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APPLICATION OF NATURAL GROWTH PROMOTERS TO IMPROVE THE GROWTH AND FLOWERING OF *GOMPHRENA GLOBOSA* L. PLANT

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ABSTRACT: Our study aimed to test the promoting effect of chitosan at rates100, 300 and 500 mg l^{-1} and humic acid at rates 100, 500 and 700 mg l^{-1} as a foliar application on *Gomphrena globosa* L. plus control plants sprayed with distilled water during 2022 and 2023 seasons. The obtained results cleared that the plants that received foliar application of chitosan at 300 mg l^{-1} showed the highest plant height value, Number of leaves, number of branches per, root length, shoot and root (fresh and dry weights). Moreover, the application of humic acid at a rate of 700 mg l^{-1} raised all the flowering traits including number of inflorescences, inflorescence diameter, inflorescence length, and inflorescences (fresh and dry weights). Furthermore, it was found that the most of chemical compositions including photosynthetic pigments, total sugars, flavonoids content in leaves, and betalain in inflorescences were increased in plants treated with chitosan 300 mg l^{-1} except total phenols content in leaves which showed the highest values in plants sprayed with humic acid at 700 mg l^{-1}.

Keywords: *Gomphrena globosa*, humic acid, chitosan, vegetative growth, flowering parameters, chemical compositions

INTRODUCTION

Globe amaranth (*Gomphrena globosa* L.) is a flowering ornamental plant belonging to the family Amaranthaceae. It is an annual plant that may reach 60 cm in height. It has colorful cloverlike spikes which may be white, red, purple, carmine, and different shades of pink round, and papery, the spikes lengths are about 3–4 cm. The narrow green leaves are opposite and oblong, 10–15 cm in length, and woolly-white when young, becoming sparsely white-hairy as they grow up (Yaseen and Khan, 2022). Gomphrena is used in ornamental beds, borders and edges in the gardens, pot plants, hanging baskets, and also as a potential summer cut flower (Cocozza-Talia, 1993).

In addition, the flowers of *Gomphrena globosa* are rich sources of the pigment betacyanins which can be used in the food industry and cosmetics. Betalain pigments that have a red-violet color are ideal as natural food dyes. The betacyanins, are identified as gomphrenin and isogomphrenin (Roriz *et al*., 2017).

Mohamed *et al*. (2022), Elsayed *et al*. (2022) and Mohamed *et al*. (2023) cleared that natural growth promoters are considered clean, safe and environmentally friendly sources that it easy to obtain due to their availability in the surrounding environment, and many studies have proven that these natural materials can trigger plant growth. Farouk *et al.* (2011) revealed that chitosan and humic acid enhanced the growth, yield and improved physiological processes in plant.

Chitosan is a natural polysaccharide derived from the low acetyl form of chitin, consisting primarily of glucosamine and N-acetylglucosamine, produced commercially from crab shells, shrimp shells, lobsters and squid, as well as from filamentous fungi (Kumaresapillai *et al*., 2011). biodegradable environmentally friendly, and widely used in agriculture. Previous studies have shown that chitosan can stimulate the growth index of plants (Farouk *et al*., 2008). Chitosan is a natural biopolymer modified by chitin that can serve as a potential biostimulant and trigger in agriculture. It is safe, bioactive, biodegradable and biocompatible, with potentially wide applications. Previous investigations have demonstrated that chitosan has positive acts on some ornamental plants under stress-free conditions, such as increasing growth and flowering characteristics, chlorophyll content, photosynthesis and mineral nutrient absorption (Dzung *et al*., 2011; Salachna *et al*., 2015; Byczyńska, 2018). It is also used as a fertilizer and in controlled agrochemical release, to increase plant productivity (New *et al*., 2004), protect plants against microorganisms (Farouk *et al*., 2008), against oxidative stress (Guan *et al*., 2009) and stimulate plant growth (Farouk *et al*., 2011).

Humic acid (HA) is a Natural organic molecule with acidic groups such as carboxyl and phenolic hydroxyl (OH) functional groups. As a result, it gives organic macromolecules a crucial role in metal transport, bioavailability, and solubility (Chen and Zhu, 2006). Because of its effect on physiological and metabolic processes, it is utilized to boost early growth and blooming as well as root and nutrient efficiency. The beneficial impact of HA is related to its indirect effects on improving physical, chemical, and microbiological soil qualities, as well as its direct effects on physiological, biochemical, and hormone-like activities (Canellas and Olivares, 2014). Humic acid's method for stimulating plant development is assumed to be connected to increased cell membrane permeability, oxygen intake, respiration, photosynthesis, phosphorus uptake, and root cell elongation as plant growth factors proposed by many authors to explain the promotive effect of humic acid on such plant measurement (Cacco and Dell Agnolla, 1984 and Russo and Berlyn, 1990). Furthermore, HA has important acts for the transit and accessibility of micronutrients and has positive effects on its chemical synthesis, availability and soil structure. It also increases the amount of accessible microorganisms that promote nutrient intake (Bohme and Lua, 1997).

The purpose of this study is to investigate the ability of chitosan and humic acid to improve the growth and flowering of *Gomprena globosa* plant.

MATERIALS AND METHODS

The experiment of this study was conducted during 2022 and 2023 seasons in the greenhouse of the Horticulture Research Institute, Agricultural Research Center, Giza, Egypt. The seeds of *Gomprena globosa* were obtained from the Horticulture Research Institute, and sown in plastic pots on the 1st of March during the two seasons; the emergency seedlings were transplanted in April when they started having 4 to 6 real leaves in 20 cm pots filled with sand and clay. The physical and chemical analysis of the used media were shown in Table (1) which was determined according to George *et al*. (2013).

Table 1. Physical and chemical analysis of the used potting media.

Chemical analysis		Physical analysis	
pH	7.45	**V.C.S**	10.19%
EC (1:1)	16.46 dS m^{-1}	**C.S.**	20.13%
CO_3^{-2}	0.00	**M.S.**	41.25%
HCO_3^-	8.80 meq l^{-1}	**F.S.**	14.41%
Cl^-	112.0 meq l^{-1}	**V.F.S.**	7.81%
SO_4^{-2}	34.66 meq l^{-1}	**Silt+Clay**	6.21%
Ca^{+2}	27.18 meq l^{-1}		
Mg^{+2}	23.36 meq l^{-1}		
K^+	15.04 meq l^{-1}		
Na^+	89.08 meq l^{-1}		

Where; V.C.S: very coarse sand, C.S.: coarse sand, M.S.: medium sand, F.S.: fine sand and V.F.S.: very fine sand.

Three weeks from transplanting, the seedlings were sprayed with chitosan at rates (100, 300 and 500 mg l^{-1}) and humic acid at rates (300, 500 and 700 mg l^{-1}) in addition to control plants which were sprayed with distilled water, the second time was applied after on month from first spraying, and the same for third one. The common cultural practices were followed, including hand-picking of weeds and monthly plant fertilization with commercial Kristalon (NPK 19-19-19) at the rate of 2 g pot^{-1}.

The plants were harvested in August for each season to record the following data:

Vegetative growth parameters:

1. Plant height (cm).
2. Stem diameter (cm).
3. Leaf area (cm^2).
4. Number of leaves (leaf $plant^{-1}$).
5. Number of branches (branch $plant^{-1}$).
6. Root length (cm).
7. Shoot fresh weight (g $plant^{-1}$).
8. Shoot dry weight (g $plant^{-1}$).
9. Root fresh weight (g $plant^{-1}$).
10. Root dry weight (g $plant^{-1}$).

Inflorescences parameters:

1. Number of inflorescences (inflorescence $plant^{-1}$).
2. Inflorescence diameter (cm).
3. Inflorescence height (cm).
4. Inflorescence fresh weight (g $plant^{-1}$).
5. Inflorescence dry weight (g $plant^{-1}$).

Chemical analysis:

1. Photosynthetic pigments including chlorophyll a, b and carotenoid (mg g^{-1} F.W.) were determined according to Saric *et al.* (1967).
2. Total sugar content (mg g^{-1} F.W.) was determined according to the methods described by Dubois *et al*. (1956).
3. Total flavonoid content (mg g^{-1} F.W.) was determined according to Singleton *et al*. (1999).
4. Total phenols content (mg g^{-1} F.W.) was determined according to Quettier *et al*. (2000).
5. Betalain pigment in inflorescence (mg 100 g^{-1} F.W.) was determined according to Francis (2000) and Castellar *et al*. (2003).

Experiment layout and statistical analysis:

The experiment was arranged in a completely randomized design with 7 treatments with 3 replicates for each season. ANOVA was used to evaluate the collected data, and the means of the treatments were compared for significance using Duncan's new multiple range test (DMRT) at the 5% level of probability (Duncan, 1955). For each value, standard division (SD) was computed.

RESULTS

Vegetative growth parameters:

The current study illustrated that the natural growth promoters including chitosan and humic acid enhanced the growth G*omphrena globosa* plant. Data in Tables (2 and 3) showed that the parameters of vegetative growth in terms of plant height, number of leaves, number of branches, root length, shoot (fresh and dry weights), and root (fresh and dry weights) were positively affected by both chitosan and humic acid at the different concentration as compared with control. Chitosan at the rate of 300 mg l^{-1} gave the highest plant parameters (cm) 36.87±1.21, 131.00±4.58, 15.67±3.22, 26.77±1.79, 27.55±2.07, 7.10±0.08, 3.87±0.40 and 1.46±0.06, respectively, in the first season and 36.25±1.99, 135.00±3.61, 16.00±1.73, 29.30±1.71, 29.02±1.35, 7.48±0.08, 4.60± 0.16 and 1.73± 0.06, respectively, in the second season except stem diameter which significantly increased by treatment humic acid at rate 700 mg l^{-1} giving (cm) 0.66 ± 0.03 and 0.64 ± 0.04, respectively in 1^{st} and 2^{nd} seasons.

Table 2. Effect of chitosan (CHT) and humic acid (HA) on some growth parameters of *Gomphrena globosa* plants during 2022 and 2023 seasons.

Treatment (mg l^{-1})	Plant height (cm)	Stem diameter (cm)	Leaf area (cm^2)	No. of leaves (leaf $plant^{-1}$)	No. of branches (branch $plant^{-1}$)
			2022		
Control	30.23±1.77^{c}	0.48±0.03^{d}	9.15±0.41^{e}	102.00±4.36^{f}	10.00±1.73^{d}
CHT 100	34.50±1.74^{b}	0.56±0.03^{c}	11.00±0.49^{d}	124.00±5.20^{bc}	13.00±2.65^{bc}
CHT 300	36.87±1.21^{a}	0.62±0.03^{ab}	12.68±0.40^{c}	131.00±4.58^{a}	15.67±3.22^{a}
CHT 500	31.10±2.35^{c}	0.61±0.04^{b}	14.74±0.55^{ab}	114.00±2.65^{d}	11.67±2.08^{cd}
HA 300	33.10±1.45^{b}	0.60±0.04^{bc}	13.33±0.63^{c}	109.67±3.50^{e}	11.00±2.00^{cd}
HA 500	34.03±2.75^{b}	0.51±0.04^{d}	14.50±0.38^{b}	122.33±3.78^{c}	12.67±1.53^{bc}
HA 700	34.17±2.60^{b}	0.66±0.03^{a}	15.57±0.41^{a}	126.00±3.46^{b}	14.67±3.22^{ab}
			2023		
Control	31.17±1.98^{e}	0.50±0.04^{d}	10.66±0.47^{f}	105.67±5.86^{f}	11.00±1.00^{d}
CHT 100	35.17±2.37^{ab}	0.54±0.03^{cd}	11.72±0.36^{e}	122.33±5.03^{c}	14.67±1.53^{ab}
CHT 300	36.25±1.99^{a}	0.61±0.05^{ab}	13.50±0.39^{d}	135.00±3.61^{a}	16.00±1.73^{a}
CHT 500	32.00±1.73^{de}	0.57±0.03^{bc}	15.09±0.39^{b}	117.00±3.61^{d}	12.67±1.15^{bcd}
HA 300	32.40±1.84^{cde}	0.56±0.04^{bc}	14.27±0.40^{c}	111.67±3.79^{e}	11.33±1.53^{cd}
HA 500	33.43±2.28^{cd}	0.52±0.03^{cd}	14.85±0.42^{b}	120.00±4.36^{cd}	13.67±1.57^{abc}
HA 700	33.90±2.82^{bc}	0.64±0.04^{a}	16.48±0.31^{a}	130.33±3.79^{b}	15.33±2.08^{a}

Mean values (± SD) of the same letter in the same column do not significantly differ based on DMRT at 5% level.

Table 3. Effect of chitosan (CHT) and humic acid (HA) on some growth parameters of *Gomphrena globosa* plants during 2022 and 2023 seasons

Treatment (mg l^{-1})	Root length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)
			2022		
Control	15.13±1.48^{e}	13.56±1.19^{f}	3.12±0.07^{g}	1.57±0.24^{d}	0.54±0.06^{e}
CHT 100	25.20±2.39^{b}	24.78±1.89^{bc}	6.09±0.05^{c}	3.68±0.31^{a}	1.33±0.08^{b}
CHT 300	26.77±1.79^{a}	27.55±2.07^{a}	7.10±0.08^{a}	3.87±0.40^{a}	1.46±0.06^{a}
CHT 500	23.57±2.46^{c}	20.33±1.25^{d}	4.86±0.05^{e}	2.39±0.39^{c}	0.85±0.04^{d}
HA 300	20.87±1.87^{d}	17.58±1.78^{e}	4.15±0.06^{f}	1.73±0.24^{d}	0.61±0.05^{e}
HA 500	21.27±2.98^{d}	24.42±1.72^{c}	5.89±0.06^{d}	2.89±0.46^{b}	1.04±0.06^{c}
HA 700	24.00±2.86^{bc}	26.03±2.15^{b}	6.57±0.09^{b}	3.71±0.27^{a}	1.37±0.07^{ab}
			2023		
Control	15.77±1.65^{d}	14.76±1.32^{f}	3.40±0.06^{g}	1.88±0.19^{g}	0.64±0.05^{g}
CHT 100	25.27±1.50^{b}	26.14±1.70^{bc}	6.43±0.07^{c}	3.65±0.22^{c}	1.32±0.06^{c}
CHT 300	29.30±1.71^{a}	29.02±1.35^{a}	7.48±0.08^{a}	4.60±0.16^{a}	1.73±0.06^{a}
CHT 500	24.27±1.69^{b}	21.64±1.40^{d}	5.18±0.07^{e}	2.78±0.13^{e}	0.98±0.06^{e}
HA 300	19.63±1.35^{c}	18.00±1.46^{e}	4.25±0.06^{f}	2.19±0.10^{f}	0.76±0.07^{f}
HA 500	21.00±0.95^{c}	24.85±2.33^{c}	6.00±0.08^{d}	3.28±0.15^{d}	1.17±0.07^{d}
HA 700	27.83±1.86^{a}	27.73±1.13^{ab}	6.98±0.06^{b}	3.96±0.19^{b}	1.47±0.07^{b}

Mean values (± SD) of the same letter in the same column do not significantly differ based on DMRT at 5% level.

Flowering characteristics:

The obtained results showed an improvement in flowering characteristics when treated with chitosan and humic acid. Table (4) illustrates that the plants were treated with humic acid at the concentration at a rate of 700 mg l^{-1} significantly increased number of inflorescences giving values 25.33±1.53 and 24.67±1.53, inflorescences diameter giving values 1.53±0.21 and 1.61±0.13, inflorescences height giving values 2.42±0.11 and 2.37±0.15, inflorescences fresh weight 4.68±0.15 and 4.42±0.23 and inflorescences dry weight giving values 1.45±0.06 and 1.37±0.05, respectively, in both seasons. The plants treated with chitosan at the rate of 300 mg l^{-1} also showed a significant effect on inflorescence diameter giving values of 1.51±0.10 and 1.56±0.11, respectively, in both seasons.

Chemical compositions:

Data presented in Table (5) pointed to the application of chitosan at the rate of 300 mg l^{-1} most effective treatment for the content of photosynthetic pigments including chlorophyll a, b and carotenoids giving values 0.53±0.03, 0.23±0.03 and 0.36±0.04, respectively, in 1st season and 0.57±0.04, 0.25±0.03 and 0.47±0.04, in 2nd season. Followed by the application of humic acid treatment at the concentration of 700 mg l^{-1} giving values 0.49±0.03, 0.22±0.03 and 0.34±0.04, respectively, in the first season and 0.51±0.04, 0.22±0.03 and 0.44±0.03, respectively, in the second season.

Data presented in Table (5) ascertained that the utilization of chitosan and humic acid affected total sugars and flavonoids content in leaves, with the highest values obtained from the treatment of chitosan at a concentration of 300 mg l^{-1} giving 0.71±0.04 and 3.30±0.11, respectively, in the first season and 0.76±0.05 and 3.41±0.11, respectively, in the second season. Plants treated with humic acid at a concentration of 700 mg l^{-1}, on the other hand, had higher total phenols content, with values of 1.59±0.09 and 1.64±0.10 in the first and second seasons, respectively.

Regarding betalain pigments in the inflorescence, the data presented in the same Table showed that the highest content of betalain was obtained from the plants treated with chitosan at a concentration of 300 mg l^{-1} giving values 1.08±0.09 and 1.10±0.06, respectively, in both seasons. Followed by the plants treated with humic acid at a concentration of 700 mg l^{-1} giving values 0.96±0.06 and 1.03±0.06, respectively, in both seasons.

DISCUSSION

Natural growth promoters had a clear effect on growth and flowering characteristics and the content of some chemical components in *Gomphrena globosa* plant. Chitosan is an important amino polysaccharide and a deacetylated, modified version of chitin. It has great advantages, including non-toxicity, biocompatibility, and biodegradability (Cardona and Rutherford, 2019).

Zong *et al*. (2017) indicated that chitosan application improved plant growth; it may be due to increasing the thickness of the leaf blade by increasing the thickness of the mesophyll tissue and (through the midrib region) the midrib vascular bundle. It also increased the thickness of the water storage tissue and increased the area of the xylem and phloem by stimulating pro-cambial activity in the midrib bundle during differentiation (Farouk and Ramadan, 2012), or may be attributed to an increase in the availability and uptake of water and

Table 4. Effect of chitosan (CHT) and humic acid (HA) on inflorescence characteristics of *Gomphrena globosa* plants during 2022 and 2023 seasons.

Treatment (mg l^{-1})	Number of Inflorescences (inflorescence $plant^{-1}$)	Inflorescence diameter (cm)	Inflorescence height (cm)	Inflorescence fresh weight (g)	Inflorescence dry weight (g)
			2022		
Control	11.33±0.58^{e}	0.76±0.12^{d}	1.20±0.26^{e}	1.41±0.10^{f}	0.40±0.05^{f}
CHT 100	12.33±1.15^{e}	1.07±0.15^{c}	1.60±0.17^{d}	2.57±0.11^{e}	0.74±0.06^{e}
CHT 300	20.67±2.08^{b}	1.51±0.10^{a}	2.26±0.15^{ab}	4.15±0.24^{b}	1.27±0.07^{b}
CHT 500	17.00±1.00^{cd}	1.20±0.22^{bc}	1.97±0.20^{bc}	3.30±0.21^{d}	0.99±0.05^{d}
HA 300	15.33±1.52^{d}	1.16±0.12^{bc}	1.73±0.11^{cd}	3.22±0.14^{d}	0.94±0.07^{d}
HA 500	18.33±1.53^{c}	1.32±0.11^{b}	2.21±0.26^{ab}	3.69±0.18^{c}	1.11±0.05^{c}
HA 700	25.33±1.53^{a}	1.53±0.21^{a}	2.42±0.11^{a}	4.68±0.15^{a}	1.45±0.06^{a}
			2023		
Control	12.00±1.73^{f}	0.93±0.09^{d}	1.36±0.10^{f}	1.64±0.11^{g}	0.46±0.07^{f}
CHT 100	13.67±1.53^{e}	1.18±0.12^{c}	1.56±0.13^{f}	2.71±0.18^{f}	0.78±0.08^{e}
CHT 300	22.33±2.08^{b}	1.56±0.11^{a}	2.22±0.14^{ab}	4.26±0.15^{b}	1.30±0.08^{ab}
CHT 500	17.67±1.53^{d}	1.30±0.13^{bc}	2.04±0.19^{c}	3.51±0.22^{d}	1.05±0.06^{c}
HA 300	16.67±1.53^{d}	1.23±0.10^{c}	1.88±0.22^{d}	3.16±0.16^{e}	0.92±0.05^{d}
HA 500	20.00±2.00^{c}	1.49±0.12^{ab}	2.14±0.11^{bc}	4.00±0.25^{c}	1.20±0.05^{b}
HA 700	24.67±1.53^{a}	1.61±0.13^{a}	2.37±0.15^{a}	4.42±0.23^{a}	1.37±0.05^{a}

Mean values (± SD) of the same letter in the same column do not significantly differ based on DMRT at 5% level.

Table 5. Effect of chitosan (CHT) and humic acid (HA) on chemical compositions of *Gomphrena globosa* plants during 2022 and 2023 seasons.

Treatment (mg l^{-1})	Chlorophyll a (mg g^{-1} F.W.)	Chlorophyll b (mg g^{-1} F.W.)	Carotenoids (mg g^{-1} F.W.)	Total sugars content (mg g^{-1} F.W.)	Total flavonoid content (mg g^{-1} F.W.)	Total Phenols content (mg g^{-1} F.W.)	Betalain (mg 100 g^{-1} F.W.)
				2022			
Control	0.20±0.01^{g}	0.09±0.02^{f}	0.14±0.02^{f}	0.40±0.04f	1.58±0.09f	1.13±0.07^{d}	0.63±0.06^{e}
CHT 100	0.41±0.02^{c}	0.19±0.03^{b}	0.30±0.03^{bc}	0.61±0.04c	2.70±0.10b	1.36±0.09^{b}	0.92±0.09^{b}
CHT 300	0.53±0.03^{a}	0.23±0.03^{a}	0.36±0.04^{a}	0.71±0.04a	3.30±0.11a	1.52±0.09^{a}	1.08±0.09^{a}
CHT 500	0.29±0.03^{f}	0.11±0.03^{e}	0.19±0.03^{ef}	0.43±0.03f	1.70±0.11e	1.17±0.08^{cd}	0.71±0.06^{de}
HA 300	0.33±0.02^{e}	0.14±0.03^{d}	0.20±0.03^{de}	0.49±0.03e	2.25±0.09d	1.20±0.07^{cd}	0.77±0.04^{cd}
HA 500	0.37±0.04^{d}	0.17±0.03^{c}	0.25±0.03^{cd}	0.56±0.05d	2.58±0.10c	1.29±0.08^{bc}	0.85±0.06^{bc}
HA 700	0.49±0.03^{b}	0.22±0.03^{a}	0.34±0.04^{ab}	0.65±0.04b	2.71±0.08b	1.59±0.09^{a}	0.96±0.06^{ab}
				2023			
Control	0.22±0.03^{e}	0.11±0.02f	0.18±0.04^{e}	0.42±0.03e	1.83±0.08f	1.16±0.08^{d}	0.67±0.06^{e}
CHT 100	0.43±0.04^{c}	0.20±0.02^{c}	0.37±0.03^{b}	0.68±0.04b	2.87±0.09c	1.40±0.10^{b}	0.90±0.04^{b}
CHT 300	0.57±0.04^{a}	0.25±0.03^{a}	0.47±0.04^{a}	0.76±0.05a	3.41±0.11a	1.57±0.08^{a}	1.10±0.06^{a}
CHT 500	0.31±0.03^{d}	0.14±0.03^{e}	0.22±0.03^{de}	0.51±0.05d	2.23±0.09e	1.22±0.07^{cd}	0.74±0.05^{de}
HA 300	0.38±0.03^{c}	0.17±0.04^{d}	0.26±0.04^{d}	0.57±0.03c	2.49±0.10d	1.27±0.06^{bcd}	0.80±0.05^{cd}
HA 500	0.40±0.03^{c}	0.18±0.02^{d}	0.31±0.04^{c}	0.61±0.04c	2.65±0.11d	1.32±0.09^{bc}	0.88±0.07^{bc}
HA 700	0.51±0.04^{b}	0.22±0.03^{b}	0.44±0.03^{a}	0.73±0.04ab	3.10±0.09b	1.64±0.10^{a}	1.03±0.06^{a}

Mean values (± SD) of the same letter in the same column do not significantly differ based on DMRT at 5% level.

essential nutrients through adjusting cell osmotic pressure (Guan *et al*., 2009). It may occur due to an increase in the main enzymatic activities of nitrogen metabolism (nitrate reductase, glutamine synthetase, and protease) and also improved transportation of nitrogen (N) in the functional leaves, which enhances the photosynthesis process and improves plant growth and development (Mondal *et al*., 2012).

Khan *et al*. (2002) chitosan foliar application improved net photosynthetic rates and was associated with increases in stomatal conductance and transpiration rate, but had no influence on intercellular CO_2 concentration in soybean and maize. Chitosan may enhance levels of cytokinins, which induce chlorophyll synthesis (Chibu and Shibayama, 2001). Moreover, chitosan has the potential to protect the membranes and help to eliminate active oxygen species (AOS) (Xue *et al*., 2004). Ahmed *et al*. (2023) explained that the growth parameters, carbohydrate content, and photosynthetic pigments of *Rosmarinus officinalis* plant were enhanced by chitosan treatments. Godase *et al*. (2023) illustrated the growth characters and photosynthetic pigments of *Lablab purpureus* L. Sweet. were positively affected by chitosan application. Furthermore, Nofal *et al*. (2021) proved the stimulative effect of chitosan application on *Catharanthus roseus* plants as compared to the other bio-stimulants. Humates are natural organic substances, high in humic acid and containing most of the known trace minerals necessary for plant growth and production. Humic acid is a natural polymer organic compound (Senn, 1991). Humic acid, which has been complexed with potassium and has multiple actions related to water relations, protein and fat synthesis, and magnesium stimulation of several plant enzymes required for vegetative growth, could explain the observed increase. Humic acid also functions as a catalyst, increasing soil microbial activity. (Sharif *et al*., 2002). Furthermore, one of the most bioactive humate molecules increases potassium levels in leaves. These findings are like those reported by Ali *et al*. (2008) on gerbera. Increasing the number of branches involves getting better and higher quality. One of the most notable effects of fulvic acid is that it promotes root development and respiration, which improves plant growth and yield; these findings are like those published by Rongting *et al.* (2017) on mums' plants. It has been discovered that nitrogen molecules included in humic acid play a vital role in plant development, also humic acid boosts shoot development by promoting calcium, nitrogen, phosphorus, manganese, potassium, iron, zinc and copper intake, as well as having hormone-like effects. Humic acid was also reported to improve plant development by raising the activity of the RuBisCO enzyme, which led to an increase in photosynthetic activity (Abaszadeh *et al*., 2018). Likewise, humic acid lowers the pH of alkaline soils and improves plant development by influencing metabolic activity and improving nutrient uptake, particularly nitrogen absorption (Akladious and Mohamed, 2018). The results were obtained in the same line with Abdellatif *et al*. (2017) on a tomato plant, Hafiz (2018) on *a Lepidium sativum* plant, furthermore El-Sayed *et al*. (2022) on *Dimorphotheca ecklonis*. Moreover, Abd El-baset and Kasem (2022) pointed out that the application of humic acid has a great effect on vegetative growth parameters, and flowering traits, and also promote total chlorophylls, carotenoids, and total carbohydrates of the *Dendranthema grandiflorum* plant.

CONCLUSION

Based on our results, it may be concluded that the concentration of 300 mg l^{-1} of chitosan had a significant effect on the growth, flowering, and chemical constituents of *Gomphrena globosa* plants, followed by humic acid at 700 mg l^{-1}.

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تطبيق منشطات النمو الطبيعية لتحسين نمو وتزهير نبات المدنة

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الهدف من الدراسة هو اختبار التأثير المعزز للشيتوزان بمعدلات ١٠٠ و ٣٠٠ و ٥٠٠ ملجرام لتر$^{-١}$ وحمض الهيوميك بمعدلات ١٠٠ و ٥٠٠ و ٧٠٠ ملجرام لتر$^{-١}$ كتطبيق ورقي على نبات المدنة بالإضافة إلى النباتات الغير معاملة التي تم رشها بالماء المقطر خلال الموسمين ٢٠٢٢ و ٢٠٢٣. أظهرت النتائج المتحصل عليها أن النباتات التي تم رشها ورقياً بالشيتوزان بتركيز ٣٠٠ ملجرام لتر$^{-١}$ أعطت أعلى معدل لارتفاع النبات، عدد الأوراق، عدد الأفرع، طول الجذر، و الأوزان الطازجة و الجافة للمجموع الخضري و الجذري. علاوة على ذلك فإن إضافة حامض الهيوميك بمعدل ٧٠٠ ملجرام لتر$^{-١}$ أدى إلى زيادة قيم جميع صفات التزهير بما في ذلك عدد النورات، قطر النورات، طول النورات، وزن النورات الطازجة والجافة. كما وجد أن معظم المكونات الكيميائية بما في ذلك صبغات البناء الضوئي والسكريات الكلية والفلافونويدات في الأوراق و صبغة البيتالين في النورات زادت في النباتات المعاملة بالشيتوزان ٣٠٠ ملجرام لتر$^{-١}$ باستثناء محتوى الفينولات الكلي في الأوراق الذي أظهر أعلى القيم في النباتات المعاملة بحمض الهيوميك بتركيز ٧٠٠ ملجرام لتر$^{-١}$.