Article

Evaluation of asexual propagation by cuttings in *Sesuvium verrucosum* Raf. (Aizoaceae)

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Abstract

Drought and salinity are conditions in some soils that limit agricultural production worldwide. To combat these effects, emphasis has been placed on a technique called phytodesalination, which consists of the use of halophyte species with the ability to extract significant amounts of sodium (Na^+) from the affected environment. However, this is an agricultural practice that demands a large amount of plant material per hectare, which makes it difficult to implement in production systems with salinity problems. The objective of this work was to determine the rooting capacity of the cuttings of the halophytic species *S. verrucosum* and to analyze the magnitude changes in its biometric parameters, from different concentrations in the hormonal treatment, in a period of 90 days. For the development of the experiment, a completely randomized experimental design was used and two factors were considered: the concentrations of indole butyric acid (IBA) (0, 800, 1 200, 1 600, 2 000 and 4 000 mg L^{-1}) and the position of the cuttings (basal-intermediate and intermediate-apical). The results obtained showed significant differences between the different treatments. The cuttings of the intermediate-apical portion were those that obtained the highest percentage of rooting, number of roots, fresh and dry weight, both of the root and the area of the plant, stem diameter and plant height, mainly at a concentration of 2 000 mg L^{-1}. Through this method, it is possible to implement phytodesalination extensively.

Keywords: adventitious roots, phytoregulators, rooting, vegetative propagation.

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Introduction

Drought and salinity are conditions in some soils that limit agricultural production worldwide, due to the fact that they produce a series of morphological, physiological and biochemical effects that negatively affect the growth and development of crops (Munns and Tester, 2008). Worldwide, drought and salinity influence at least 75 countries (Qadir *et al*., 1997).

In the case of Mexico, the levels of effects due to salinity cover around one million ha (Serrato *et al*., 2002), so it is expected that productivity and crop yields will be affected in more 50% for the second half of this century (Reyes *et al*., 2014).

To combat the effects of salinity and rehabilitate the soils that have been affected, various studies have proposed the implementation of phytodesalination; this is a sustainable agricultural practice, which consists of the use of various halophyte species that have the ability to extract significant amounts of sodium (Na^+) from the affected environment and remove it through the absorption of plant roots and its translocation to the stems and leaves (Nouri *et al*., 2017).

The relevance of this practice lies in the ability of these species to desalinate saline soils in a relatively inexpensive way, present a low level of disturbance in the soils where it is implemented and provide additional income to farmers at the end of their cultivation, since they can be used as fodder, biofuels, medicines and food for man (Nikalje *et al*., 2018).

However, since phytodesalination is a practice that demands a large amount of plant material per hectare (McSorley *et al*., 2016), by having to take plants from their habitat to transfer them to the sites that are intended to be remedied, the implementation of this practice can lead to an intensive exploitation of the species, to the point of putting its gene pool at risk in the absence of protocols that ensure its production in a sustainable way.

Hence the need to find new alternatives that allow the massive propagation of plant material, at low cost for farmers, in the shortest possible time; this must be done, without losing sight of the homogeneity in the quality of the plants, the supply flow and the continuous availability in the agricultural field.

According to Veras *et al*. (2018), an effective alternative to solve the shortage of seeds and plant material is vegetative or asexual propagation, which is based on the principle of totipotency (Cabahug *et al*., 2018), which means that each cell of plants contains the genetic information necessary to form new individuals with characteristics identical to those of the mother plant.

This can be done through cuttings from the stem, since in addition to shortening the propagation period, making its management efficient and reducing production costs, it allows to maintain the genetic characteristics of the parent plant and transmit it from generation to generation (Ramos-Hernández *et al*., 2013). Above all, it can be an optimal strategy for late-rooting species (Tosta *et al*., 2012).

The asexual vegetative propagation through cuttings, generally relies on growth regulators in order to stimulate the rooting of the cuttings for their correct development, due to their influence on cell division and elongation. Such is the case of indole butyric acid (IBA), a synthetic auxin that has proven to be effective in stimulating cell production and growth, as well as intervening in different activities of the plant, such as: stem growth, root formation, the inhibition of lateral buds, abscission of leaves and fruits, as well as the activation of cambium cells (Akwatulira *et al*., 2011).

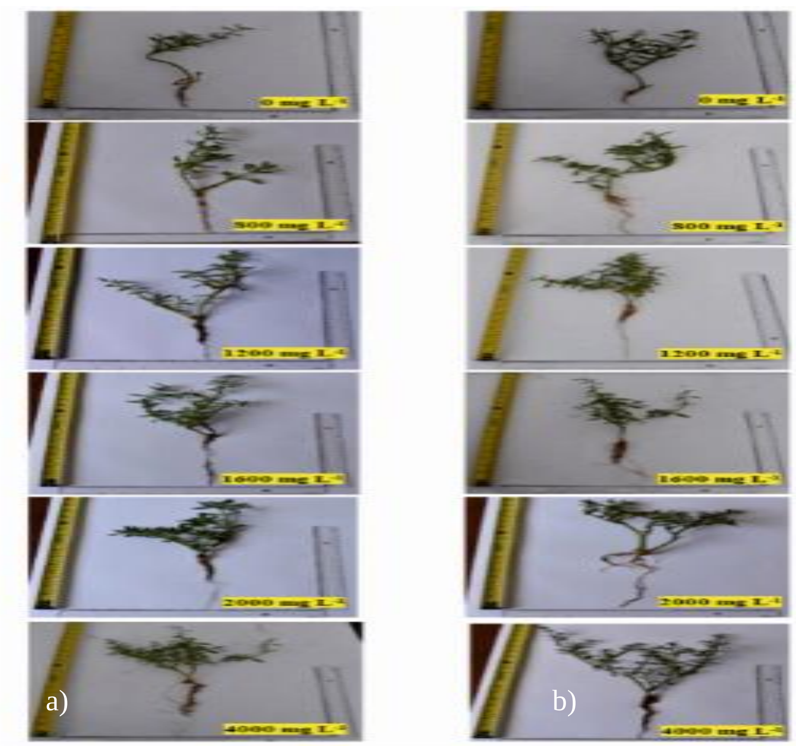

Figure 1. Images of the basal-intermediate and intermediate-apical portions (a); and from the *S. verrucosum* cuttings (b) 90 days after the application of the IBA.

According to several studies, IBA is possibly the best growth regulator for general use, because it is not toxic to plants in a wide range of concentration levels, it has greater stability against degradation and metabolism and is usually even more effective than other growth regulators such as indoleacetic acid IAA (Ludwig-Müller, 2000).

Although it is true that asexual vegetative propagation has been implemented in numerous species of great commercial relevance, such as: *Annona diversifolia* Saff. (Annonaceae) (Orozco-Castillo and González-Esquinca, 2017), *Punica granatum* L. (Lythraceae) (Singh, 2014), *Stevia rebaudiana* Bertoni (Asteraceae) (López-Medina *et al*., 2016), *Vanilla planifolia* (Orchidaceae) (Azofeifa-Bolaños *et al*., 2018), so far there are no operative rooting protocols that effectively guide the production of succulent halophyte species.

This may be due to the fact that the optimal IBA concentration varies according to the species and the endogenous level of phytohormones that are present in the mother plants during the cuttings (Cabahug *et al*., 2018). Recently, it was reported that, in the municipality of Villamar, Michoacán, Mexico, a perennial native halophyte species with enormous phytodesalination potential grows called *Sesuvium verrucosum* by bioaccumulating 0.96 t ha^{-1} of Na^+ (Lastiri-Hernández *et al*., 2020), a dicotyledonous of the Aizoaceae family with C_3 photosynthesis, which has a wide phenotypic plasticity due to the formation of successive changes that this species has developed in its ontogenetic system, such as secondary thickening patterns and the formation of the internal phloem, which they allow for greater mechanical resistance, flexibility and above all, a greater storage capacity for water and cations, mainly Na^+ (Elbar, 2015).

However, in the absence of research and an operating protocol that helps to establish the bases for the correct development of the halophyte *S. verrucosum*; through cuttings, the objective of this work was to determine the rooting capacity and analyze the magnitude changes in its biometric parameters, from different concentrations in the hormonal treatment.

Materials and methods

The study was carried out under greenhouse conditions during the period of July-September 2019, which is located in the municipality of Jiquilpan de Juárez, Michoacán, Mexico, at an altitude of 1 560 meters above sea level and coordinates 19° 59’ 57.6456” North latitude and -102° 42’ 24.0336” West longitude. On average, the temperature and relative humidity conditions in the greenhouse were 36/10 °C (day/night) and 60% (±10%), respectively.

Vegetal material

The plant material (mother plants) used for the development of the experiment was extracted from a geothermal area known as Los Negritos, belonging to the municipality of Villamar, Michoacán, Mexico, at an altitude of 1 540 masl, at coordinates 20° 03’ 47.2248” north latitude and -102° 36’ 52.776” west longitude. The type of vegetation in this area is secondary.

The plants were extracted at the beginning of June 2019, at the time of the beginning of the rains, when they were approximately eight months old and showed a vegetative phenological stage. An extraction of 20 plants in the area was carried out, their height was measured with a Truper® brand tape measure and the stems of each of them were counted. The plants were also weighed with an Ohaus Compass™ CX brand scale and their stems were measured with a Truper® brand Vernier 14388 digital caliper, later they were placed in black polystyrene bags with a capacity of 10 kg to be taken to the greenhouse.

The halophytes showed an initial fresh weight of 38.67 ±4.13 g, an average height of 23.86 ±3.65 cm, an average stem diameter at ground level of 6.42 ±1.79 mm and an average number of stems of 6.36.

Previous agronomic management

Fifteen days before starting the experiment, the mother plants were watered with running water in order to maintain turgor in the cells. A dose of fertilization was also applied to each bag with plants in order to favor the appearance of vigorous regrowths.

As there are no studies on NPK fertilization doses that maximize the foliage yield of this species, the fertilization formula (300-150-80) proposed by Montoya-García *et al*. (2018) for a succulent species (*Portulaca oleracea*) that shares the same habitat. The fertilizers applied were Diammonium phosphate (DAP), urea and triple 17-17-17 [0.38 g of DAP (100%) + 1.19 g of urea (100%) + 1.17 g of triple 17-17-17 (100%)].

Physicochemical analysis of the substrate

The substrate used for the development of the experiment was a mixture of soil and bovine manure, which was placed in black polystyrene bags with a capacity of 1 kg, which were filled with 750 g of soil and 150 g of dry manure, in a ratio (5:1), respectively.

The bags were not perforated to avoid washing of the cations. The manure was acquired from a barn located in the municipality of Jiquilpan, Michoacán, at coordinates 20° 00' 01.5804" north latitude and -102° 42' 25.1424" west longitude.

The soil used as substrate presented the following characteristics: Vertisol with a clay texture (31.16% sand, 46.48% clay, 22.36% silt); an electrical conductivity ECe of 1.45 dS m^{-1}, a pH of 8.17, a percentage of humidity of 12.5%, 2.6% of organic matter (% of OM), an apparent density (AD) of 1.02, a percentage of porosity of 59.7, a water retention capacity (CRA) of 39.4%, a sodium adsorption ratio (SAR) of 5.78 (mmolc $L^{-1})^{1/2}$, a cation exchange capacity (CEC) of 45.7 cmolc kg^{-1} and a percentage of exchangeable sodium (ESP) of 13.21, as well as 0.21% of total nitrogen, 8.65 mg kg^{-1} of available phosphorus, 2.1 mmolc L^{-1} of carbonates, 9.26 mmolc L^{-1} of bicarbonates, 3.17 mmolc L^{-1} of chlorides and 3.04 mmolc L^{-1} of Sulfates.

The portion of bovine manure showed an ECe electrical conductivity of 5.82 dS m^{-1}, a pH of 8.68, a humidity percentage of 46.28%, 21.7% organic matter (% OM), an apparent density (AD) of 0.525, a porosity percentage of 76.92, a water retention capacity (CRA) of 60.98%, total organic carbon of 35.9 mg kg^{-1} and total nitrogen of 5.7 g kg^{-1}.

Chemical and microbiological characteristics of irrigation water

The application of the irrigation was carried out with running water. The chemical characteristics of the water were: ECe of 0.58 dS m^{-1}, pH of 8.1 and a hardness of 262 mmolc L^{-1}. Total dissolved solids (TDS) of 155 ppm, Ca^{2+} of 1.2 mmolc L^{-1}, Mg^{2+} of 2.1 mmolc L^{-1}, Na^{+} of 1.75 mmolc L^{-1}, K^{+} of 0.3 mmolc L^{-1}, CO_3^{-2} of 0.48 mmolc L^{-1}, HCO_3^{-} of 8.6 mmolc L^{-1}, SO_4^{-2} of 0.153 mmolc L^{-1} and a sodium adsorption ratio (RAS) of 1.36.

The microbiological characteristics of the irrigation water were total coliforms of 17 MPN/100 ml, fecal coliforms of 3 MPN/100 ml and *Escherichia coli* of 3 MPN/100 ml.

Handling of utensils

The razors, scissors and containers used were disinfected by immersion in a 20% chlorine solution for 10 min. The cuts made to the stems of the mother plants were made in a bevel, with an angle of 45º just below the nodes. The basal-intermediate portion was considered from the lower part of the plant stems to the middle part of the same, while the intermediate-apical portion was considered from the remaining middle part of the stems to the apex of each of they.

The cuttings were cleaned and placed in a container with distilled water, to avoid dehydration. This activity was carried out in the morning hours, in order to reduce perspiration. The cuttings from each portion (basal-intermediate and intermediate-apical) were weighed with an Ohaus Compass™ CX brand scale and their stem was measured with a 14388 digital Vernier caliper from Truper® brand.

The number of cuttings obtained from the mother plants averaged 12.7. The cuttings had an initial fresh weight of 4.49 ±0.34 g, a length of 9.56 ±2.73 cm and an average stem diameter of 4.82 ±0.09 mm in the basal-intermediate part; while, in the intermediate-apical part, the cuttings had an initial fresh weight of 4.21 ±0.27 g, a length of 9.19 ±2.49 cm and an average stem diameter of 4.67 ±0.07 mm.

Treatments

A completely randomized experimental design was used and two factors were considered: the IBA concentrations and the position of the cuttings taken from each stem. The first factor consisted of six levels (0, 800, 1 200, 1 600, 2 000 and 4 000 mg L^{-1}), the second factor consisted of two levels (basal-intermediate and intermediate-apical), giving a total of 12 treatments and twelve repetitions. Each experimental unit consisted of a single cutting, which meant the evaluation of 144 experimental units.

Once the cuttings were planted in the prepared substrate, at a depth of 2 ± 0.5 cm, they were brought to 70% of the container capacity and watered periodically, the watering were carried out with a manual sprinkler for 90 days (time that the experiment lasted). The same amount of water that was evaporated was applied in an evaporimeter tank (30 cm in diameter by 10 cm in height) installed in the greenhouse.

Growth regulator

The growth regulator used was indole-3-butyric acid (4-(1 H-indole-3-yl) butyric acid) from the commercial brand RADIX® 10 000-Intercontinental, with a purity level of 1% as an ingredient. active and 99% inert ingredients. This was dissolved in distilled water adding potassium hydroxide (KOH 1N), until obtaining a complete dilution with adjustment of pH to 8. Its application was made by immersing approximately 1 cm of the base of each cutting for 1 h in the solution, according with the concentration of each treatment.

Fertilization

Fifteen days after starting the experiment, 0.4 g of urea (46-00-00) was applied weekly to each experimental unit, until week six (day 43), with the purpose of promoting growth and stimulating cell division.

Variables evaluated

The variables evaluated in each portion (basal-intermediate and intermediate-apical) at the end of the experiment were: the height of the plant, the diameter of the stem, the length of the main root, the number of roots, the percentage of rooting and the weight fresh and dry from both the root and the area. Plant height was measured with a Truper® brand flexometer, stem diameter and root length were measured with a Truper® brand Vernier 14388 digital caliper, the number of roots was quantified from the roots greater than 1 mm in length.

The percentage of rooting was determined by counting the number of cuttings (rooted), divided by the total of cuttings initially established and multiplied by 100. The plants were washed with distilled water, the roots and the aerial part (stems and leaves) were separated and quantified by their fresh weight (g); subsequently, the samples were dried in an oven at 70 ºC for 48 h to evaluate their dry weight (g).

Data analysis

The data obtained from the evaluated variables were subjected to the Shapiro-Wilk normality test ($p\leq 0.05$) and the Levene test for homogeneity of variance. The variables that fulfilled both tests were applied the analysis of variance (Anova) and the Tukey mean comparison test ($p\leq 0.05$).

The variables that did not comply with the tests of homogeneity of variance or normality were transformed to the natural logarithm (ln) until normality and homoscedasticity were observed, later the Anova and the Tukey mean comparison test ($p\leq 0.05$) were calculated.

The data that did not comply with both tests were subjected to a non-parametric analysis of Kruskal-Wallis and the summation of Wilcoxon ranks, according to the methodology of Siegel (1974). For all cases, the statistical program Statistical Analysis System (SAS) Version 9.1 (SAS Institute, 2004) was used.

Results and discussion

Table 1 shows the effects of auxin IBA on the roots of *S. verrucosum* cuttings, after being exposed to different concentrations during a period of 90 days. The treatments evaluated, both in the basal-intermediate and intermediate-apical portions of the *S. verrucosum* cuttings, showed significant differences ($p\leq 0.05$) in all the variables evaluated with respect to their own control, mainly when the cuttings were subjected to high IBA concentrations. At 2 000 and 4 000 mg L^{-1} IBA concentration, no difference could be observed.

Table 1. Effects of auxin IBA on the roots of *S. verrucosum* cuttings 90 days after its application.

Portion	Treatments	Concentration (mg L^{-1})	Rooting (%)	Fresh root weight (g)	Root dry weight (g)	Root length (cm)	Number of roots
Intermediate-apical	Control	0	66.66 d	1.145 ±0.17 g	0.178 ±0.03 g	13.87 ±1.14 f	31.68 ±3.45 f
	AIB	800	66.66 d	1.613 ±0.22 fe	0.242 ±0.03 f	16.84 ±1.27 d	46.35 ±4.12 e
	AIB	1 200	75 c	2.185 ±0.28 c	0.327 ±0.03 d	19.91 ±1.16 c	55.41 ±3.03 d
	AIB	1 600	83.33 b	2.674 ±0.16 b	0.409 ±0.02 b	22.96 ±1.06 b	64.26 ±4.51 c
	AIB	2 000	91.67 a	3.139 ±0.19 a	0.493± 0.02 a	25.58 ±1.25 a	72.95 ±3.77 b
	AIB	4 000	91.67 a	3.261 ±0.25 a	0.511 ±0.03 a	26.25 ±1.17 a	78.52 ±5.07 ab
Basal-intermediate	Control	0	41.66 f	0.805 ±0.12 h	0.142 ±0.02 h	12.69 ±1.25 f	23.17 ±4.28 g
	AIB	800	58.33 e	1.127 ± 0.09 g	0.191 ±0.01 g	15.35 ±1.15 e	35.78 ±5.19 f
	AIB	1 200	66.66 d	1.443 ±0.07 f	0.246 ±0.01 f	17.98 ±1.21 d	46.12 ±4.93 e
	AIB	1 600	75 c	1.69 ±0.09 e	0.298 ±0.02 e	20.63 ±1.09 c	56.65 ± 5.32 d
	AIB	2 000	75 c	1.912 ±0.1 d	0.345 ±0.01 dc	22.37 ±0.98 b	66.81 ±3.45 c
	AIB	4 000	83.33 b	2.016 ±0.13 dc	0.362 ±0.02 c	23.34 ±1.05 b	73.03 ±4.79 bc

In each column, equal letters do not differ significantly from each other according to Tukey's test ($p \leq 0.05$), the values indicate the mean ± SE (n= 12).

These results suggest that, at concentrations higher than those established in the present study, phytotoxic effects could be triggered in *S. verrucosum* cuttings, which would lead to a reduction in the quality of the adventitious root system (Delgado *et al*., 2008). In addition, it was found that the intermediate-apical portion achieved higher rooting percentages than the basal-intermediate portion, varying in 25%, 8.33%, 8.33%, 8.33%, 16.67% and 8.33% among the treatments evaluated at 0, 800, 1 200, 1 600, 2 000 and 4 000 mg L^{-1} of IBA, respectively (Table 1). Hence, the rooting capacity of *S. verrucosum* cuttings drastically decreases in the basipetal direction.

Similarly, it was found that the intermediate-apical portion achieved a higher phytomass than the basal-intermediate portion, achieving increases of 29.69% and 20.22% in the fresh and dry weight of the root, in the treatments used as control, 30.13 % and 21.07% between the treatments evaluated at 800 mg L^{-1}, 33.95% and 24.77% between the treatments evaluated at 1200 mg L^{-1}, 36.79% and 27.13% between the treatments evaluated at 1 600 mg L^{-1}, 39.08% and 30.02% among the treatments evaluated at 2 000 mg L^{-1} and 38.17% and 29.15% among the treatments evaluated at 4 000 mg L^{-1} of IBA, respectively (Table 1).

Regarding the length of the roots, it was found that the intermediate-apical portion achieved greater increases, compared to the basal-intermediate portion, by varying in 8.5%, 8.84%, 9.69%, 10.14%, 12.54% and 11.08% among treatments evaluated at 0, 800, 1 200, 1 600, 2 000, and 4 000 mg L^{-1} of IBA, respectively.

On the other hand, it was observed that the intermediate-apical portion achieved a greater increase in the number of roots, compared to the basal-intermediate portion, by varying in 26.88%, 22.80%, 16.76%, 13.54%, 8.41% and 6.99 % among treatments evaluated at 0, 800, 1 200, 1 600, 2 000, and 4 000 mg L^{-1} of IBA, respectively. However, at 4 000 mg L^{-1} of IBA, no significant differences ($p \leq 0.05$) were observed between these two portions.

The fact that the cuttings of the intermediate-apical portion showed a greater increase in the percentage of rooting, fresh and dry weight of the root, as well as in the number of roots with respect to the basal-intermediate portion, could be explained by the high concentrations of endogenous auxins that accumulate in this portion of the stem (Mustafa and Khan, 2016), which facilitate the biosynthesis pathways and a wide variety of development processes, among which are: the beginning of leaf primordia, phototropism, cell division and differentiation of vascular tissues, which as a whole, promote the production of adventitious roots (Vanneste and Friml, 2009). This translates into a better absorption of the root system, to the benefit of the vigor obtained in the aerial part of the cuttings (López-Acosta *et al*., 2008), a situation that was reflected through the number, length and production of root phytomass as IBA concentration levels increased.

In addition to this, the higher percentage of rooting, formation and size of the root system in the cuttings of the intermediate-apical portion, can be attributed to various factors, among which are: a) the photosynthesis process in the leaves, as the main organ carbohydrate synthesizer for the plant; b) the formation of young leaves, as a source of photoassimilates, responsible for the production of auxins and cofactors that are essential in the process of cell division; c) the polar transport of auxins, responsible for the auxins being synthesized in the apical meristem and translocated towards the basal part of the plants; d) the porosity of the substrate and the depth of the transplantation of the cuttings, both responsible for the penetration of the roots, the mobilization and translocation of nutrients. As well as an adequate water balance within the cuttings; and e) the physicochemical conditions of the substrate to guarantee adequate aeration and moisture retention conditions (Akwatulira *et al*., 2011; López-Medina *et al*., 2016; Ferriani *et al*., 2018).

Table 2 shows the effects of auxin IBA on the aerial part of *S. verrucosum* cuttings, after being exposed to different concentrations during a period of 90 days. The treatments evaluated, both in the basal-intermediate and intermediate-apical portions of the *S. verrucosum* cuttings, showed significant differences ($p \leq 0.05$) in all the variables evaluated with respect to their own control, mainly when the cuttings were subjected to high IBA concentrations.

Table 2. Effects of auxin IBA on the aerial part of *S. verrucosum* cuttings 90 days after its application.

Portion	Treatments	Concentration (mg L^{-1})	Fresh weight aerial part (g)	Dry weight aerial part (g)	Stem diameter (cm)	Total height (cm)
Intermediate-apical	Control	0	14.659 ±1.39 fe	1.759 ±0.19 h	0.513 ±0.09 f	17.02 ±0.76 g
	AIB	800	18.795 ±1.52 d	2.312 ±0.27g	0.538 ±0.06 d	19.35 ±0.93 e
	AIB	1 200	24.963 ±1.63 c	3.291 ±0.24 e	0.562 ±0.07 c	21.52 ±0.69 d
	AIB	1 600	31.892 ±1.41 b	4.165 ±0.21 c	0.581 ±0.08 b	23.88 ±1.04 c
	AIB	2 000	39.486 ±1.71 a	4.928 ±0.23 b	0.607 ±0.05 a	26.01 ±0.85 b
	AIB	4 000	40.709 ±1.83 a	5.274 ±0.3 ab	0.612 ±0.07 a	27.63 ±1.23 ab
Basal-intermediate	Control	0	10.226 ±1.35 b	1.371 ±0.18 i	0.502 ±0.07 g	16.24 ±0.83 g
	AIB	800	12.897 ±1.22 f	1.768 ±0.2 h	0.523 ±0.05 e	18.31 ±1.02 f
	AIB	1 200	16.459 ±1.44 e	2.424 ±0.26 g	0.54 ±0.06 d	20.19 ±0.71 e
	AIB	1 600	20.086 ±1.87 d	2.973 ±0.17 f	0.556 ±0.04 c	22.34 ±0.95 d
	AIB	2 000	23.673 ±1.62 c	3.312 ±0.18 e	0.578 ±0.06 b	24.22 ±0.68 c
	AIB	4 000	24.514 ±2.16 c	3.646 ±0.23 de	0.585 ±0.07 b	25.81 ±1.12 bc

In each column, equal letters do not differ significantly from each other according to Tukey's test ($p\leq 0.05$), the values indicate the mean ± SE (n= 12).

The aerial part of the cuttings from both the basal-intermediate and intermediate-apical portions did not show significant differences in the concentration levels of 2 000 and 4 000 mg L^{-1} of IBA. Regarding the fresh and dry weight of the aerial part, it was found that the intermediate-apical portion was greater than the basal-intermediate portion, achieving increases of 30.24% and 22.05%, respectively, among the treatments used as control, 31.38% and 23.52% between the treatments evaluated at 800 mg L^{-1}, 34.06% and 26.34% between the treatments evaluated at 1 200 mg L^{-1}, 37.01% and 28.61% between the treatments evaluated at 1 600 mg L^{-1}, 40.04% and 32.79% between the treatments evaluated at 2 000 mg L^{-1} and 39.78% and 30.86% between the treatments evaluated at 4 000 mg L^{-1} of IBA.

Regarding the diameter of the stem, it was found that the intermediate-apical portion achieved greater increases, compared to the basal-intermediate portion, by varying in 2.14%, 2.78%, 3.91%, 4.30%, 4.77% and 4.41% between treatments. evaluated at 0, 800, 1 200, 1 600, 2 000, and 4 000 mg L^{-1} IBA, respectively.

Regarding the total height of the cuttings, it was observed that the intermediate-apical portion was greater than the basal-intermediate portion, achieving increases of 4.58%, 5.37%, 6.18%, 6.49%, 6.88% and 6.58%. among treatments evaluated at 0, 800, 1 200, 1 600, 2 000, and 4 000 mg L^{-1} of IBA, respectively. Unlike the concentration level of 4 000 mg L^{-1}, where no significant difference ($p \leq 0.05$) was observed between both portions (Table 2).

According to Vercruyssen *et al*. (2011), the architecture of the roots provides an important anchor for plants and allows the synthesis of hormones that influence the development of sprouts, these factors could have led to the intermediate-apical portion achieving a greater increase in the phytomass of the aerial part, as well as better energy activity.

In addition, the effectiveness in the percentage of rooting from the concentration of 800 mg L^{-1} of IBA, both in the basal-intermediate and intermediate-apical portions of the *S*. *verrucosum* cuttings, confirmed the low requirement of exogenous auxins that they are needed to trigger their rooting; this shows that the species is easy to root. This could be explained by the processes that take place during rooting, such as: the accumulation of metabolites at the site of application of auxins, the synthesis of new proteins and the division of the vascular cells of the cambium (Mehta *et al*., 2018). According to Veras *et al*. (2018), from the exogenous application of IBA, the formation of tracheids is stimulated by differentiation of callus cells, mainly in the xylem, which in turn leads to a greater production and formation of adventitious roots.

However, from the concentration of 2 000 mg L^{-1} of IBA in both the basal-intermediate and intermediate-apical portions of the *S*. *verrucosum* cuttings, no significant differences were observed ($p \leq 0.05$) in terms of the increase in the variables studied (biomass of the root and aerial part, length of the root, number of roots, diameter of the stem and height of the plants), which may be due to the rooting speed and the sprouts that were originated in response to the IBA concentration, since the optimal dose depends on each species (Carranza *et al*., 2012).

To this, it must be added that several studies have indicated that the existence of endophytic bacteria, present in the species *S*. *verrucosum*, promote the growth of these plants and their physiology, by altering their regulation processes in osmotic pressure, changes in the responses of the stomata, the adjustment in the morphology of the root size, the modification of nitrogen accumulation and metabolism, the production of hormones such as auxins, gibberellins and zeatin, as well as the absorption and translocation of certain minerals (El-Awady *et al*., 2015).

Conclusions

The results of this research showed that the use of IBA to treat cuttings of the species *S*. *verrucosum*, improved the rooting rate and the magnitude of the biometric parameters, both in the intermediate-apical portion and in the basal-intermediate portion.

Also, it was found that with the use of clay soil and manure in a ratio (5:1), the massive spread of *S*. *verrucosum* benefits; by presenting a high growth and survival rate that is potentiated with the help of IBA, mainly to 2 000 mg L^{-1}.

Therefore, through this method of propagation, it can contribute to safeguarding the most vulnerable sectors, especially in regions with low productive systems, given the high salinity conditions in which they are immersed.

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