorine
cm	Centimetre
CMS	cell membrane stability, a decrease in
Cont.	Control without any treatment
DW	Dry weight
f.w	Fresh weight
Fig.	Figure
g	Gram
H1	humic acid at 0.2 g/l,
H2	humic acid at 0.4 g/l,
HA	Humic acid
kh	Potassium humate
l	Litre
L.S.D	Least significant difference
mg	Milligram
N.P.K	Nitrogen. Phosphorus. Potassium
Na	Sodium
ppm	Parts per million
RCBD	randomized complete block design
ROS	Reactive oxygen species
SA	Salicylic acid
SA1	salicylic acid at 300 ppm
SA2	salicylic acid at 450 ppm.
SAS	Statistical analysis system
v/v	Volume/Volume Percentage Definition
w/w	weight in weight.

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