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The role of chitosan and natural polymer in growth parameters of *Senna occidentalis* L. under water stress conditions

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Abstract

A factorial experiment was conducted in a plastic greenhouse designated for this purpose in Al-Husseiniya sub-district (14 km southeast of Karbala province) to study the effect of natural compounds on the growth of plants under water stress. The experiment included three equally important factors: the first factor involved three irrigation intervals (4, 6, and 8 days), the second factor involved treating the soil medium with different levels of fabric polyter (0.0, 2.5, and 5.0 g per pot), and the third factor involved foliar spraying with different concentrations of nano-chitosan (0.0, 100, and 200 mg L^{-1}).The experiment was designed in a randomized complete block design (RCBD) with three replicates for each treatment, with each replicate consisting of three experimental units. Each pot represented an independent experimental unit, with one plant per pot.The results showed significant differences in growth parameters due to the studied factors. The combination treatment of 2.5 g polyter and foliar spraying with 200 mg L^{-1} chitosan for plants irrigated every 4 days resulted in significantly superior performance in plant height (127.67 cm), number of leaves (444.3 leaves), and number of roots (8.33 roots), which did not differ significantly from the same combination when irrigated every 8 days. Leaf chlorophyll content also increased (60.43 SPAD units). The longest root length (38.67 cm) was observed in the combination of 5.0 g polyter and water-only spraying under 8-day irrigation intervals. The lowest values were recorded in the control treatment. These findings suggest that eco-friendly and sustainable environmental factors have a significant impact on enhancing the vegetative growth parameters of *Senna occidentalis* L.under varying irrigation intervals.

Keywords: *Senna occidentalis* L., Water stress, polyter, Nano-chitosan

Introduction

Senna occidentalis L. is a herbaceous, evergreen shrub. It is a highly attractive plant that propagates by seeds. *Senna occidentalis* L. is native to tropical and subtropical regions and belongs to the Fabaceae (Legume) family. It has an upright stem that bears beautiful yellow flowers which bloom throughout the year. The plant can grow up to 2.5 meters in height and is originally native to Australia and East Africa. It is cultivated in warm, humid, hot, and semi-hot regions and is used for medicinal purposes as well as for landscaping parks and streets [1].

Shrubs are known as a group of woody perennial plants characterized by a green leafy mass that holds considerable environmental, industrial, and nutritional importance. Their usage extends beyond these functions, as they are essential elements in soil stabilization, combating desertification, preventing sand encroachment, serving as windbreaks, and enhancing landscape design due to their attractive foliage, flowers, or regular growth habits. They also contribute to biodiversity [2] Moreover, shrubs play a prominent role in the environment through their ability to absorb toxic CO_2 from the atmosphere and improve climatic conditions [3]

Due to the water scarcity faced by Middle Eastern countries and the challenges arising from reduced rainfall and weakened upstream water supply, plants have been increasingly exposed to abiotic environmental stress, particularly water stress. This form of stress is considered one of the most critical and dangerous challenges to plant growth [4]. Water stress often negatively impacts vegetative growth parameters by stimulating the production of free radicals, which exert oxidative effects on plant cells, leading to compounded stress due to insufficient water availability, and thereby further deteriorating growth indicators [5]. One of the most important modern approaches to mitigating water stress is the use of natural chemical compounds with biostimulant properties, as suggested by recent studies. These compounds help overcome anticipated water shortages. Soil can reduce water loss and retain moisture to cope with drought through the use of natural compounds such as polyter, which forms a cellulose fiber-like network that binds to soil particles, preventing water permeability and enabling moisture retention for longer periods [6]. Plants can also reduce moisture loss by using anti-transpirants, which are a group of effective compounds capable of limiting water vapor loss through transpiration when applied as foliar sprays. An example is chitosan, a biostimulant compound that enhances cell division and growth and acts as an anti-transpirant to reduce water loss[7]. Based on the above, this study aims to assess the growth performance of Senna occidentalis L. shrubs under water-stress conditions, while examining how their response is influenced by treatments with safe and naturally derived compounds that may enhance their tolerance and overall growth attributes.

Materials and Methods

A factorial experiment was conducted in a plastic greenhouse specifically designated for this purpose in Al-Husseiniya sub-district (14 km southeast of Karbala Governorate), located at 44°09′E longitude and 32°39′N latitude, during the period from the end of October 2024 to the end of August 2025. The aim was to study the effect of natural compounds on the vegetative growth of *Senna occidentalis* L.plants subjected to water stress under greenhouse conditions.

Seedlings of *Senna occidentalis* L.were obtained from the Agricultural Research Directorate in Baghdad (Al-Zaafaraniya), and the remaining number was completed from a private nursery in Babylon Province. The seedlings were 1–2 years old, propagated from seeds, with an average height ranging between 30 and 60 cm. The seedlings were transplanted into plastic pots with a diameter of 30 cm and a capacity of 8 kg, using a soil mixture of sand and peat moss in a 2:3 ratio (Table 1), on 10 October 2024. One plant was placed per pot. The soil was firmly compacted during transplanting to prevent seedling movement. All necessary horticultural practices were performed as needed during the experimental period. Humic acid was applied as a fertilizer at a concentration of 2.5 ml·L^{-1} to all pots twice during the study — once during transplanting and once afterward.

Table (1): Some physical and chemical properties of the experimental soil

Soil Texture	Soil particle size distribution			Available Potassium (mg. kg^{-1})	Available Phosphorus (mg. kg^{-1})	Total Nitrogen (mg. kg^{-1})	Organic Matter (%)	E.C ms. cm^{-1}	pH
	Sand (%)	Silt (%)	Clay (%)						
Sandy	89.50	8.46	2.03	106.96	0.3	9.1	0.33	18.96	7.58

Experimental Treatments

The experiment involved three factors, organized based on the adopted experimental design, as follows:

1- Irrigation Intervals Three irrigation frequencies were used: every 4, 6, and 8 days, respectively. The irrigation program was implemented after the initiation of the treatment applications.
2- Fabric Polyter :The soil conditioner polyter was mixed with the soil before transplanting at three levels: 0.0, 2.5, and 5.0 g·pot^{-1}, following the manufacturer's recommendations. It was applied as a powder at a depth of 5–7 cm below the soil surface, targeting the root zone.
3- Nano-Chitosan : Nano-chitosan was applied as a foliar spray at three concentrations: 0, 100, and 200 mg·L^{-1}. Four sprays were conducted, each 20 days apart, starting from March 29, 2025, until June 1, 2025. Spraying was done in the early morning until full foliage wetting was achieved.

Measured Parameters

1- Plant Height (cm):Measured from the base of the stem at soil level to the apex of the plant using a metric measuring tape. Five plants per treatment replicate were measured, and the average was calculated.
2- Number of Leaves (leaves·$plant^{-1}$):Leaves were counted for each plant within each replicate, and the average was determined.

3- Leaf Chlorophyll Content (SPAD):Measured using a SPAD Plus-502 meter (Japan). Three readings were taken per leaf (top, middle, and bottom leaves of one plant), and the mean value was recorded.
4- Main Root Length (cm):Measured on August 17, 2025, at the end of the experiment. One plant was randomly selected from each replicate. Plants were uprooted, washed to remove soil and polyter residues, and root length was measured from the crown to the root tip using a metric ruler.
5- Number of Roots (roots·plant^{-1}):Counted for each plant in every replicate, then the average was calculated.

Experimental Design and Statistical Analysis

The experiment was conducted as a 3×3×3 factorial in a Randomized Complete Block Design (RCBD) with three replicates per treatment. Each replicate included three experimental units, totaling 27 treatments, each randomly distributed. Each replicate contained four pots (one plant per pot), resulting in a total of 324 pots.

Data were statistically analyzed using GenStat 2012 software. Differences between treatment means were evaluated using the Least Significant Difference (LSD) test at the 5% probability level [8].
(LSD) test at the 5% probability level [8].

Results and Discussion

Plant Height (cm)

The statistical analysis presented in Table 2 indicates that irrigation intervals had a significant effect on plant height. A clear inverse relationship was observed, where increasing the irrigation interval led to a decrease in plant height. The highest average plant height was recorded at the 4-day irrigation interval, reaching 113.83 cm, which was significantly superior to the other treatments. In contrast, the lowest average height was observed in the 8-day irrigation treatment, with a value of 105.43 cm.
Significant differences were also observed in plant height as a result of the application of fabric polyter at different levels to the planting medium. Plants treated with 2.5 g polyter per pot achieved the highest mean height of 112.63 cm, which was significantly greater than the 5.0 g treatment, which recorded the lowest mean of 107.30 cm. However, the latter did not differ significantly from the control treatment, which had an average of 110.63 cm.

Furthermore, foliar application of nano-chitosan resulted in significant variations in plant height. The concentration of 200 mg·L^{-1} produced the tallest plants, with a mean height of 121.78 cm, significantly outperforming all other treatments. In contrast, the control treatment (no chitosan application) recorded the lowest average plant height of 98.52 cm.

Table (2): Effect of polyter, nano-chitosan, and their interactions on the plant height (cm) of *Senna occidentalis* L. grown under different irrigation intervals

Irrigation period (day)	Polyter (gm.pot^{-1})	Nanochitosan (mgm.L^{-1})			Irrigation period X polyter
		0.00	100	200	
4	0.00	103.00	115.00	123.33	113.8
	2.50	106.00	112.67	127.67	115.5
	5.00	100.67	111.33	122.00	112.3
6	0.00	104.67	114.67	123.00	112.8
	2.50	100.67	113.33	126.00	113.3
	5.00	94.00	108.67	120.67	107.8
8	0.00	90.33	106.00	119.67	105.3
	2.50	94.33	113.00	120.00	109.1
	5.00	94.00	97.67	113.67	101.8
L.S.D. $_{0.05}$		6.366			3.676
Irrigation period X Nanochitosan					**Irrigation period**
4		104.2	113.0	124.3	113.83
6		98.5	112.2	123.2	111.30
8		92.9	105.6	117.8	105.43
L.S.D. $_{0.05}$		3.676			2.122
Nanochitosan X polyter					**polyter**
0.00		98.0	111.9	122.0	110.63
2.50		100.3	113.0	124.6	112.63
5.00		97.2	105.9	118.8	107.30
L.S.D. $_{0.05}$		3.676			2.122
Nanochitosan		98.52	110.26	121.78	
L.S.D. $_{0.05}$		2.122			

The same table (Table 2) also shows that plant height was significantly influenced by the two-way interactions among the experimental factors:

The interaction between irrigation interval and polyter showed significant differences, where the treatment of watering every 4 days combined with 2.5 g of polyter recorded the highest plant height, reaching 115.5 cm, while the lowest height (101.8 cm) was recorded in plants irrigated every 8 days and treated with 5.0 g of polyter. Similarly, the interaction between irrigation and nano-chitosan revealed significant differences. The treatment of irrigation every 4 days with 200 mg·L^{-1} chitosan spray recorded the highest plant height (124.3 cm), whereas the lowest average height (92.9 cm) was recorded in plants irrigated every 8 days with no chitosan spray.

As for the interaction between polyter and chitosan, the highest plant height (124.6 cm) was recorded when 2.5 g of polyter was combined with 200 mg·L^{-1} of chitosan, while the lowest value (97.2 cm) was recorded in plants treated with 5.0 g polyter and water spray only.

A significant response was also observed in the three-way interaction among all experimental factors. The combination of watering every 4 days, soil treatment with 2.5 g polyter, and foliar spraying with 200 mg·L^{-1} chitosan recorded the highest plant height of 127.67 cm, significantly outperforming most other combinations. In contrast, the lowest height (90.33 cm) was recorded in the control treatment (plants irrigated every 8 days with no polyter or chitosan application).

Number of Leaves (leaves·plant^{-1})

The statistical results in Table 3 show that irrigation intervals significantly affected the number of leaves. The highest average number of leaves (355.6) was observed in plants irrigated every 4 days, while the lowest (230.9) was recorded in plants irrigated every 8 days.

Application of polyter also had a significant effect. Both 2.5 g and 5.0 g treatments led to higher leaf numbers (295.0 and 293.2 leaves, respectively), with no significant difference between them. These were significantly higher than the control, which had the lowest average of 253.9 leaves.

Similarly, foliar application of nano-chitosan showed a significant impact. The 200 mg·L^{-1} treatment recorded the highest leaf number (310.5), while the control recorded the lowest (256.7).

Significant differences were observed in two-way interactions:

The interaction of 4-day irrigation interval with 2.5 g polyter produced the highest average number of leaves (375.1), while the lowest (209.3) was recorded in plants irrigated every 8 days with no polyter treatment.

The interaction between irrigation and chitosan showed that watering every 4 days combined with 200 mg·L^{-1} chitosan spray resulted in the highest number of leaves (411.4), significantly outperforming all other combinations. Conversely, the lowest number of leaves (221.9) was recorded in plants irrigated every 8 days with no chitosan application.The interaction between polyter and chitosan also revealed significant effects. The highest average (331.6 leaves) was achieved with the 2.5 g polyter + 200 mg·L^{-1} chitosan treatment, whereas the control (no polyter or chitosan) resulted in the lowest value (222.4 leaves).

A significant three-way interaction was also found among the three factors. The combination of 4-day irrigation interval, 2.5 g polyter, and 200 mg·L^{-1} chitosan led to the highest average number of leaves (444.3), significantly outperforming all other three-way combinations. The lowest value (195.0 leaves) was recorded in the control treatment under 8-day irrigation with no polyter or chitosan application.

Table (3): Effect of polyter, nano-chitosan, and their interactions on the number of leaves of plant (leaf.plant^{-1}) of *Senna occidentalis* L. grown under different irrigation intervals

Irrigation period (day)	Polyter (gm.pot-1)	Nanochitosan (mgm.L-1) 0.00	100	200	Irrigation period X polyter
4	0.00	257.0	295.3	403.3	318.6
	2.50	316.7	364.3	444.3	375.1
	5.00	365.3	367.3	386.7	373.1
6	0.00	215.3	233.0	253.0	233.8
	2.50	240.0	277.3	291.7	269.7
	5.00	250.7	259.7	279.3	263.2
8	0.00	195.0	210.0	223.0	209.3
	2.50	231.3	230.3	258.7	240.1
	5.00	239.3	235.7	254.7	243.2
L.S.D. $_{0.05}$		38.46			22.20
Irrigation period ×Nanochitosan					**Irrigation period**
4		313.0	342.3	411.4	355.6
6		235.3	256.7	274.7	255.6
8		221.9	225.3	245.4	230.9
L.S.D. $_{0.05}$		22.20			12.82
Nanochitosan X polyter					**polyter**
0.00		222.4	246.1	293.1	253.9
2.50		262.7	290.7	331.6	295.0
5.00		285.1	287.6	306.9	293.2
L.S.D. $_{0.05}$		22.20			12.82
Nanochitosan		256.7	274.8	310.5	
L.S.D. $_{0.05}$		12.82			

Leaf Chlorophyll Content (SPAD Value)

Table (4): Effect of polyter, nano-chitosan, and their interactions on the leaf Chlorophyll Content (SPAD Value) of *Senna occidentalis* L. grown under different irrigation intervals

Irrigation period (day)	Polyter (gm.pot-1)	Nanochitosan (mgm.L-1) 0.00	100	200	Irrigation period X polyter
4	0.00	51.86	57.47	58.58	55.97
	2.50	53.55	56.74	60.43	56.91
	5.00	50.23	55.49	57.32	54.35
6	0.00	50.82	54.24	56.62	53.89
	2.50	48.59	49.45	56.75	51.60
	5.00	45.31	47.79	51.98	48.36

8	0.00	49.23	51.35	51.43	50.67
	2.50	48.46	45.54	49.63	47.88
	5.00	45.31	45.85	50.01	47.06
L.S.D. $_{0.05}$		4.039			2.332
Nanochitosan X irrigation period					**Irrigation period**
4		51.88	56.57	58.78	55.74
6		48.24	50.49	55.12	51.28
8		47.67	47.58	50.36	48.53
L.S.D. $_{0.05}$		2.332			1.346
Nanochitosan X polyter					**polyter**
0.00		50.63	54.35	55.54	53.51
2.50		50.20	50.58	55.61	52.13
5.00		46.95	49.71	53.10	49.92
L.S.D. $_{0.05}$		2.332			1.346
Nanochitosan		49.26	51.55	54.75	
L.S.D. $_{0.05}$		1.346			

Statistical analysis data in Table 4 revealed significant differences in leaf chlorophyll content as affected by irrigation frequency. A reverse relationship was observed between chlorophyll content and the length of the irrigation interval, with the highest value (55.74 SPAD) recorded in plants irrigated every 4 days, significantly surpassing the other treatments. Conversely, the lowest value (48.53 SPAD) was recorded in plants irrigated every 8 days.

As for polyter soil application, the control treatment (no polyter) recorded the highest mean chlorophyll content (53.51 SPAD), which significantly exceeded the 5.0 g treatment (49.92 SPAD), though it did not differ significantly from the 2.5 g treatment (52.13 SPAD).

Nano-chitosan foliar application had a significant effect as well. The treatment with 200 mg·L^{-1} yielded the highest chlorophyll content (54.75 SPAD), significantly outperforming the other treatments, while the control gave the lowest average (49.26 SPAD).

Significant two-way interactions were found: The 4-day irrigation interval with 2.5 g polyter produced the highest SPAD value (56.91), while the lowest (47.06) was in plants irrigated every 8 days without polyter.

The 4-day irrigation combined with 200 mg·L^{-1} chitosan resulted in the highest SPAD value (58.78), while plants irrigated every 8 days and sprayed with 100 mg·L^{-1} had the lowest (47.58 SPAD).

The interaction between 2.5 g polyter and 200 mg·L^{-1} chitosan gave the highest value (55.61 SPAD), whereas 5.0 g polyter with no chitosan yielded the lowest (46.95 SPAD).

The three-way interaction also showed significant differences, with the 4-day irrigation + 2.5 g polyter + 200 mg·L^{-1} chitosan combination recording the highest

SPAD value (60.43). The lowest value (45.31 SPAD) was recorded in plants irrigated every 6 or 8 days without polyter or chitosan.

Main Root Length (cm)

Table (5): Effect of polyter, nano-chitosan, and their interactions on the Main Root Length (cm) of *Senna occidentalis* L. grown under different irrigation intervals

Irrigation period (day)	Polyter (gm.pot-1)	Nanochitosan (mgm.L-1)			Irrigation period X polyter
		0.00	100	200	
4	0.00	25.00	28.00	28.00	27.00
	2.50	24.00	27.33	27.33	26.22
	5.00	27.67	27.00	25.00	26.56
6	0.00	26.00	28.67	27.67	27.44
	2.50	29.67	27.00	29.67	28.78
	5.00	29.00	30.00	31.33	30.11
8	0.00	33.00	34.67	32.00	33.22
	2.50	36.67	35.00	33.33	35.00
	5.00	38.67	37.33	36.33	37.44
L.S.D. $_{0.05}$		4.517			2.608
Irrigation period X Nanochitosan					**Irrigation period**
4		25.56	27.44	26.78	26.59
6		28.22	28.56	29.56	28.78
8		36.11	35.67	33.89	35.22
L.S.D. $_{0.05}$		2.608			1.506
polyter × Nanochitosan					**polyter**
0.00		28.00	30.44	29.22	29.22
2.50		30.11	29.78	30.11	30.00
5.00		31.78	31.44	30.89	31.37
L.S.D. $_{0.05}$		2.608			1.506
Nanochitosan		29.96	30.56	30.07	
L.S.D. $_{0.05}$		*N. S.*			

According to Table 5, irrigation frequency significantly influenced main root length. Plants irrigated every 8 days recorded the longest roots (35.22 cm), while the shortest (26.59 cm) was observed in the control group (4-day irrigation without treatments).

Soil application of polyter had a significant effect. The 5.0 g treatment produced the longest roots (31.37 cm), significantly exceeding the control (29.22 cm). However, nano-chitosan application did not result in significant differences for this trait. Significant two-way interactions were observed:

The 8-day irrigation + 5.0 g polyter treatment produced the highest root length (37.44 cm), while the lowest (26.22 cm) was recorded in 4-day irrigation + 2.5 g polyter.

The 8-day irrigation with no chitosan resulted in the longest roots (36.11 cm), significantly higher than the 4-day irrigation without chitosan (25.56 cm).

For polyter × chitosan, the 5.0 g polyter with no chitosan combination recorded the highest value (31.78 cm), while the control gave the lowest (28.00 cm).

The three-way interaction had a significant effect as well. The combination of 8-day irrigation + 5.0 g polyter + no chitosan yielded the longest main root (38.67 cm), whereas the combination of 4-day irrigation + 2.5 g polyter + no chitosan recorded the shortest root length (24.00 cm).

Number of Roots (roots·plant⁻¹)

Table (6): Effect of polyter, nano-chitosan, and their interactions on the Number of Roots (roots·plant⁻¹) of *Senna occidentalis* L. grown under different irrigation intervals

Irrigation period (day)	Polyter (gm.pot-1)	Nanochitosan (mgm.L-1)			Irrigation period X polyter
		0.00	100	200	
4	0.00	6.67	7.33	6.67	6.89
	2.50	6.33	7.00	8.33	7.22
	5.00	7.67	6.67	7.33	7.22
6	0.00	5.00	5.67	5.33	5.33
	2.50	6.33	6.67	6.00	6.33
	5.00	6.33	6.67	7.33	6.78
8	0.00	6.00	6.33	6.67	6.33
	2.50	6.33	7.33	8.33	7.33
	5.00	6.67	6.67	7.67	7.00
L.S.D. 0.05		1.680			0.970
Irrigation period × Nanochitosan					**Irrigation period**
4		6.89	7.00	7.44	7.11
6		5.89	6.33	6.22	6.15
8		6.33	6.78	7.56	6.89
L.S.D. 0.05		0.970			0.560
polyter × Nanochitosan					**Polyter**
0.00		5.89	6.44	6.22	6.19
2.50		6.33	7.00	7.56	6.96
5.00		6.89	6.67	7.44	7.00
L.S.D. 0.05		0.970			0.560
Nanochitosan		6.37	6.70	7.07	
L.S.D. 0.05		0.560			

As shown in Table 6, irrigation frequency significantly influenced the number of roots. The 4-day irrigation treatment gave the highest root number (7.11 roots), while the lowest (6.15) was observed in the 6-day irrigation group.

Polyter application significantly increased root numbers, with 2.5 g and 5.0 g treatments producing 6.96 and 7.00 roots, respectively. These did not differ significantly from each other but were both higher than the control (6.19 roots).

Nano-chitosan also had a significant effect. The 100 and 200 $mg \cdot L^{-1}$ concentrations resulted in 6.70 and 7.07 roots, respectively, significantly higher than the control (6.37 roots). Significant interaction effects were observed:

The 8-day irrigation + 2.5 g polyter treatment resulted in the highest root number (7.33 roots), while the 6-day irrigation without polyter yielded the lowest (5.33 roots).

The 8-day irrigation + 200 $mg \cdot L^{-1}$ chitosan treatment gave the highest average (7.56 roots), while the 6-day irrigation without chitosan produced the lowest (5.89 roots). Similarly, the 2.5 g polyter + 200 $mg \cdot L^{-1}$ chitosan treatment recorded the highest number (7.56 roots), and the control had the lowest (5.89 roots).

For the three-way interaction, the combinations of: 4-day irrigation + 2.5 g polyter + 200 $mg \cdot L^{-1}$ chitosan, and 8-day irrigation + 2.5 g polyter + 200 $mg \cdot L^{-1}$ chitosan both produced the highest number of roots (8.33 roots), significantly surpassing most other treatments. The lowest root number (5.00 roots) was recorded in the 6-day irrigation with no polyter or chitosan.

The considerable differences observed in the evaluated vegetative growth traits (as presented in Tables 2–6) can largely be explained by the varying experimental factors and the direct roles they played in influencing plant growth and developmental processes throughout the growth cycle. The decline in growth performance of plants subjected to irrigation every 8 days is most likely a consequence of water stress, which restricts the amount of water available during the critical vegetative phase. Such limited water availability disrupts normal physiological functioning, resulting in reduced formation of essential growth structures and weakening key metabolic activities. Among these, chlorophyll biosynthesis appears to be particularly affected, ultimately diminishing the plant's ability to photosynthesize efficiently and sustain healthy growth. [9].

Moreover, the decline in growth traits may also be associated with a reduction in protein content within plant tissues, given that proteins play a fundamental role in structural formation and the regulation of numerous metabolic processes. Under water-stress conditions, plants often experience an elevation in growth-inhibitory hormones, particularly abscisic acid (ABA), which further suppresses vegetative growth by restricting cell division, elongation, and overall physiological activity [10].

Notably, the observed increase in root length under prolonged irrigation intervals may reflect an adaptive survival mechanism, whereby water-stressed plants extend their root systems deeper or farther into the soil profile in an effort to access more distant or limited water reserves [11].

The beneficial effects of nano-chitosan may be linked to its physiological functions, particularly its ability to stimulate internal auxin biosynthesis by enhancing tryptophan formation, which in turn promotes increased cell division and overall plant growth [12]. Moreover, chitosan's antioxidant and protective properties against pests and viruses likely improved plant growth and increased leaf number [13]. Its high nitrogen content (~6.89%) may have also contributed to the increased chlorophyll content [14].

The Polyter polymer exerted a crucial influence owing to its exceptional superabsorbent capacity, functioning as an effective water reservoir within the soil. By retaining substantial amounts of moisture and gradually releasing it into the root zone, Polyter significantly reduced water loss through evaporation and improved the soil's water-holding efficiency. This sustained moisture availability enhanced overall plant performance, particularly under stressful or water-limited conditions. Additionally, Polyter supported more robust root development, in some cases stimulating a three- to five-fold increase in root hair formation, which contributed to greater root mass, improved nutrient uptake, and enhanced plant vigor [15,16].

The evaluated factors exerted a significant impact on the vegetative growth characteristics of *Senna occidentalis*. The application of Polyter, particularly at a rate of 2.5 g, enhanced nutrient availability and improved soil properties, thereby contributing to better plant performance and increasing the economic viability of the experiment. Additionally, foliar application of nano-chitosan further promoted overall plant growth. Conversely, water stress resulting from 8-day irrigation intervals adversely affected most of the measured growth parameters.

References

1) Ali, N. A. 2023. Effect of pinching and spraying paclobutrazol and kinetin on growth and flowering of *Senna occidentalis* L. Master Thesis, College of Agriculture, University of Al-Qasim Green. IRAQ.

2) Tseliou, A.; I. Koletsis; E. Thoma; N. Proutsos; S. Lyhoudis; K. Pantavou and Tsiros, I. X. 2021. A model-based study on the impact of different tree configurations on the thermal conditions of an urban square. 17th Int. Conf. Envion. Sci. & Tech.

3) Sharmin, M.; M. G. Tjoelker; S. Pfautsch; M. E. Rodriguez; P. D. Rymer and Power, S. A. 2023. Tree traits and microclimatic conditions determine cooling benefits of urban trees. Atmosphere J., 14(606): 1–19.

4) Borghett, M. 2009. Water Transport in Plants Under Climatic Stress. Cambridge Univ., UK.

5) Lushchack, V. and Semchyshy H. M. 2012. Oxidative stress-molecular mechanisms and biological effects, In Tech Janeza Trdine, Rijeka, Croatia: 362.

6) Konfe, Z.; B. Zonou and Edmond, H. 2019. Influence d,intrants innovants sur les propriétés du sol la production de tomato (*Solanum lycopersicum* L.) et d,aubergine (*Solanum melongena* L.) sur un sol ferrugineux tropical en zone soudano-sahélienne au Burkina Faso.

7) Al-Shireefy, A. H. H. 2023. Bio stimulation of normal and nano-chitosan on some growth characteristics of Tacoma seedlings. Master Thesis, College of Agriculture, University of Kerbala. IRAQ.

8) Al-Asadi, M. H. S. 2019. GenStat for The Analysis of Agricultural Experiments. Dar Al Jazeera for publishing, Printing and Distribution. 1st edition. The Republic of Iraq. 165 pages.

9) Hassan, Ali Abdul-Hadi, & Shatha Abdul-Hassan Ahmed. 2014. The Role of ABA Addition in Improving Some Morphological Traits of Sunflower under Water Stress. Iraqi Journal of Agricultural Sciences, 45(2), 133–142.

10) Magid, H. R. and Al-Bahadly, S. E. 2015. Response of sunflower to proline under different irrigation intervals. Al-Muthana J. Agric. Sci., 3(1):: 1–9.

11) Su, Z.; X. Ma; H. Guo; N. L. Sukiran; B. Guo; S. M. Assmann and Ma, H. 2013. Flower development under drought stress: morphological and transcriptomic analyses reveal acute responses and long-term acclimation in *Arabidopsis*. Amer. Soc. Plant Biol., 25: 3785–3807.

12) Ahmadi, B. and Shariatpanahi, M. E. 2015. Proline and chitosan enhanced efficiency of microspore embryogenesis induction and plantlet regeneration in *Brassica napus* L. Plant Cell, Tissue and Organ Culture, 123(1): 57–65.

13) Behboudi, F.; Z. T. Sarvestani; M. Kassaee; S. A. Sanavi; A. Sorooshzadeh and

14) Toan, N. V. 2009. Production of Chitin and Chitosan from Partially Autolyzed Shrimp Shell Materials. The Open Biomaterials J., 1: 21–24.

15) Tali, Mohammad. 2016. Preparation of New Superabsorbent Polymeric Materials Using Two Novel Synthesis Techniques and Their Testing in Agricultural Applications. PhD Dissertation, Higher Institute for Applied Sciences and Technology, Department of Physics, Syrian Arab Republic.

16) Zhu, Y.; Y. Zheng and Wang, A. 2015. A simple approach to fabricate granular adsorbent for adsorption of rare elements. Int. J. Biolo. Macromol., 72: 410–420.