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ALLEVIATION OF THE SALINITY EFFECTS ON THE GROWTH AND DEVELOPMENT OF *Populus nigra* BY EXOGENOUS APPLICATION OF SILICON AND GLYCINE BETAINE

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ABSTRACT

Populus nigra plants were subjected to four soil salinity levels (0. 0,3.0, 5.0 and 7.0 dSm^{-1}) in a pot experiment with two types of nutrients foliar applications (silicon at 100 and 200 mg/l and glycine betaine at 200 and 400 mg/l). Salinity treatments reduced all growth characters. On the other hand, sugars, proline, Na and Cl contents increased by increasing salinity levels, while chlorophylls, N, P and K diminished. Foliar application of silicon or glycine betaine enhanced all the studied growth characters, as well as the organic (sugars, proline and chlorophylls) and inorganic components (N,P and K), while Na and Cl decreased. The combination of Si (200 mg/l) + GB (400 mg /l)**,** gave the best results, alleviating the adverse salinity effects on the growth and development of *Populus nigra.*

Key words: *Populus nigra , salinity , glycinebetain.*

1. INTRODUCTION

Black poplar (*Populus nigra* L) is a pioneer deciduous tree species, widely distributed across Europe, Asia and North Africa. It is often used as an ornamental tree, with much desirable wood quality, relatively fire resistant and shock proof, and it has a soft fine texture. Traditionally, it is used for clogs, carts, furniture and flooring near open fireplaces (Zhao *et al.*, 2019), for pulp and paper production, along with fast growth rate, which makes it a suitable bio-energy tree (Zhang *et al.*, 2017). Extracts from the tree have been shown to have antioxidant and anti-inflammatory effects (Yer *et al.*, 2018).

Salinity is a major abiotic stress that affects plant growth and productivity (Parida and Das 2004). Salt stress constitutes an agricultural and environmental problem worldwide, and is expected to cause serious salinization problems for more than 50% of all arable lands until 2050 (Ehlting *et al.*, 2007). On the other hand, increasing human population, rapid economic growth and the shortage of fresh water have become a fundamental and chronic problem for sustainable agriculture development in arid region (Jiang *et al.,* 2012). So, irrigation with saline water has become inevitable in arid and semi-arid regions (Letey and Feng, 2007) .

Silicon (Si) is the second most prevalent element after oxygen in the soil. According to more recent definition of the essentiality of elements proposed by Epstein and Bloom (2005), silicon should be considered an essential element for higher plants because silicon-deprived plants tend to grow abnormally , whereas silicon supplemented plants grow normally (Agarie *et al.,* 1992*).* Regardless of its essentiality in higher plants, Si has been reported to be beneficial in mitigating both biotic and abotic stresses *(*Bockhaven *et al.,* 2013). Silicon reduces the accumulation of toxic ions by decreasing transpiration due to its deposition as silica in leaves (Matoh *et al.,* 1986). Gong *et al.* (2006) reported a significant decrease in the uptake of Na^+ ion in a saline soil due to the deposition of silicon in plant roots. Exogenously applied Si proved to be beneficial for enhancing salt tolerance in plants by adjusting the levels of compatible solutes such as increasing soluble sugars and increasing proline content in the salt stressed and decreasing the synthesis of phenolic compounds (Hashemi *et al.*, 2010).

Glycine Betaine (GB) is a quaternary amine plays a highly beneficial role in plants exposed to various stress conditions such as high level of salts and low temperature. Many plant species naturally accumulate GB and proline as major organic osmolytes when subjected to different abiotic stress,where these compounds are thought to play adaptive roles in mediating osmotic adjustment and protecting subcellular structures in stressed plants. However, not all plants accumulate GB or proline in sufficient amounts to help averting adverse effects. Thus, an exogenous application of these osmolytes to plants growing under stress conditions may enhance their tolerance to abiotic stress (Kanu *et al.*, 2017). Exogenous foliar application of GB has been suggested as an approach to induce stress tolerance in crops with poor or no solute accumulating ability (Ashraf and Foolad, 2007).

The aim of this investigation is to alleviate the salinity harmful effects on the growth and development of *Populus nigra* seedlings by exogenous application of silicon and glycine betaine

2. MATERIALS AND METHODS

The work was carried out at the experimental area of Timber Trees and Forestry Dep., Hort. Res. Inst., A.R.C. Giza, Egypt, during two successive seasons of 2018/2019 and 2019/2020 to study the effects of salinity, silicon and glycine betaine on *Populus nigra* seedlings grown under sandy loamy soil conditions. Seedlings (one year old) with an average height of 25-30 cm, stem diameter at base of 0.3 cm, were used. The seedlings were obtained from the nursery of Forestry Department, Horticultural Research Institute. The seedlings were transplanted individually in plastic pots of (30 cm height and 25 cm diameter),filled with 12 kg mixture of sand and clay (2:1,v:v).

The chemical and physical analysis of the used soil mixture are shown in Table (1) Chemical analysis of the soil samples was performed according to the method of Black, (1982). Seedlings were planted on February 1st in both seasons (2018/2019 and 2019/2020). The soil mixture was subjected to three salinity levels (3.0, 5.0 and 7.0 dsm^{-1}) which were obtained by adding a mixture of (sodium chloride, calcium chloride and magnesium sulphate at the ratio of 2:2:1 by weight, respectively, besides the control (tap water).

2.1. Preparation of the salt solution

A stock solution with concentration of (100 dSm $^{-1}$) was prepared as follows:

25.6 g of NaCl, 25.6 g of $CaCl_2$ and 12.8 g of $MgSO_4$ were dissolved in one liter of tap water to prepare the solution. The following volumes were used to prepare the solutions in the next Table:

Concentration (dS m $^{-1}$)	Volume from stock(ml)	Final volume (ml)
3 (dS m $^{-1}$)	30ml	1000ml
5 (dS m $^{-1}$)	50ml	1000 ml
7 (dS m $^{-1}$)	70ml	1000ml

Three salt concentrations (3,5 and 7dSm $^{-1}$) whereas:

(1 dS m $^{-1}$) = 640ppm, as well as the control (Tap water).

Foliar application of two substances were used in this experiment (silicon and glycine betaine) individually , and as a mixture (Sigma Chemicals, USA), with three concentrations levels of (0.0, 100 and 200 mg/l) calcium silicate (CaO_4Si), and (0.0, 200 and 400 mg/l) of Glycine betaine (trimethly glycine ($C_5H_{11}NO_2$).

For each salinity level, the pots were divided to nine groups according to foliar application of Si and GB treatments.

Foliar applications were sprayed twice per month starting after 30 days from transplanting and the saline solution (the volume of water added to plants was 3.450 l /pot according to 100% field capacity determined in used soil) was used three time weekly in the summer and twice a week in the winter, and the pots leached with tap water up to field capacity once each month to avoid salt accumulation in root zone.

Hence, the experiment included three levels of salinity as well as control in which the plants irrigated with tap water (control) and nine levels

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

Sand (%)	Silt(%)	Clay(%)	Texture class
87.0	**7.8**	**5.2**	**Sandy loamy**

pH 1:2.5	E.C dSm^{-1}	Soluble cations (meq/l)				Soluble anions (meq/l)			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO^{-}_3	$HCO^{-}3$	Cl^{-}	$SO^{-}4$
7.40	0.87	2.20	1.45	1.73	2.96	-	2.45	3.40	2.49

of foliar application of Si and GB, making 36 treaments with three replicates for each treatment as follows:

1- Tap water(control)

2-Spraying with 100 mg/l Si (Si_1)

3- Spraying with 200mg/l Si (Si_2)

4- Spraying with 200mg/l GB (GB_1)

5- Spraying with400mg/l GB (GB_2)

6- Spraying with 100mg/l Si+ 200mg/l GB ($Si_{1+}GB_1$)

7- Spraying with 100mg/lSi + .400m g/l GB ($Si_{1+}GB_2$)

8- Spraying with 200mg/l Si +200mg/l GB (Si_2+GB_1)

9- Spraying with200mg /l Si +400mg/l GB ($Si_{2+}GB_2$)

The following data were recorded at the end of September of both seasons.

- Seedling height (cm)
-Root length (cm)
- Stem diameter (cm).
-Number of leaves /seedling
-Fresh and dry weights of shoots and roots (g/ seedling).

2.2. Chemical analysis

- Total chlorophylls (mg/g fresh weight of leaves) were extracted with dimethyl formamide solution according to Mornai (1982).
- Total sugars were determined in shoots using the phenol sulphuric acid reagent as the method described by Dubois *et al.* (1956)
- Free proline concentration in shoots was measured colorimetrically using ninhydrin reagent according to Bates *et al*. (1973).

Nutritional elements determination:

The wet digestion of 0.5 g of dry plant material (shoots) with sulphuric and perchloric acid was used as described by Piper (1947).

a) Nitrogen concentration was detrmined by Nessler method according to the Official Methods of Analysis A.O.A.C. (1990).
b) Phosphorus concentration was estimated colorimetrically using the chlorostannous reduced molybdophosphoric blue colour method as described by King (1951).
c) Sodium and potassium concentrations were determined using the flame photometer apparatus CORNINGM410 as described by Chapman and Pratt (1961).
e) Chloride concentration was detrmined by titration method with silver nitrate according to Brown and Jackson (1955).

2.3. Statistical analysis

The layout of the experiment was split plot design, as the main plots were salinity levels and subplots were the foliar applications of Si and GB ,so the experiment included 36 treatments, each treatment had three replicates. The obtained data were statistically analyzed according to Duncan multiple range test 5% (1955) and Snederor and Cochran (1980).

3. RESULTS AND DISCUSSIONS

3.1. Alleviation of salinity effects on the growth parameters of *Populus nigra* seedlings by exogenous application of silicon and glycine betaine

3.1.1. Seedling height

Data presented in Table (2) indicated that increasing salinity levels significantly decreased seedling height in descending order (98.90, 91.37 and 86.39 cm) with the treatments 3.0, 5.0 and 7.0 dSm^{-1} ,respectively, in the first season compared to the control (132.4 cm).

Regarding foliar application of Si and GB, the data illustrated that all treatments significantly increased the seedling height as compared to control, moreover increasing the concentration of both Si and/or GB significantly increased seedling height except for the treatment of $Si_{1+}GB_1$ and $Si_{2+}GB_{1.}$

The interaction between salinity level of irrigation water and foliar application of Si and/or GB, showed that in the first season, plants irrigated with the lowest level of salinity (3 dSm^{-1}) and sprayed with $Si_{2+}GB_2$ resulted in the tallest seedlings (125.0cm), whereas control recorded (120.0 cm), and this increased seedling height by 4.2%, whereas shortest seedlings were recorded in the plants irrigated with high level of salinity (7 dSm^{-1}) without exogenous application (72.0cm), but the highest value under the same salinity level was found with Si_2+GB_2 treatment (96.67 cm). Similar results were obtained in the second season.

Table (2): Alleviation of salinity effects on seedling height (cm)of *Populus nigra* seedlings by exogenous application of silicon and glycine betaine during 2018/2019 and 2019/2020.

Charactere	Seedlings height (cm) Salinity levels (dSm^{-1})									
Salinity levels	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean
Treatments	First season 2018/2019					Second season 2019/2020				
Control	120.7e	88.00no	79.67s	72.00t*	90.09H	125.0j	101.7m	87.33p	66.00u*	95.01H
Si_1	123.0de	89.00m-o	83.00qr	80.67rs	93.92G	128.3i	115.3k	92.33o	69.33t	101.32G
Si_2	125.30d	91.67j-l	85.00pq	82.33r	96.08F	135.7f	123.7j	95.33n	73.00s	106.93F
GB_1	132.3c	94.00ij	90.67k-m	85.33pq	100.58E	143.7e	130.70hi	111.7l	76.00r	115.53D
GB_2	133.3c	96.00hi	92.33j-l	87.00op	102.16D	147.0d	136.7f	117.7k	53.67v	113.77E
Si_1+GB_1	137.3b	100.70g	96.0hi	90.17l-n	106.04C	150.7c	143.3e	124.0j	82.33q	125.08C
Si_1+GB_2	140.7a	103.7f	97.33h	93.00jk	108.68B	155.0b	146.7d	132.7gh	86.67p	130.27B
Si_2+GB_1	137.0b	102.0fg	95.67hi	90.33l-n	106.25C	152.0c	141.0e	123.3j	80.67q	124.25C
Si_2+GB_2	142.3a	125.0d	102.7fg	96.67h	116.67A	162.0a	150.3c	134.7fg	90.67o	134.42A
****Mean**	132.4A	98.90B	91.37C	86.39D		144.38A	132.16B	113.23C	75.37D	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l)

***Means values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.

**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%.

*Mean values in the same row or column within the interaction followed by the same small letter are not significant at 5%.

3.1.2. Stem diameter

As shown in Table (3) the data indicated that increased salinization levels significantly decreased stem diameter in a descending order (1.29, 1.18 and 1.04 cm) with the treatments of 3.0,5.0 and 7.0 dSm^{-1}, the respectively in the first season compared to control (1.36 cm).

Regarding foliar application of Si and GB the data illustrated that all treatments significantly increased stem diameter as compared to control (neither salinized nor sprayed plants). On the other hand, increasing concentration of both Si and/or GB significantly increased stem diameter..

Also, the data about the interaction between salinity level and foliar application of Si and/or GB, in the first season showed that, the plants irrigated with the lowest level of salinity (3 dSm^{-1}) and sprayed with Si_2+GB_2 recorded the thickest stem diameter (1.74 cm) compared to control (neither salinized nor sprayed) which recorded (0.95 cm) giving 83% increment, whereas the lowest value of stem diameter exhibited in the plants irrigated with high level of salinity (7 dSm^{-1}) without any exogenous application of Si or GB (0.74 cm) but the highest value under the same salinity level was recorded with Si_2+GB_2 (1.30 cm). Similar results were obtained in the second season except with Si_1+ GB_2 and Si_2 + GB_1 which showed no significant difference.

3.1.3. Root length

Data in Table (4) indicated that increasing salinization levels significantly decreased root length giving 55.22, 52.19 and 47.78 cm with the treatments of 3.0, 5.0 and 7.0 dSm^{-1} salinity level respectively in the first season compared to control (non salinized 59.59 cm). The foliar application of Si and GB treatments significantly increased the root length as compared to control (neither salinized nor sprayed). On the other hand, increasing the concentration of both Si and/or GB significantly increased root length.

Concerning the interaction effects, it was found that the plants irrigated with salinity at 3 dSm^{-1} and sprayed with Si_2 +GB_2 recorded the longest roots (66.67 cm) compared to the control (46.0 cm) and this increased root length by 45%, whereas shortest roots, exhibited in the plants irrigated with salinity at 7 dSm^{-1} and did not receive any exogenous application of Si or GB (35.0 cm) but the longest roots under the same salinity level were obtained with Si_2+GB_2 (57.0 cm). Similar results were obtained in the second season, except for the treatments of Si_1 +GB_1 and Si_2+GB_1 .

Table (3): Alleviation of salinity effects on Stem diameter (cm) of *Populus nigra* seedlings by exogenous application of silicon and glycine betaine during 2018/2019 and2019/2020.

Charactere	Stem diameter (cm) Salinity levels (dSm^{-1})									
Salinity levels / Treatments	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean
	First season 2018/2019					Second season 2019/2020				
Control	0.95q	0.86s	0.81t	0.74v*	0.84I	1.22q	0.91s	0.81t	0.66v*	0.90H
Si $_1$	1.12o	1.09p	0.91r	0.79u	0.98H	1.25o	1.21p	0.83r	0.69u	1.00G
Si $_2$	1.18n	1.14o	0.97q	0.81t	1.02G	1.29n	1.23o	0.86q	0.72t	1.03F
GB $_1$	1.27j	1.20m	1.12o	0.95q	1.14F	1.31j	1.26lm	0.91o	0.75q	1.06E
GB $_2$	1.44f	1.25k	1.25k	1.17n	1.28E	1.34f	1.30k	0.94k	0.79n	1.09D
Si $_{1+}$GB $_1$	1.45ef	1.45ef	1.31i	1.19m	1.35C	1.37f	1.32f	1.33i	0.82m	1.21B
Si $_{1+}$GB $_2$	1.48d	1.46e	1.34h	1.23k	1.38B	1.43d	1.37e	1.09f	0.87k	1.19BC
Si $_{2+}$GB $_1$	1.45ef	1.40g	1.30i	1.21l	1.34D	1.38ef	1.34g	1.09i	0.88l	1.17C
Si $_{2+}$GB $_2$	1.91a	1.74b	1.59c	1.30i	1.63A	1.64a	1.43b	1.22c	0.93i	1.30A
****Mean**	1.36A	1.29B	1.18C	1.04D		1.36A	1.26B	1.01C	0.79D	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l).
values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.
**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%.
*Mean values in the same row orcolumn within the interaction followed by the same small

Table (4): Alleviation of salinity effects on Root length (cm) of *Populus nigra* seedlings by exogenous application of silicon and glycine betaine during 2018/2019 and2019/2020.

Charactere	Root length (cm) Salinity levels (dSm^{-1})									
Salinity levels / Treatments	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean
	First season 2018/2019					Second season 2019/2020				
Control	46.00qr	43.00st	40.00u	35.00v*	41.00I	60.33g	44.00mn	35.00op	27.67q*	41.75H
Si $_1$	51.00l-n	46.00qr	45.33qr	41.67tu	46.00H	65.33f	47.33kl	42.00n	34.00p	47.17G
Si $_2$	53.00i-l	50.33m-o	46.67q	44.00rs	48.50G	67.00d-f	51.00ij	44.33mn	37.00o	49.83F
GB $_1$	55.67f-h	52.00j-m	48.67op	47.33pq	50.92F	69.00de	55.33h	47.67kl	42.3n	53.58E
GB $_2$	60.33e	55.00g-i	53.33i-k	50.33m-o	54.5E	73.00c	60.33g	52.33i	45.33lm	57.75D
Si $_{1+}$GB $_1$	66.00bc	60.33e	56.00f-h	51.33k-n	58.42C	75.33bc	65.67f	56.00h	49.33jk	61.58C
Si $_{1+}$GB $_2$	67.67b	66.33bc	59.67e	54.00h-j	61.92B	75.67b	69.00de	60.00g	56.67h	65.34B
Si $_{2+}$GB $_1$	65.00cd	57.33f	56.00f-h	49.33no	56.92D	75.33bc	66.67ef	56.33h	47.00kl	61.33C
Si $_{2+}$GB $_2$	71.67a	66.67bc	64.00d	57.00fg	64.84A	85.67a	77.00b	69.33d	60.33g	73.08A
****Mean**	59.59A	55.22B	52.19C	47.78D		71.85A	59.59B	51.44C	44.41D	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l)
***Means values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.
**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%.
*Mean values in the same row or column within the interaction followed by the same small letter are not significant at 5%.

3.1.4.Number of leaves/seedling

Data presented in Table (5) indicated that there were significant decreases in the number of leaves in a descending order (58.70, 49.30 and 31.26 leaves/plant) with the treatments of 3.0,5.0 and 7.0 dSm^{-1} salinity level, respectively, in the first season compared to the control (70.70 leaves/plant).

Regarding foliar application of Si and GB data illustrated that all treatments significantly increased the number of leaves as compared to control (non salinized). On the other hand, increasing concentration of both Si and/or GB significantly increased the number of leaves.

Regarding the interaction effect between salinity level and foliar application of Si and/or GB, the obtained data showed that the plants irrigated with the lowest level of salinity (3dSm^{-1}) and sprayed with Si_2+GB $_2$ formed the highest the number of leaves (89.67 leaves/plant) compared to control (35.33 leaves/plant) and this increased number of leaves by 154% , whereas the least number of leaves was exhibited in the plants irrigated with high level of salinity (7 dSm^{-1}) and did not receive any exogenous application of Si or GB (16.00 leaves/plant), but the highest value under the same salinity level was recorded in plants sprayed with Si_2+GB_2 (55.67leaves/plant). Similar results obtained in the second season except withSi_1+GB_1 and Si_2+GB_1 which showed no significant differences.

Table (5): Alleviation of salinity effects on numberof leaves/plant of *Populus nigra* seedlings by exogenous application of silicon and glycine betaine during 2018/2019 and2019/2020.

Charactere	No. of leaves/plant Salinity levels (dSm^{-1})									
Salinity levels	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean
Treatments	First season 2018/2019					Second season 2019/2020				
Control	35.33o	25.33r	22.00s	16.00t	24.67I	50.33kl	34.33o	27.00pq	20.67r	33.08H
Si $_1$	38.67n	32.33pq	60.67q	20.33s	30.50H	55.33hi	42.33m	33.67o	24.67q	39.00G
Si $_2$	44.00m	40.00n	34.00op	21.67s	34.92G	60.33g	48.00l	38.00n	29.00p	43.83F
GB $_1$	75.33f	52.67l	43.67m	24.67r	49.09F	65.00f	57.00hi	44.00m	33.00o	49.75E
GB $_2$	82.00e	62.00ij	56.67k	27.00r	56.92E	69.00d	62.00g	48.67kl	38.67n	54.59D
Si $_1$+GB $_1$	76.67d	66.33h	60.00j	31.67pq	61.17D	72.67c	67.00d-f	51.33h	43.00m	58.50C
Si $_1$+GB $_2$	92.00b	82.67e	64.33hi	43.67m	70.67B	80.33b	73.00c	57.33h	47.67l	64.58B
Si $_2$+GB $_1$	87.33cd	77.33f	60.00j	40.67n	66.33C	75.00c	65.67ef	55.00hi	44.00m	59.92C
Si $_2$+GB $_2$	95.00a	89.67bc	72.33g	55.67k	78.17A	87.00a	78.33b	67.67de	54.00ij	72.00A
****Mean**	70.70A	58.70B	49.30C	31.26D		68.33A	58.63B	47.07C	37.19D	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l)

***Means values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.

**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%.

*Mean values in the same row orcolumn within the interaction followed by the same small letter are not significant at 5%.

3.1.5. Fresh and dry weights of shoots

Data presented in Tables (6 and 7) indicated that increased salinization levels significantly decreased fresh and dry weights of shoots in descending order giving (141.2,131.1 and 111.6 g/plant) and (49.50, 43.28 and 35.91 g/plant) with the treatments of (3.0, 5.0 and 7.0 dSm^{-1} salinity level),respectively, in the first season compared to the control non salinized 149.1 and 53.13 g/plant, respectively.

Regarding foliar application of Si and GB, it was found that all treatments significantly increased fresh and dry weights of shoots as compared to control (neither salinized nor sprayed). On the other hand, increasing concentration of both Si and/or GB significantly increased fresh and dry weights of shoots except with Si_1+GB_1, Si_2+GB_1 and Si_1+GB_2 which showed no significant differences in the dry weight.

As for the interaction, the data showed that the plants irrigated with the lowest level of salinity (3 dSm^{-1}) and sprayed with Si_2+GB $_2$ recorded the highest value of fresh and dry

Table (6): Alleviation of salinity effects on fresh weights of shoots (g/plant)of *Populus nigra* seedlings by exogenous application of silicon and glycine betaine during 2018/2019 and2019/2020.

Charactere		Fresh weights of shoots (g/plant) Salinity levels (dSm^{-1})									
Salinity levels	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean
Treatments		First season 2018/2019				Second season 2019/2020				
Control	126.7kl	118.3no	92.67q	82.00s*	104.9I	141.0kl	125.7o	118.0p	71.33v*	114.0I
Si $_1$	131.3j	121.7mn	115.0op	86.67r	113.7H	145.7j	135.0mn	126.7o	76.00u	120.9H
Si $_2$	134.0ij	131.7j	121.7mn	92.33q	119.9G	150.7hi	140.3kl	132.0n	82.67t	126.4G
GB $_1$	143.7g	137.0hi	133.0ij	111.0p	131.2F	158.0fg	143.3jk	138.0lm	85.33st	131.2F
GB $_2$	151.3de	141.7g	137.0hi	120.0mn	137.5E	162.7de	147.3ij	141.3kl	89.00s	135.1E
Si $_{1+}$GB $_1$	156.0c	148.7ef	141.0gh	124.0lm	142.4D	168.0c	151.7h	146.0j	94.00r	139.9D
Si $_{1+}$GB $_2$	165.0b	155.0cd	145.3fg	130.3jk	148.9B	172.0b	161.3ef	150.7hi	96.67r	145.2B
Si $_{2+}$GB $_1$	162.3b	151.7c-e	142.0g	126.0l	145.5C	166.7c	157.0g	150.3hi	94.67r	142.2C
Si $_{2+}$GB $_2$	171.3a	165.0b	152.0c-e	132.3j	155.2A	182.7a	166.0cd	158.3fg	111.0q	154.5A
****Mean**	149.1A	141.2B	131.1C	111.6D		160.8A	147.5B	140.1C	88.96D	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l)

***Means values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.

**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%.

*Mean values in the same row orcolumn within the interaction followed by the same small letter are not significant at 5%.

Table (7): Alleviation of salinity effects on dry weights of shoots (g/plant)of *Populus nigra* **seedlings by exogenous application of silicon and glycine betaine. during 2018/2019 and2019/2020.**

Charactere		Dry weights of shoots (g/plant) Salinity levels (dSm^{-1})								
Salinity levels	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean
Treatments		First season 2018/2019				Second season 2019/2020				
Control	46.33f-h	42.53j-l	31.93o	27.00p*	36.95I	43.60kl	38.07o	35.60p	20.79v*	34.52H
Si $_1$	47.73f	44.57g-j	35.63n	28.33p	39.04H	48.53e-h	41.20l-n	39.07no	22.31uv	37.78G
Si $_2$	48.17f	46.57f-h	40.20lm	27.93p	40.72G	46.27h-j	43.43kl	40.73mn	24.17tu	38.65G
GB $_1$	51.53de	47.23fg	43.57i-k	31.67o	43.50F	48.67e-h	45.23jk	42.27lm	25.67st	40.46F
GB $_2$	53.67cd	47.23fg	45.63f-i	38.43m	46.24E	50.54c-e	46.73h-j	43.47kl	26.35r-t	41.77E
Si $_{1+}$GB $_1$	55.67bc	51.89de	46.70fg	41.30kl	48.89CD	52.30bc	47.83f-i	45.80i-k	28.37qr	43.58D
Si $_{1+}$GB $_2$	57.89b	55.64bc	48.00f	42.07j-l	50.90B	53.71ab	50.33c-e	47.00h-j	29.21q	45.06BC
Si $_{2+}$GB $_1$	56.87b	53.87cd	47.00fg	42.57j-l	50.08BC	51.90b-d	49.67d-g	47.53g-j	27.73q-s	44.21CD
Si $_{2+}$GB $_2$	60.33a	56.01bc	50.90e	43.93h-k	52.79A	55.23a	51.50b-d	50.03c-f	33.63p	47.60A
****Mean**	53.13A	49.50B	43.28C	35.91D		50.08A	46.00B	43.50C	26.47D	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l)

***Means values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.

**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%.

*Mean values in the same row orcolumn within the interaction followed by the same small letter are not significant at 5%.

weights of shoots (165.0 and 56.01 g/plant) compared to the control (126.7 and 46.33 g/plant), which increased the fresh and dry weights of shoots by 30 % and 21%, respectively, whereas the lowest value was obtained in the plants irrigated with high level of salinity (7 dSm^{-1}) without exogenous application of Si and GB (82.0 and 27.0 g/plant) but the highest values under the same salinity level was recorded in plants sprayed with Si_2+GB_2 (132.3 and 43. 93 g/plant). Similar results were obtained in the second season.

3.1.6. Fresh and dry weights of roots

Data presented in Tables (8 and 9) indicated that increased salinity levels in irrigation water significantly decreased fresh and dry weights of roots in descending order (57.07,51.70 and 48.26 g/plant) and (16.31, 14.88 and 11.75 g/plant) with the treatments of (3.0, 5.0 and 7.0 $dSm^{-1/}$) compared to the control (62.29 and 17.40 g /plant).

With regard to the effect of Si and GB, the data illustrated that all treatments significantly increased fresh and dry weights of roots as compared to control (neither salinized nor sprayed). On the other hand, increasing concentration of both Si and/or GB significantly increased fresh and dry weights of roots except with Si_1+GB_1 and Si_2+ $GB_{1,}$ which showed no significant difference .

The interaction showed that the plants irrigated with the lowest level of salinity (3 d Sm^{-1}) and sprayed with Si_2+GB $_2$ recorded the highest value of fresh and dry weights of roots (70.33 and 20.43 g/plant) compared to the control (46.33 and12.47 g/plant) which increased 52 % and 39% over the control, respectively. Whereas, the lowest value of fresh and dry weights of roots exhibited in the plants irrigated with high level of salinity (7dSm^{-1}) and did not receive any exogenous application (28.67 and 5.63 g/plant) but the highest value under the same salinity level was obtained with Si_2+ GB_2 (61.00 and 16.27 g/plant). Similar results were obtained in the second season .

Finally, the obtained results showed that salinity deteriorated all growth parameters of *Populus nigra* seedlings and this deterioration increased with increasing the salinity level of irrigation. This inhibitory effect of salinity may be due to a number of physiological processes such as a decrease in meristematic activity and/ or cell enlargement (Sakr *et al.,* 2007) and also may be attributed to high osmotic pressure of soil solution which restricted the absorption of water by plant root and /or to the toxic effects of certain ions present in soil solution (Nour ElDin *et al.*, 1984).

Table (8): Alleviation of salinity effects on Fresh weights of roots(g/plant)of *Populus nigra* seedlings by exogenous application of silicon and glycine betaine. during 2018/2019 and2019/2020.

Charactere	Fresh weights of roots (g/plant) Salinity levels (dSm^{-1})									
Salinity levels / Treatments	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean
	First season 2018/2019					Second season 2019/2020				
Control	46.33l	40.33m	33.00n	28.67o*	37.08H	62.00kl	49.33q	40.33st	25.33w*	44.25H
Si $_1$	51.67k	46.67l	41.00m	34.00n	43.34G	65.33h-j	52.67lm	46.00r	29.33v	48.33G
Si $_2$	55.33ij	50.33k	43.00m	40.33m	47.25F	67.33gh	57.00n	51.33pq	32.00uv	51.92F
GB $_1$	60.33cd	55.33ij	50.33k	43.67m	52.42E	72.33e	60.67lm	55.33no	34.00u	55.58E
GB $_2$	63.00ef	60.33f-h	55.33ij	52.00jk	57.67D	77.33e	64.00i-k	58.33mn	38.00t	59.42D
Si $_{1+}$GB $_1$	67.33cd	63.00ef	59.33f-h	57.67g-i	61.83C	81.33c	66.67g-i	61.33kl	41.00s	62.58C
Si $_{1+}$GB $_2$	71.33b	65.33de	61.67f	59.67f-h	64.50B	86.00b	71.67ef	69.00fg	44.67r	67.84B
Si $_{2+}$GB $_1$	69.00bc	62.00ef	59.67f-h	57.33hi	62.00C	79.00cd	71.00ef	63.33j-l	41.67s	63.75C
Si $_{2+}$GB $_2$	76.33a	70.33bc	62.00ef	61.00fg	67.42A	92.67a	80.67c	71.33ef	57.33n	75.50A
****Mean**	62.29A	57.07B	51.70C	48.26D		75.92A	63.74B	57.34C	38.15D	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l)

***Means values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.

**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%.

*Mean values in the same row orcolumn within the interaction followed by the same small letter are not significant at 5%.

Table (9): Alleviation of salinity effects on dry weights of roots(g/plant)of *Populus nigra* seedlings by exogenous application of silicon and glycine betaine during 2018/2019 and2019/2020..

Charactere	Dry weights of roots (g/plant) Salinity levels (dSm^{-1})									
Salinity levels / Treatments	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean
		First season 2018/2019				Second season 2019/2020				
Control	12.47k-m	10.47no	8.33p	5.63q*	9.23H	16.67i-l	14.10no	9.47s	4.90v*	11.29H
Si_1	13.89i-l	12.78j-m	11.67mn	8.08p	11.61G	17.72i-k	15.87lm	11.29qr	6.11u	12.75G
Si_2	15.43f-i	14.08h-k	12.33lm	9.17op	12.75F	19.21h	16.63j-l	13.10op	7.43t	14.09F
GB_1	17.10d-f	15.78f-h	14.08h-k	10.63no	14.40E	21.47ef	17.93ij	13.50o	7.93t	15.21E
GB_2	18.23cd	17.77c-e	15.73f-h	12.60k-m	16.08D	22.65de	18.01i	15.20mn	9.67s	16.38D
$Si_{1+}GB_1$	18.21cd	18.33cd	16.87d-f	14.17h-k	16.90C	24.03c	19.73gh	16.44k-m	10.87r	17.77C
$Si_{1+}GB_2$	20.33b	19.11bc	18.19cd	14.87g-i	18.13B	25.60b	20.87fg	17.23i-k	12.23pq	18.98B
$Si_{2+}GB_1$	18.10cd	18.00cd	17.57c-e	14.37h-j	17.01C	23.63cd	20.55fg	17.20i-k	11.60qr	18.25C
$Si_{2+}GB_2$	22.87a	20.43b	19.13bc	16.27e-g	19.68A	28.23a	23.58cd	20.04gh	15.43lm	21.82A
****Mean**	17.40A	16.31B	14.88C	11.75D		22.13A	18.59B	14.83C	9.57D	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l)

***Means values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.

**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%.

*Mean values in the same row orcolumn within the interaction followed by the same small letter are not significant at 5%.

Also, the results revealed that exogenous foliar application of Si and/or GB could alleviate the harmful effects of salinity on all growth parameters of the plant, which may be due to that, Si have been associated with an increase in antioxidant defense abilities and enhanced plant tolerance to abiotic stress (Liang *et al.,* 2006 and Gong *et al* ., 2005). Exogenous application of GB to plants before ,during or after stress exposure have been shown to enhance plant growth and final crop yield under stress conditions (Kanu *et al*., 2017). The exact mechanism of the effect of these osmoregulators may be due to osmotic protection (Arteca, 1996) or promotion of the uptake of essential macro-nutrients which then facilitated normal growth and development (Foyer and Spencer 1986).

3.2. Alleviation of salinity effects on chemical composition of *Populus nigra* seedlings by exogenous application of silicon and glycine betaine

3.2.1. Total chlorophylls

Data presented in Table (10) indicated that increased salinization levels significantly decreased total chlorophylls in a descending order (0.75, 0.71 and 0.64 mg/g F.W.), the treatments were (3.0, 5.0 and 7.0 dSm^{-1} salinity levels), respectively, compared to the control (0.80 mg/g F.W).

Regarding foliar application of Si and GB, the obtained data indicated that all treatments significantly increased total chlorophylls as compared to control, but increasing concentration of both Si and/or GB significantly increased it. Also, the data of the interaction between salinity level and foliar application of Si and/or GB showed that the plants irrigated with the lowest level of salinity (3 dSm^{-1}) and sprayed with Si_2+ GB_2 recorded the highest value of total chlorophylls (0.82 mg/g F.W) compared to control (0.72 mg/g F.W), whereas the least value was recorded in the plants irrigated with high level of salinity (7 dSm^{-1}) only (0.53 mg/g F.W), while the highest value under the same salinity level was obtained with spraying with Si_2+ GB_2 (0.69 mg/g F.W.).

3.2.2. Total sugars

There were significant increases in total sugars mg/g F.W. with increased salinization levels in an ascending order (5.25, 6.52 and 6.96 mg/g F.W.) with (3.0, 5.0 and 7.0 dSm^{-1} salinity levels),respectively, compared to control (4.67mg/g F.W.) as indicated in Table (10).

As regard foliar application of Si and GB data illustrated that all treatments significantly increased total sugars mg/g F.W as compared to control. On the other hand, increasing concentration of both Si and/or GB significantly increased it.

Table (10): Alleviation of salinity effectson Total chlorophylls (mg/g F.w.), Total sugar (mg/g F.w.)and Proline(mg/g D.w) in shoots of *Populus nigra* by exogenous application of silicon and glycine betaine during 2019 /2020.

Character	Total chlorophylls (mg/g F.w) Salinity levels (dSm^{-1})				
Salinity levels / Treatments	**Control**	**3 dSm^{-1}**	**5 dSm^{-1}**	**7 dSm^{-1}**	*****Mean**
Control	0.72k	0.60p	0.55q	0.53r*	0.60H
Si_1	0.76gh	0.73jk	0.68l	0.60p	0.69G
Si_2	0.78f	0.74ij	0.69l	0.63o	0.71F
GB_1	0.79ef	0.76gh	0.68l	0.65n	0.72E
GB_2	0.81cd	0.78f	0.73jk	0.67lm	0.75D
Si_1+GB_1	0.83b	0.78f	0.75hi	0.67lm	0.76C
Si_1+GB_2	0.85a	0.80de	0.77fg	0.68l	0.78B
Si_2+GB_1	0.81cd	0.79ef	0.75hi	0.66mn	0.75D
Si_2+GB_2	0.86a	0.82bc	0.79ef	0.69l	0.79A
****Mean**	0.80A	0.75B	0.71C	0.64D	
	Total sugars (mg/g F.w)				
Control	3.40r	4.00 p	5.50i-k	6.00h	4.73H
Si_1	3.80q	4.50no	5.9oh	6.40g	5. 15G
Si_2	4.10p	4.70n	6.20g	6.70ef	5.42F
GB_1	4.40o	4.90m	6.40g	6.90de	5.65E
GB_2	4.70n	5.20l	6.70ef	7.10b-d	5.92D
Si_1+GB_1	5.20l	5.40j-l	6.90de	7.20bc	6.17C
Si_1+GB_2	5.50i-k	5.70i	7.0cd	7.30b	6.37C
Si_2+GB_1	5.30kl	6.30g	6.90de	7.20bc	6.52B
Si_2+GB_2	5.60ij	6. 60f	7.20bc	7.90a	6.82A
Mean	4.67D	5.25C	6.52B	6.96A	
	Proline(mg/gD.w)				
Control	2.20k	2.40j	2.50i	2.90de	2.50F
Si_1	2.40j	2.70h	2.75gh	3.20c	2.76E
Si_2	2.44ij	2.75gh	2.80fg	3.30b	2.82D
GB_1	2.45ij	2.77f-h	2.82e-g	3.30b	2.84D
GB_2	2.47ij	2.79fg	2.85d-f	3.40a	2.88C
Si_1+GB_1	2.49i	2.80fg	2.89de	3.44a	2.91BC
Si_1+GB_2	2.52i	2.82e-g	2.90de	3.47a	2.93B
Si_2+GB_1	2.50i	2.80fg	2.89de	3.42a	2.90BC
Si_2+GB_2	2.70h	2.84d-f	2.92d	3.45a	2.98A
Mean	2.46D	2.74C	2.81B	3.32A	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l)

***Means values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.

**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%

*Mean values in the same row orcolumn within the interaction followed by the same small letter are not significant at 5%.

Also, data of the interaction between salinity level and foliar application of Si and/or GB, showed that the plants irrigated with the highest level of salinity (7 dSm^{-1}) and sprayed with Si_2+GB_2 increased significantly it (7.90 mg/g F.W) compared to the control (3.40 mg/g F.W), whereas the other spray treatments under the highest salinity level had no significant effect, irrespective to the obvious non significant results of the other salinity treatments.

3.2.3.Proline content(mg/gD.W)

As shown in Table (10), increasing salinization levels significantly increased proline content in an ascending order (2.74, 2.81 and 3.32 mg/g D.W) with the 3.0, 5.0 and 7.0 dSm^{-1} salinity levels, respectively, compared to the control (2.46 mg/gD.W).

The foliar application of Si and GB significantly increased the proline content as compared to control. Also, increasing the concentration of both Si and/or GB significantly increased it.

The interaction between salinity level and foliar application of Si and/or GB, showed that the highest level of salinity (7 dSm^{-1}) with Si_1+ GB_2 significantly increased proline content (3.47 mg/gD.W) without significant differences between it and other foliar applications treatments.

These results could be ascribed to that biosynthesis of chlorophylls is generally inhibited by the depressive effect of salt stress on the absorption of some ions which are involved in the chloroplast formation, such as Mg, Fe which could be expected as a reason for chlorophyll suppression in leaves and/ or an increase of growth inhibitors ,such as ethylene or abscisic acid production which enhances senescence which occurred under stress conditions (El-Bagoury *et al.*, 1999) on *Casuarina equisetifolia* L.. In fact, Na^+ accumulation affects photosynthesis components such as enzymes, chlorophylls and carotonids (Davenport *et al* ., 2005). The highest content of total chlorophyll was obtained by spraying Si or GB either alone or in combination which may be due to improve photosynthesis activity, enhanced K/Na selectively ratio, increased enzyme activity and increased concentration of soluble substances in the xylem.

The beneficial effects of Si on photosynthetic pigments have observed in *Spartina densiflora* (Mateos *et al.*, 2013), which may be partly attributed to a Si mediated decrease in Na+ uptake and increase in K+ uptake and enhanced antioxidant defense, so it can be concluded that Si could alleviate the oxidative damage in plants under salt stress Yongxing and Haijun (2014). In this respect Ahmed *et al.* (2000) reported that the accumulation of non toxic substances such as sucrose, proline and organic acids are considered to be a protective adaptation and that the survival of plants under salinity conditions depends upon the regulation of metabolic processes and quantitive ratio between the protective and the toxic intermediates. Also, Yin *et al.* (2013) found that Si could significantly increase the level of sugar in sorghum under salt stress and could alleviate salt- induced osmotic stress. Proline is considered as a cytoplasm protective osmolyte necessary for adaptation to stress and the increased porline concentration could be a good parameter for salt tolerance plant (Ibrahim, 2008).

3.2.4. N,P and K.

Data presented in Table (11) indicated that all salinization levels significantly decreased N,P and K % in a descending order giving (3.60, 3.40 and 3.10 as for N%), (0.38, 0.35 and 0. 31 for P%) and (3.55, 2.99 and 2.51 for K%) with treatment of (3.0, 5.0 and 7.0 dSm^{-1}), respectively, as compared tocontrol (3.94, 0.43 and 3.83 %for N,P and K respectively.

As for foliar application of Si and GB, the data illustrated that all treatments significantly increased N, P and K % as compared to control (neither salinized nor sprayed). On the other hand, increasing concentration of both Si and/or GB significantly increased N,P and K %and Si_2+GB_2 recorded the highest effective value, whereas means of other treatments showed no significant difference between them.

Also, the data about the interaction between salinity level and foliar application of Si and/or GB, showed that the plants irrigated with the lowest level of salinity (3 dSm^{-1}) and sprayed with Si_2+GB_2 recorded the highest value of N,P and K % (3.78, 0.46 and 3.93%) compared to the control (neither salinized nor sprayed) which recorded (3.60, 0.32 and 3.30 %), whereas the lowest value of N, P and K% exhibited in the plants irrigated with high level of salinity (7 dSm^{-1}) and did not receive any exogenous application (2.70, 0.28 and 2.00 %) but the highest value under the same salinity level was on spraying with Si_2+ GB_2 (3.34, 0.34 and 2.92 %).

Table (11): Alleviation of salinity effects on N, P and K% in shoots of *Populus nigra* by exogenous application of silicon and glycine betaine during and2019/2020.

Character	(N%) Salinity levels (dSm^{-1})				
Salinity levels / Treatment	Control	3 dSm^{-1}	5 dSm^{-1}	7 dSm^{-1}	***Mean
Control	3.60gh	3.30l-n	3.10pq	2.70s*	3.18F
Si 1	3.80de	3.40j-l	3.20n-p	2.90 r	3.33 E
Si 2	3.88cd	3.50h-j	3.30l-n	3.00qr	3.42D
GB 1	3.92bc	3.60gh	3.40j-l	3.10pq	3.51 C
GB 2	3.97bc	3.62fg	3.43i-k	3.17op	3.55 C
Si 1+GB 1	4. 02ab	3.72ef	3.50h-j	3.20n-p	3.61 B
Si 1GB 2	4.12a	3.78de	3.57gh	3.27m-o	3.69A
Si2+GB1	4.08a	3.72ef	3.51g-i	3.21no	3.63B
Si 2+GB 2	4.10a	3.78de	3.60gh	3.34 k-m	3.70A
**Mean	3.94A	3.60B	3.40C	3.10 D	
	(P%)				
Control	0.32kl	0.29mn	0.28no	0.28o	0.29G
Si 1	0.33g-j	0.32kl	0.30 m	0.28o	0.31F
Si 2	0.34gh	0.34g-i	0.31l	0.29mn	0.32E
GB 1	0.46c	0.35fg	0.33h-j	0.32kl	0.36D
GB 2	0.47b	0.36f	0.34g-i	0.32j-l	0.37C
Si 1+GB 1	0.48b	0.45c	0.38e	0.33i-k	0.41B
Si 1+GB 2	0.48b	0.45c	0.39de	0.33i-k	0.41B
Si2+GB1	0.48b	0.45c	0.38e	0.33i-k	0.41B
Si 2+GB 2	0.49a	0.46c	0.39d	0.34gh	0.42A
**Mean	0.43A	0.38B	0.35C	0.31D	
	(K %)				
Control	3.30i	3.00k	2.30p	2.00r	2.65H
Si 1	3.50h	3.20j	2.50o	2.20q	2.85G
Si 2	3.60g	3.30i	2.70m	2.30p	2.98F
GB 1	3.70f	3.50h	2.90l	2.50o	3.15E
GB 2	3.90cd	3.70f	3.20j	2.60n	3.35D
Si 1+GB 1	3.98bc	3. 74ef	3.26ij	2.67mn	3.41C
Si 1+GB 2	4.00b	3.82de	3.32i	2.70m	3.46B
Si2+GB1	3.92bc	3.78ef	3.29i	2.7 0m	3.42 BC
Si 2+GB 2	4.60a	3.93bc	3.42h	2.92l	3.72A
**Mean	3.83A	3.55B	2.99C	2.51D	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l)

***Means values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.

**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%

*Mean values in the same row orcolumn within the interaction followed by the same small letter are not significant at 5%.

3.2.5. Na and Cl %

The data in Table (12) indicated that there were significant increase in Na and Cl % in a ascending order (0.19, 0.24 and 0.29 Na %) and (0.28 , 0.30 and 0.35 Cl %) with the treatments of 3.0,5.0 and 7.0 dSm^{-1} salinity level, respectively, compared to the control (0.11Na % and 0.16 Cl %).

As for foliar application of Si and GB data illustrated that all treatments significantly decreased Na and Cl % as compared to the Control (neither salinized nor sprayed). On the other hand, increasing concentration of both Si and/or GB significantly decreased Na and Cl % and the lowest value obtained with $Si_{2+}GB_2$ wherease other combinations of Si and GB regard Na% showed no significant difference between their effects, while as regard Cl % other combinations of Si $_1$+GB_1 and Si_1+ GB_2 showed no significant difference between their effects.

Table (12): Alleviation of salinity effects on Na and Cl % in shoots of *Populus nigra* by exogenous application of silicon and glycine betaine during 2019/2020.

Character / Salinity levels / Treatments	Na% Salinity levels (dSm^{-1})				
	Control	**3 dSm^{-1}**	**5 dSm^{-1}**	**7 dSm^{-1}**	*****Mean**
Control	0.14i-k	0.33c	0.39b	0.54a*	0.35A
Si_1	0.13j-l	0.24e	0.32c	0.39b	0.27B
Si_2	0. 12kl	0.22f	0.28d	0.38b	0.25 C
GB_1	0.12kl	0.19g	0.24e	0.32c	0.22D
GB_2	0.11lm	0.15hi	0.21f	0.28d	0.19 E
Si_1+GB_1	0.11lm	0.14ij	0.23ef	0.24e	0.18 E
Si_1+GB_2	0.10m	0.14i-k	0.16hi	0.17h	0.14F
Si_2+GB_1	0. 10m	0.14i-k	0.15hi	0.17h	0.14F
Si_2+GB_2	0.06n	0.13j-l	0.14i-k	0.15hi	0.12G%
****Mean**	0.11D	0.19C	0.24B	0.29A	
	Cl %				
Control	0.26lm	0.32ef	0.42c	0.56a	0.39A
Si_1	0.20n	0. 32e-g	0.34e	0.46b	0.33B
Si_2	0.16 qr	0.31f-h	0.33e	0.38d	0.29C
GB_1	0.14rs	0.29h-j	0.32e-g	0.33e	0.27D
GB_2	0.13st	0.29 i-k	0.30 –j	0.32e-g	0.26E
Si_1+GB_1	0.13st	0.28jk	0.29h-j	0.30g-i	0.25EF
Si_1+GB_2	0.13st	0.27kl	0.28i-k	0.30 h-j	0.25F
Si_2+GB_1	0.13st	0.25m	0.25m	0.29h-j	0.23G
Si_2+GB_2	0.12t	0.17pq	0.19 no	0.19op	0.17H
****Mean**	0.16D	0.28C	0.30B	0.35A	

Si_1(Silicon100mg/l),S_2(Silicon200mg/l),GB_1(Glycinbetian 200mg/l),GB_2(Glycinbetian 400mg/l)

***Means values in the same column within each spraying substances followed by the same capital letters are not significant al level 5% probability.

**Means values in the same row within each irrigated with different levels of salinity followed by same capital letters are not significant at level of 5%

*Mean values in the same row orcolumn within the interaction followed by the same small letter are not significant at 5%.

The interaction was found that irrigating with the lowest level of salinity (3 dSm^{-1}) with Si_2 + GB_2 treatment recorded the lowest value of Na and Cl % (0.13 Na and 0.17 Cl %) compared to the control (0.14 Na and 0. 26 Cl%), whereas the highest value of Na and Cl % exhibited in the plants irrigated with high level of salinity (7 dSm^{-1}) and did not receive any exogenous application (0.54 Na % and 0.56Cl %) but the lowest value under the same salinity level on spraying with Si_2+ GB_2 was (0.15 Na and 0. 19 Cl%).

Generally, it can be mentioned that N,P and K concentrations decreased significantly corresponding to the increase in salinity levels, and this was with an agreement with Ahmed *et al.*, 2000) who suggested that , salinity might be implicated indirectly in decreasing nitrogen concentration of plant due to the role played by chloride ions, and several detrimental effects of salinity stress on growth characters might be partially due to a decrease in nitrogen concentration. The reduction of P % in plant by increasing salinity level might be explained as that P is vital element which is involved metabolic processes, but in salt stressed plants more metabolic activities and respiration processes are performed requiring more energy supply to be achieved consequent more P is consumed (Haniyat *et al.*, 1992). In the same direction, K concentration in plants subjected to salinity stress exhibited a significant gradual decline by increasing salinity level,That may be due to the Na+ ions that can substitute K+ ions partially in plant tissue, hence the more concentrated salinity treatment, the more Na+ substitution to consequently K+ ions decrease in plant tissue. (Ashraf and O' leary , 1996).

However there was a general tendency to increase Na and Cl, with increasing salt concentration. It was found that accumulation of Na^+ and Cl^- in the leaves caused damage of seedling which, at last, they died. This indicated that, the ability of some species tolerant to salinity seems to depend on its ability for chloride exclusion. Thus, it could be stated that, salinity appears to affect growth and plant tissue due to either toxic effects of Na+ and/or Cl^- accumulation or to the high osmotic potential of the soil solution, (Wang and Han , 2007).

The exogenous application of Si or GB decreased the Na+ and Cl^- accumulation in the shoots, this was proposed to be the key mechanism of Si salt tolerance in plants (Liang and Ding, 2002 and Shi *et al.*, 2013). So, it is noticeable worth that *Populus nigra* plants irrigated with low level of salinity(3 dSm-1) and sprayed with $Si_2 + GB_2$ resulted in an increase in all growth parameters and improving the chemistry of the plants than those irrigated with control (neither salinized nor sprayed). At high salinity (7 dSm^{-1}) spraying the plants with Si_2+ GB_2 showed similar effects than those irrigated with saline water without any exogenous application. So, it can be concluded that spraying the *Populus nigra* plants with Si and/or GB counteracted the injurious effects resulting from salinity stress of irrigation.

Conclusion

It could be concluded that, high levels of salinity in irrigation water had a depressive effect on all parameters of growth, also had an effect on chemical composition of *Populus nigra.* On the other hand, these injuries due to salinity could be avoided by foliar application of silicon or glycine betaine individually or in combination as, they have an ameliorating effect on all morphological and physiological characters. Also, it prevented degradation of chlorophyll, enhanced accumulation of sugars and proline concentration, they improved N, P, K and decreased Na and Cl levels ,so the best growth was recorded with a mixture of Si 200 mg/l and GB 400 mg/l. Moreover, further researches are needed to investigate the effects of Si and GB foliar application on overcoming the harmful effects of salinity under field conditions, where the problem is more complex.

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تحسين تأثير الملوحة على نمو شتلات الحور الأسود *Populus nigra*
بإستخدام الرش بالسيليكون والجلسين بيتايين

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ملخص

عرضت شتلات الحو الأسود *Populus nigra* إلى ثلاث مستويات مختلفة من الملوحة $3.0, 5.0$ and $7.0\ dSm^{-1}$ بالإضافة إلى الكنترول.

تم رش أوراق النباتات بتركيزين من سليكات البوتاسيوم (100 ، و200 ملليجرام /لتر) ومن الجلسين بيتايين (200 و400 مليجرام /لتر) بالإضافة إلى الكنترول لكل معاملة و كانت أهم النتائج المتحصل عليها كالآتى:-

1- أدى معاملات الملوحة إلى تقليل كل صفات النمو المدروسة. كذلك قلة محتوى النبات من الكلورفيل والنتروجين والفوسفور وكذلك البوتاسيوم، بينما أدت زيادة مستويات الملوحة إلى زيادة محتوى النباتات من الصوديوم والكلوريد والسكريات و البرولين.

2- أدى إستخدام الرش بنوعيه إلى تحسين كل صفات النمو المدروسة وكذلك زيادة كل من النتروجين و الفوسفور والبوتاسيوم وأيضا زيادة كل من الكلورفيل والسكريات والبرولين، بينما أدى الرش إلى قلة محتويات النباتات من الصوديوم وكذلك الكلوريد.

3- كان أفضل النتائج المتحصل عليها عند إستخدام معاملات الرش السابقة مركبة من السيليكون والجليسين بالتركيزات الأعلى لكل منهما (200 مليجرام / لتر سليكات البوتاسيوم + 400 ملليجرام /لتر جليسين بيتايين، للتخفيف من الآثار الضارة للملوحة).