Article

Natrum muriaticum modifies productive response variables in *Salicornia bigelovii* (Torr.)

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Abstract

Salicornia bigelovii (Torr.) is a plant with promising agro-industrial potential and homeopathy is a natural alternative that does not affect the safety of the treated organism. The objective of the study was to evaluate the effect of the homeopathic medicine *Natrum muriaticum* (NaM) on productive response variables of *S. bigelovii* with different levels of salinity (NS) in hydroponic culture, applying a completely randomized experimental design, with factorial arrangement (3A x 3B) and three repetitions of 15 plants each. Two salinity levels (NS-50 and NS-100) and a control without salinity (NS-0) were applied as factor A, and two centesimal dynamizations of NaM (NaM-7CH and NaM-31CH) and a control without medicine (NaM-0CH) as factor B. The response variables evaluated were aerial part length (APL), root part length (RPL), stem thickness (ST), leaf area (LA), water potential (WP), relative water content (RWC), chlorophyll 'a', chlorophyll 'b' and total chlorophyll. With the homeopathic treatment NaM-7CH, higher values were recorded in RPL and with NaM-31CH, higher average values in chlorophyll 'a', chlorophyll 'b' and total chlorophyll. With the saline treatment NS-50, higher values were obtained for APL, RPL, ST, LA, RWC, chlorophylls 'a', 'b' and total. The highest average values in plant morphology corresponded to the interactions NS-50/NaM-7CH and NS-50/NaM-31CH. This suggests a positive effect of NaM on relevant productive response variables of *S. bigelovii* and its potential applicability in the hydroponic culture of this coastal halophyte.

Keywords: agricultural homeopathy, halophytes, hydroponics, salinity.

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Introduction

Salicornia bigelovii is a facultative halophytic plant, it is the only species of the *Chenopodiaceae* family that is part of the flora of the Gulf of California, has potential as an alternative crop irrigated with seawater for livestock fodder and due to its nutritional and organoleptic properties, it can be used as fresh food for human use (Garza-Torres *et al*., 2020). The application of homeopathic products or medicines for disease control, soil protection and plant growth stimulation are called 'agrohomeopathy' (Meneses, 2017) and more recently, 'agricultural homeopathy' (Mazón-Suástegui *et al*., 2018a, 2019).

Homeopathic medicines are highly diluted bioactive compounds (HDBCs) whose productive application is increasing, not only in agriculture, but also in marine and freshwater aquaculture (Mazón-Suástegui *et al*., 2018b; López-Carvallo *et al*., 2021). Agricultural homeopathy is an ecofriendly alternative to the use and abuse of agrochemicals, since through its application various physiological processes of plants are intervened and enhanced, increasing resistance to salt stress and the immune response, improving their development, general performance and biological productivity at the time of harvest (Mazón-Suástegui *et al*., 2019, Rodríguez-Álvarez *et al*., 2020).

Agricultural homeopathy is compatible with certified organic farming systems (Mazón-Suástegui *et al*., 2019), improves germination and emergence of *S. bigelovii* (Mazón-Suástegui *et al*., 2020), reduces salt stress in basil (*Ocimum basilicum* L.) grown in hydroponics (Mazón-Suástegui *et al*., 2018a). Hydroponic cultivation of halotolerant species would allow agricultural development in the coastal zone not suitable for traditional crops and agricultural homeopathy could be applicable (Mazón-Suástegui *et al*., 2019, 2020; Rodríguez-Álvarez *et al*., 2020).

Natrum muriaticum (NaM) is a homeopathic medicine for human use that is biosafe for plant species such as *Capsicum annum* var Glabriusculum (Rodríguez-Álvarez *et al*., 2020), *S. bigelovii* Mazón-Suástegui *et al*. (2020), *Phaseolus vulgaris* L. variety Quivican (García-Bernal *et al*., 2020; Mazón-Suástegui *et al*., 2020) and *S. bigelovii* (Rodríguez-Álvarez *et al*., 2022). The objective of the present study was to evaluate the effect of NaM on productive response variables of *S. bigelovii* and its interaction with different levels of salinity, to obtain new scientific knowledge potentially applicable for its hydroponic cultivation (Rueda-Puente *et al*., 2017).

Materials and methods

Study area

The research was carried out in the experimental agricultural field of the Center for Biological Research of the Northwest, SC (CIBNOR, for its acronym in Spanish), in a metal structure completely covered with polyethylene anti-aphid mesh, model 1.610 PME CR, of 16 × 10 threads cm^{-2} with a weaving and separation of 0.4 × 0.8 mm, crystal color, with 18% of shade. The study site is located on coastal lands of 'El Comitán', in the southern portion of the Baja California Sur peninsula, at 24° 08' north latitude and 110° 24' west longitude, 7 masl and 17 km west of the city of La Paz, BCS, Mexico.

Evaluated species and crop management

Seedlings of *S. bigelovii* of 10 cm of average height collected in intertidal ponds of CIBNOR acclimatized for two weeks in a hydroponic system were used. The experimental culture unit consisted of 12 plastic container boxes of 73 cm long, 42 cm wide and 35 cm high, Monterrey type (Novatec®, CDMX, MX), with 45 L of nominal capacity and 35 L of volume for the culture medium, and 12 polyethylene culture trays with 1 mm caliber, 53 cm long x 27 cm wide x 5.2 cm high with 50 cavities of 6.3 cm upper diameter x 2.4 cm lower diameter x 5.2 cm height and 25 ml volume per cavity. A piece of sponge was placed in the basal part of each cavity to support the stem and support of each plant.

The trays with 45 seedlings each were placed in the plastic boxes described above, containing 35 L of seawater at different salinity levels (0, 50 and 100%, equivalent to N-0, N-50 and N-100), added with nutrient solution (45 seedlings per tray and 135 seedlings in total). A black semirigid liner-type plastic cover was installed, externally attached to the boxes to hold the trays and avoid the light incidence and growth of moss and filamentous algae, in the liquid medium, allowing direct contact of the roots with the nutrient solution (Figure 1) with the different saline treatments included in the experimental design (Figure 2). Permanent aeration was provided by a high efficiency blower, pressure 21 KPa, suction -16 KPa and a flow of 130 $m^3 h^{-1}$, 110 volts/220 single-phase (Ring Blower QM machine, RB-750).

Figure 1. *Salicornia bigelovii* grown in hydroponic system with different salinity levels (0, 50 and 100%).

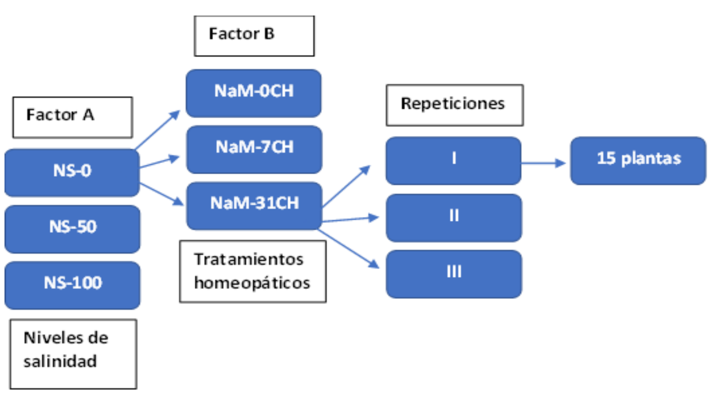

Figure 2. Experimental design applied.

Saline treatments

The saline treatments (salinity levels) were prepared with drinking water and seawater treated with sand filter, filter bags of 10 and 1 μm, and UV radiation, provided by the Experimental Laboratory of Aquacultural Homeopathy and Marine Seeds of CIBNOR. The pH was adjusted to 6, adding a solution of HCl or KOH according to the required adjustment. The electrical conductivity (EC) of the water used for each saline treatment and control was measured with portable equipment (Thermo Scientific® model: Orion™ Star A222, series: K12692, USA). The treatments applied were: NS-0 with drinking water (control), NS-50 adding 50% of seawater and 50% of drinking water and NS-100 constituted 100% with sea water. Once the mixtures were made, the nutrient concentrations were added, the pH was measured and adjusted from 5.5 to 6.5 with a 5% HCl solution. An electrical conductivity (EC) of 2.13 mS cm^{-1} was recorded in the drinking water of NS-0, an EC of 26.04 mS cm^{-1} in the water of NS-50 and an EC of 54.5 mS cm^{-1} in the water of NS-100.

Homeopathic treatments

Hahnemannian centesimal dilutions of *Natrum muriaticum* (7th= NaM-7CH and 31st= NaM-31CH) prepared in distilled water from the respective medicines in alcoholic dilution (NaM-6CH and NaM-30CH of Similia®, Farmacia Homeopática National® CDMX, MX) were applied. NaM is formulated from sea salt with high content of sodium chloride and trace elements such as bioavailable magnesium, potassium chloride, iron and calcium, among others, Mazón-Suástegui *et al*. (2018a). Each dilution was intensely stirred for two minutes in vortex equipment (BenchMixer®, Edison, NJ, USA), applying procedures of the Farmacopea Homeopática Mexicana (Secretaría de Salud, 2015) and procedures developed in CIBNOR (Mazón-Suástegui *et al*., 2018a, 2018b, 2019). NaM-7CH, NaM-31CH and NaM-0CH (distilled water) were applied daily in a foliar way (8:00 am) at dew level on the plants of *S. bigelovii* with approximately 100 ml.

Culture medium

The culture medium was prepared from seawater 54.5 mS cm^{-1} of EC (NS-100) and drinking water whose electrical conductivity was 2.13 mS cm^{-1} corresponding to the treatment NS-0. The combinations of seawater (50%) with drinking water (50%) made up the treatment (NS-50), whose EC was 26.04 mS cm^{-1}. Macronutrients and micronutrients from fertilizers were added. To prepare the stock solution No. 1, Phosphonitrate (45 g), phosphoric acid (58.1 g) and potassium sulfate (206 g) were added and dissolved in 3 L of water. To form the stock No. 2, calcium nitrate (680 g), (Calcinit-Yaraliva®) (230 g), Mg nitrate (Magnisal®) (188 g) and potassium nitrate (245 g) were dissolved in 3 L of water. To form the stock No. 3, the following micronutrients were dissolved in 1 L of water: Zn sulfate (0.352 g), boric acid (H_3BO_3) (1.73 g), manganese sulfate ($MnSO_4$) (1.57 g), ferrous sulfate ($FeSO_4{\cdot}7H_20$) (14.94 g), copper sulfate pentahydrate ($CuSO_4{\cdot}5H_2O$) (0.236 g), sodium molybdate ($Na_2MoO_4{\cdot}2H_2O$) (0.205 g) (Schippers, 1980). For nutrient solutions in saline treatments, 100 ml of Stock No. 1, 100 ml of Stock No. 2 and 35 ml of Stock No. 3 were added in 35 L of water from each container. The nutrient solution and saline treatments were renewed every week and the pH was measured and adjusted daily in a range of 6 ±0.5.

Response variables evaluated

Morphometric [(aerial (APL) and root part length (RPL), stem thickness (ST) and leaf area (LA)] and physiological [water potential Ψ(WP), relative water content (RWC) and chlorophylls 'a', 'b' and total] response variables were evaluated in seedlings of *S. bigelovii* with 10 cm in length (root and aerial part) for four weeks. APL and RPL were measured with a graduated ruler (cm), from the root neck ST with a digital vernier (mm), LA (cm^2) with leaf area integrator scanner equipment (Li-Cor®, model-LI-3000A, series PAM 1701), taking care that the branches and filamentous leaves were evenly distributed and without overlap. The WP was determined in MPa with a WP4-T® meter under the dew point principle, by means of sensors with condensation mirror and infrared temperature, and for this, enough pieces of the aerial part were cut to cover the area of the container. The RWC was determined in percentage (%), by the formula: RWC= (FW-DW)/(TW-DW) X 100. The chlorophyll content was determined in mg ml^{-1} (Arnon, 1949), using a UV spectrophotometer (HACH brand, model DR 3900, series 1575983).

Statistical analysis

Derived from the experimental design applied, completely randomized, with factorial arrangement (3A x 3B) and three repetitions of 15 plants/treatment (total= 135 plants), two salinity levels (NS-50 and NS-100) and a control with drinking water without seawater addition (NS-0) were applied as factor A, and NaM-7CH and NaM-31CH and a control treatment without medicine (NaM-0CH) were applied as factor B. Data resulting from this design were analyzed by means of an one-way Anova and the post hoc analysis of Fisher-LSD of Student's t-test at $p< 0.05$. All statistical analyses were performed with the Statistica program v. 10.0 for Windows® (StatSoft® Inc., 2011).

Results and discussion

Aerial part length (APL)

The statistical analysis of independent factors did not reveal significant differences ($p\geq 0.05$) for NaM, with respect to APL, but average values of APL 8% higher than NaM-31CH and 7.6% higher than NaM-0CH were obtained with NaM-7CH, as shown in Table 1. Abasolo-Pacheco *et al*. (2020a) reported higher height (38.5%) in *Brassica napus* L. plants treated with NaM-7CH, with respect to the homeopathy control treatment. Abasolo-Pacheco *et al*. (2020b) applied NaM-13CH, whose dilution factor is just at the limit of Avogadro (1×10^{-23}), in *Cucumis sativus* plants and recorded higher values in fresh biomass of aerial part (30.8 g) with respect to other homeopathic medicines and a control without homeopathy (1.2 g). Regarding the factor of salinity, significant differences ($p\leq 0.05$) were observed in APL, with values higher (23.7%) than at intermediate salinity (NS-50), above the maximum level 100% saline (NS-100) and 13% higher than NS-0 (Table 2).

Table 1. Effect of homeopathic dynamizations of *Natrum muriaticum* on morphological and physiological variables evaluated in *Salicornia bigelovii* plants grown in hydroponics.

NaM	APL (cm)	RPL (cm)	ST (mm)	LA (cm^2)	WP (MPa)	RWC (%)	Chlorophylls (mg ml^{-1})		
							‘a’	‘b’	Total
NaM-0CH	9.37 a	13 b	3.98 a	6.96 a	-5.87 a	87.05 a	5.2 b	2.7 b	8.2 b
NaM-7CH	10.12 a	15.16 a	4.25 a	8.22 a	-5.39 a	82.55 a	10.3 a	4.9 a	15.7 a
NaM-31CH	9.41 a	14.4 ab	4.27 a	6.98 a	-5.38 a	82.55 a	12.9 a	6.2 a	19.8 a

Means with equal letters do not differ statistically from each other (LSD $p\geq 0.05$). NaM= *Natrum muriaticum*; APL= aerial part length; RPL= root part length; ST= stem thickness; LA= leaf area; WP= water potential; RWC= relative water content; ‘a’= chlorophyll a; ‘b’= chlorophyll b; total= total chlorophyll.

Table 2. Effect of salinity levels on morphological and physiological variables evaluated in *Salicornia bigelovii* plants grown in a hydroponic system.

NS	APL (cm)	RPL (cm)	ST (mm)	LA (cm^2)	WP (MPa)	RWC (%)	Chlorophylls (mg ml^{-1})		
							‘a’	‘b’	Total
0	8.58 b	11.92 b	3.73 b	5.06 b	-6.92 c	67.33 c	9.1 a	4.8 a	14.3 a
50	10.62 a	15.66 a	4.6 a	10.37 a	-5.77 b	97.26 a	10 a	4.8 a	15.3 a
100	9.7 ab	15 a	4.17 ab	6.72 b	-3.94 a	87.56 b	9.4 a	4.2 a	14.1 a

Means with equal letters do not differ statistically from each other (LSD $p\geq 0.05$). NS= salinity levels; APL= aerial part length; RPL= root part length; ST= stem thickness; LA= leaf area; WP= water potential; RWC= relative water content; ‘a’= chlorophyll a; ‘b’= chlorophyll b; total= total chlorophyll.

The Anova revealed significant differences ($p\geq 0.05$) for the interaction of factors; with NS-50/NaM-7CH, there was an APL 40% higher than the control NS-0/NaM-0CH, and other interactions (Table 3). At intermediate salinity (NS-50), better performance was observed in APL independent or interactive with NaM. Salinity is a determining factor in the aerial growth of *S. bigelovii*.

Table 3. Effect of the interaction of factors NS/NaM on morphophysiological response variables in *Salicornia bigelovii* plants grown in a hydroponic system.

NS	NaM	APL (cm)	RPL (cm)	ST (mm)	LA (cm^2)	WP (MPa)	RWC (%)	Chlorophylls (mg ml^{-1})		
								‘a’	‘b’	Total
0	0CH	8.12 c	11.25 c	3.61 c	4.75 c	-7.4 e	67.59 c	2.5 d	1.8 ef	4.5 e
50	0CH	10.5 ab	13.25 bc	4.39 abc	9.9 ab	-4.6 ab	100 a	1.7 d	0.8 f	2.5 e
100	0CH	9.5 abc	14.5 abc	3.93 bc	6.22 bc	-5.59 bc	90.54 ab	11.4 b	5.4 bc	17.5 bc
0	7CH	8.87 bc	12.25 c	3.9 bc	4.56 c	-7.24 de	67.45 c	5.9 d	3.4 cde	9.7 cde
50	7CH	11.37 a	17 a	4.5 ab	12.34 a	-3.58 a	88.25 ab	14 ab	6.5 b	21.2 ab
100	7CH	10.12 abc	16.25 ab	4.35 abc	7.75 bc	-5.35 bc	91.96 ab	10.9 bc	4.7 bcd	16.2 bcd
0	31CH	8.75 bc	12.25 c	3.69 bc	5.88 bc	-6.13 cd	66.95 c	18.8 a	19 a	28.7 a
50	31CH	10 abc	16.75 a	4.89 a	8.88 abc	-3.63 a	100 a	14.2 ab	7 ab	22 ab
100	31CH	9.5 abc	14.25 abc	4.23 abc	6.2 bc	-6.39 cde	80.17 bc	5.8 cd	2.5 def	8.6 de

Means with equal letters do not differ statistically form each other (LSD $p\geq 0.05$). NS= salinity levels; NaM= *Natrum muriaticum*; APL= aerial part length; RPL= root part length; ST= stem thickness; LA= leaf area; WP= water potential; RWC= relative water content; ‘a’= chlorophyll a, ‘b’= chlorophyll b; total= total chlorophyll.

Ayala and O'Leary (1995) showed that a higher concentration (600 mM) of salts causes a lower growth in the RPL of *S. bigelovii*, which suggests a better performance at 25 to 30 mS cm^{-1} (≈ 50% of drinking water and 50% of seawater), salinity that has led to higher APL. This confirms that *S. bigelovii* has a better performance in intermediate salinity (Rodríguez-Álvarez *et al*., 2022).

Root part length (RPL)

The statistical analysis with independent factors revealed significant differences ($p\geq 0.05$) in RPL. With NaM-7CH, an RPL 10.3% higher than NaM-31CH and 16.6% higher than NaM-0CH was obtained, as shown in Table 1. This coincides with Mazón-Suástegui *et al*. (2020), who reported a superior RPL in *S. bigelovii* with NAM-7CH, and with Rodríguez-Álvarez *et al*. (2020) for *chiltepín* chili (*Capsicum annuum* L. var Glabriusculum) in hydroponic system, since RPL was 29.6% higher when applying NaM-13CH, with respect to the control without homeopathy. For the independent factor salinity, a significant difference (LSD $p\geq 0.05$) was observed for RPL, being 31.3% higher with NS-50 *versus* NS-0 (Table 2). For the interaction NS-50/NaM-7CH, significant differences ($p\geq 0.05$) were observed in RPL, being 51.1% higher *versus* the control interaction NS-0/NaM-0CH (Table 3).

Stem thickness (ST)

The Anova of independent factors did not reflect significant differences between treatments for ST, but higher values with NaM-31CH (7.2%) with respect to NaM-0CH and 0.5% higher than NaM-7CH (Table 1). This is an interesting fact, since homeopathy does not act only through chemically present molecules and nanoparticles, but in complex physical and electromagnetic processes that maintain their activity even in ultra-dilutions beyond the limit established by Avogadro's theory (Mazón-Suástegui *et al*., 2020). These authors recorded a significant increase in germination and initial development of *S. bigelovii* with NaM-7CH with respect to control treatments (distilled water), with the highest response in germination (up to 44%), and stem and radicle length, 35% above control. This confirms the positive effects of homeopathic medication on plants (Mazón-Suástegui *et al*., 2019, 2020).

Abasolo-Pacheco *et al*. (2020b) report the largest stem diameter (5 mm) for *Cucumis sativus* L. plants treated with NaM-7CH, *versus Silicea terra* (SiT-7CH) (4.64 mm). In our bioassay, we recorded differences in ST ($p\geq 0.05$) when applying NS-50, with values higher (23%) than those obtained with NS-0 and 13% higher than those obtained with NS-100 (Table 2).

Regarding the interaction of saline/homeopathic treatments and ST, significant differences ($p\geq 0.05$) were observed with NS-50/NaM-31CH, with respect to the other interactions, with the value recorded with NS-0/NaM-0CH being higher (35.4%) (Table 3). Similar values were reported by Rodríguez-Álvarez *et al*. (2022) in plants treated with 50% of seawater (AM-50= 26 mS cm^{-1}) and the homeopathic treatment NaM (AM-50/NaM-7CH) with values up to 44% higher with respect to plants irrigated with drinking water and even with 100% of seawater (AM-100).

Leaf area (LA)

No significant difference was observed between the plants treated with NaM, but higher values (18.1%) were observed with NaM-7CH *versus* NaM-0CH (Table 1). This coincides with what was reported by Mazón-Suástegui *et al*. (2020) on the initial growth of *S. bigelovii*, as biomass production was higher (0.23 g) when applying NaM-7CH. For salinity, significant differences ($p\leq$ 0.05) were obtained in LA with NS-50, being 104% higher than the control NS-0 (Table 2). This confirms that an intermediate salinity is adequate for *S. bigelovii* (Ayala and O'Leary, 1995; Flowers and Colmer, 2008). In this way it is reported for *Salicornia dolichostachya* (Katschnig *et al*., 2013) in plants subjected to 300 mM of sodium chloride (NaCl). Values 159.7% higher were obtained in LA with NS-50/NaM-7CH *versus* NS-0/NaM-0CH (Table 3), coinciding with Rodríguez-Álvarez *et al*. (2022), who recorded the highest values of 'vegetation cover' with NaM-7CH and NaM-13CH in plants irrigated with 50% of seawater.

Water potential (WP)

No significant differences were observed when applying NaM in *S. bigelovii*, as shown in Table 1. WP values are always negative; a body of pure water is considered to have a water potential of zero, that being its maximum value. If there are high concentrations of solutes in the tissue or organs of the plant, the values will be negative and at higher concentrations, they will be farther from zero. The WP values closest to zero were obtained ($p\geq$ 0.05) with 100% of seawater (NS-100) *versus* fresh water (NS-0), with a difference between the two of 56.9% (Table 2). The most favorable average values corresponded to the salinity of 54.3 mS cm^{-1}, which indicates greater water conservation in the tissues of *S. bigelovii* grown in seawater *versus* freshwater and suggests that cultivation in freshwater appears to be difficult or unfeasible. Regarding the interactions, significant differences ($p\geq$ 0.05) were observed between NS-50/NaM-7CH and NS-50/NaM-31CH, *versus* the other interactions, obtaining the most favorable values of WP with NS-50/NaM-7CH and the least favorable ($p\geq$ 0.05) with NS-0/NaM-0CH (Table 3). Values closer to zero were recorded with NaM-7CH, which suggests that there was greater 'freedom of movement' of water *versus* when applying NaM-0CH.

Relative water content (RWC)

There was a significant difference (LSD $p\geq$ 0.05) in plants treated with NS-50, with RWC 4.45% higher than that obtained with NS-0 (Table 2). This indicates that, at intermediate salinity, there is greater turgor and content of water in tissues, which could be associated with a better organoleptic condition of *S. bigelovii* for human consumption. On the other hand, in a non-halophyte species such as *chiltepín* chili (*Capsicum annum* var glabriusculum) grown in a hydroponic system added with 200 mM of NaCl (EC of 19.5 mS cm^{-1}), there was a decrease of 31.2% in RWC with respect to the control treatment (Rodríguez-Álvarez *et al*., 2020).

According to these authors, *chiltepín* plants showed loss of turgor and wilt of the aerial part due to their physiological mechanisms that allow them to tolerate certain levels of salinity, as happens for *S. bigelovii*. The double interaction of saline and homeopathic treatments showed significant differences ($p\geq$ 0.05) between the interactive treatments NS-50/NaM-0CH and NS-50/NaM-31CH, both with the highest average RWC values (up to 47.95%), compared to *S. bigelovii* grown with NaM-0CH/NS-0, with no addition of seawater or homeopathic medication (Table 3).

Chlorophyll ‘a’

The plants of *S. bigelovii* treated with NaM-7CH and NaM-31CH showed significant differences ($p \geq 0.05$) with higher values (148 and 98%, respectively) in their content of chlorophyll ‘a’, *versus* those of the control treatment without homeopathy NaM-0CH (Table 1). Regarding the double interaction of factors salinity/homeopathy, there were significant differences ($p \leq 0.05$) in chlorophyll ‘a’ for NS-0/NaM-31CH, with a higher content (up to 652%) with respect to the control NS-0/NaM-0CH (Table 3). These results differ from those of Rodríguez-Álvarez *et al*. (2022), who, for the same species, mention that the concentration of chlorophyll ‘a’ was higher when applying NaM-7CH, with the exception that the plants were irrigated with 25% of seawater.

Chlorophyll ‘b’

In plants treated with NaM-7CH and NaM-31CH, significant differences ($p \geq 0.05$) were recorded in the content of chlorophyll ‘b’, with values 81.4% and 129.6% higher, respectively, than those of plants treated with NaM-0CH. Something interesting and noteworthy is that the highest average values (48.1%) corresponded to plants treated with NaM-31CH (Table 1). This confirms that high homeopathic dilutions can induce specific and measurable biological responses in plant models and that these treatments do not have *per se* a simple suggestion effect, as could be attributed to their application in humans (Mazón-Suástegui *et al*., 2018b, 2019).

These results coincide with those reported for this same species by Rodríguez-Álvarez *et al*. (2022), who state that the concentration of chlorophyll ‘b’ was higher in plants treated with NaM-7CH, irrigated with seawater and grown in pots with substrate in different periods of the crop. Regarding the double interaction of saline and homeopathic treatments and the content of chlorophyll ‘b’ as a response variable, *S. bigelovii* plants treated with NS-0/NaM-31CH showed the best result, with a significant difference of up to 225%, in relation to the interactive control treatment NS-0/NaM-0, without the addition of seawater or homeopathic medication (Table 3).

Total chlorophyll

Significant differences ($p \geq 0.05$) were recorded in *S. bigelovii* plants treated with NaM-7CH and NaM-31CH, with respect to those of NaM-0CH which did not receive homeopathic medication. Both homeopathic dynamizations of NaM stimulated the production of total chlorophyll and consequently, its concentration in the leaves (94.4% and 191.4% respectively) was higher with respect to the plants of the control treatment, as shown in Table 1. This response could be attributed to the content of the trace element magnesium (Mg), which is present in *Natrum muriaticum* at the trace level, essential for the formation of chlorophyll molecules and indispensable in the photosynthetic process which is possible through the contribution of luminous and nutritional energy, which is reflected in greater production of plant biomass (Xiao-Xin *et al*., 2014). With reference to the factor of salinity, in general, no significant differences ($p \geq 0.05$) were observed in the total chlorophyll content (Table 2). However, the results obtained with NS-0/NaM-31CH showed significant differences ($p \geq 0.05$) of 537.7% with respect to NS-0/NaM-0CH without the addition of seawater or homeopathic medication (Table 3).

Conclusions

In plants of *Salicornia bigelovii* grown in hydroponics and treated with the homeopathic medicine developed from sea salt *Natrum muriaticum* (Similia®), higher values were recorded in RPL when applying NaM-7CH and, in chlorophyll 'a', chlorophyll 'b' and total chlorophyll with NaM-31CH. For APL, RPL, ST, LA, RWC, chlorophylls 'a', 'b' and total, the highest values were obtained with the intermediate saline treatment NS-50 with 50% of seawater. The interaction NS-50/NaM-7CH reflected the greatest benefit in morphological parameters (APL, RPL, LA and WP). The interaction NS-50/NaM-31CH had a favorable effect on ST, RWC, content of chlorophylls 'a' and 'b' and total. *Salicornia bigelovii*, despite being a facultative halophyte, grows best in an intermediate saline medium (EC≈ 26 mS cm^{-1}). These results suggest that NaM, a homeopathic medicine licensed for human use by the Secretariat of Health of Mexico, is a highly diluted ecofriendly bioactive compound with potential applicability in the cultivation of *S. bigelovii*.

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