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VEGETATIVE PROPAGATION OF CACTACEOUS SPECIES IN THE ATUNCELA INTEGRATED MANAGEMENT DISTRICT (``*DAGUA*``, ``*VALLE DEL CAUCA*``)

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Abstract: The integrated management district of Atuncela has specific characteristics of the dry forest that allow the presence of unique species within the Chocó biogeographic region, where tropical humid forest vegetation predominates. In this district, 5 species of cacti present in the area of ecological importance were evaluated: *Pilosocereus colombianus*(Britton & Rose), Melocactus curvispinus Pfeiffer subsp. loboguerreroi (Cardenas) Fern. Alonso & Xhonneux, Opuntia pittieri Britton & Rose, Opuntia bella Britton & Rose and Armatocereus humilis (Britton & Rose) Backeberg), to define adequate parameters for vegetative propagation of endemic cacti as conservation strategies of the dry - subxerophytic forest ecosystem. The behavior of the five species to the healing process and the response to 3 different substrates (unsieved soil, sieved soil, soil enriched with organic matter) was evaluated, with two different sizes of propagule (Tm1, Tm2) in a completely experimental design. random. The five species evaluated presented a differential behavior in the healing process, with material losses from 0% for A. humilis to 100% for M. curviespinus. Variations in the development of the species were observed in relation to the characteristics of each species. A. humilis reached a development of 15 cm at 90 days, unlike the 2 cm reached by P. colombianus. It was possible to determine the type of soil that favors the development of each species, and how the size of the propagule positively affected the development of A. humilis with increases of 55% in regrowth length. The factors associated with the type of soil and propagule size generated effects on the vegetative development of the five species evaluated. Accordingly, four of the five species evaluated responded positively to vegetative propagation and can be considered an efficient propagation method for *Opuntia pittieri*, Opuntia bella, Armatocereus humilis and Pilosocereus colombianus, however, the negative response of Melocactus curvispinus shows the problem in the rapid spread of this species and its disadvantage.

Keywords: Subxerophytic, development, cactus, propagation, endemism, conservation, Extremophilous.

INTRODUCTION

Cactaceae are plants native to the American continent, distributed in ecosystems with arid and semi-arid characteristics. This family is composed of approximately 200 genera and between 200 to 1500 species, of which some of them are threatened by being illegally collected in its natural habitat for ornamentation, reaching a current panorama of 31% of threatened species, this being the fifth most threatened taxonomic group(GOETTSCH et al., 2015; PÉREZ-MOLPHE et al., 2015; CABAÑAS-GARCÍA et al., 2021). The ornamental value of cacti is widely known, due to their morphological particularities. Accordingly, cacti stand out for having a variety of sizes and shapes, succulent stems, as well as edible fruits (RAMÍREZ-RODRÍGUEZ et al., 2020).

The striking features of cacti respond to morpho-physiological adaptations that allow their development in desert environments, by reducing water loss and storage.(INGLESE et al., 2017; PORRAS FLÓREZ et al., 2018). These adaptations allow the presence of cacti in different regions of the American continent. This includes the native vegetation of the dry tropical forests of Colombia (Bs-T), which is present in the departments of Antioquía, Atlántico, Bolívar, Cauca, Cesar, Cundinamarca, Guajira, Huila, Magdalena, Nariño, Norte de Santander, Sucre, Tolima and Valle del Cauca(PIZANO et al., 2014). Despite the large number of departments where it is possible to find ecosystems of thetropical dry forest, this is among the three most degraded,

fragmented and least known ecosystems in Colombia(QUIROGA et al., 2019).

The topographic diversity of the different regions and departments of Colombia limits the connection between dry forests; Due to its fragmentation, there are few mature and remaining forests, consequently the species have small distribution ranges with a tendency to be prone to population decline. (MONCADA et al., 2021). An example of this limited connection is presented andIn the subxerophytic enclave of the foothills of the Western mountain range in the Valle del Cauca, in this enclave, the district of Atuncela is located, where it is possible to find species of cactisuch as Opuntia pittieri Britton & Rose, Opuntia bella Britton & Rose, endemic species of Dagua-Loboguerrero, as well as *Melocactus curvispinus*ssp. loboguerreroi(Cárdenas) Fern. Alonso &(FLANAGAN et al., 2011; VARGAS, 2012; BARRIGA and VALDERRAMA, 2015).

Some of the cactus species in the Atuncela integrated management district belong to the genus Opuntia, which is made up of 12 species registered in the country(BERNAL, 2015; HOME, 2015)including Opuntia bellait's aerect bush, with many branches, the structure is made up of stalks in the form of oblong, erect, green blades, provided with white thorns and very striking bright yellow flowers. Another species of its genus is the Opuntia Pittieri, which consists of larger cladodes and more pronounced spines, its flowers are bright reddish orange.(GRIFFITH and PORTER, 2009; PIZANO et al., 2014). Some species of Opuntia such as O. pittieri present peaks in flower production in both rainy and dry seasons, in annually similar seasons.(CARDEÑO and RODRÍGUEZ, 2020).

Other species in the district are characterized by being columnar, such as the genera Armathocereus and Pilosocereus, which can be distinguished by their elongated stems. The Armatocereus genus corresponds to cacti that have primitive characteristics such as thorns in flowers and fruits. The only species attributed to Colombia (Armatocereus humilis) is present in the Cauca Valley. (LOAIZA and ROQUE, 2016). Armatocereus humilis is a tree plant with cylindrical branches, very marked ribs, greenish-white tubular flowers, its globose to ovoid fruits consist of strong spines like the rest of the plant.(FRANCK et al., 2019)., better known as columnar.While *Pilosocereus colombianus*It branches a little more from the base and consists of numerous ribs with strong spines. It is easily differentiated because the apical part of the stems is covered by grayish white wool. Its flowers are inconspicuous and its fruits are purple to purple. they don't have thorns(CVC – FUNAGUA, 2011).

Of the five cacti present in Atuncela, the most peculiar is that of the genus Melocactus, considering that few come from Colombia, as is the case with *Melocactus curvispinus*ssp. Loboguerreroi,which presents wide intraspecific variation, is also endemic and is the only species of cephaloid cactus in the region(FERNÁNDEZ-ALONSO and XHONNEUX, 2002). It has relatively large fruits (4-6 cm in length), highly desired by several species of birds, which can be attributed to its wide distribution of seeds. (FLANAGAN et al., 2011).

These cactus species are an important part of the tropical dry forest ecosystem, which is negatively affected by multiple factors, in the particular case of thenatural landscape of the subxerophytic enclave of the riverDagua has been transformed by 80%, with agriculture, livestock and mining being constant activities that generated fragmentation of the ecosystems and their deterioration. (LEGUÍZAMO-PARDO and VARGAS-RÍOS 2008; CVC – FUNAGUA, 2011) QConsequently, it is important to develop

conservation strategies for the protection of species that constitute important elements in the preservation of less resilient ecosystems. (PIZANO et al., 2014; PIZANO and GARCIA 2014). Therefore, the objective of this work was to establish and identify the conditions required by cactus species present in this ecosystem for their vegetative propagation as a multiplication strategy in the restoration of the native vegetation of the integrated management district of Atuncela.

MATERIAL AND METHODS

LOCATION

The study was developed in the integrated management district of Atuncela, located in **t**he village of Atuncela in the dry enclave of the Dagua River, on the eastern slope of the western mountain range of Colombia in the department of Valle del Cauca. Located between the towns of Loboguerrero and Atuncela. at 3°44'21.1"N and 76°40'42.0"W, in a height range between 850 to 950 meters above sea level, and an average precipitation of 790 mm/year.

VEGETAL MATERIAL

Five species of cacti were selected to carry out the propagation trials, two of the genus Opuntia (Opuntia pittieri Britton & Rose and Opuntia bella Britton & Rose), two of columnar cacti (Armatocereus humilis (Britton & Rose) Backeb and Pilosocereus colombianus (Rose) Byles & GD Rowley) and one of cephaloid cactus (*Melocactus curvispinus*ssp. loboguerreroi(Cárdenas) Fern. Alonso & Xhonn).

OBTAINING PROPAGULES

Considering the phenological state of each species, adult cacti were selected to avoid negative effects on the ecosystem due to the extraction of cacti, recording the data of the donor plant. Subsequently, 10 segments with two propagule sizes (Tm1 and Tm2) were collected. For Opuntia pittieri, stalks of sizes between 20 to 25 cm were taken and two types of propagules were generated: Tm1: complete stalk and Tm2: ½ stalk; For Opuntia bella, complete stalks of <9 cm for Tm1 and > 12cm for Tm2 were selected. For the columnar cacti, Armatocereus humilis and Pilosocereus colombianus, segments of two sizes were collected: 10cm for Tm1 and 20cm segments for Tm2. For Melocactus curvispinus, two segments of 5 and 10 cm were taken, corresponding to Tm1 and Tm2. With three replicas for each species.

CICATRIZATION

The healing of the cacti was carried out in controlled mesh house conditions, each type of propagule was placed on soil beds and under shade (70% polyshade) for 18 days, the healing of the controls was carried out in field conditions without application of healing agent with the objective of observing the side effects generated by biotic factors on the propagules.

GROWING CONDITIONS

Considering the factors of the plant species, substrate, propagule size and the trial, a completely randomized design (DCA) was established with six repetitions for each treatment, under net house conditions (50% polyshade). Each propagule was sown in 3-liter nursery bags with different substrate conditions (unsieved soil, sieved soil and soil enriched with 30% organic matter (litter)), the soil used was extracted from the propagule collection site, of which its physicochemical conditions were characterized (Table 1).

DATA COLLECTION

Loss of propagules

The propagule loss rate was obtained 18 days after the healing process, by quantifying the number of segments affected by biotic factors that inhibited root production and subsequent death.

$$Propagule\ loss\ rate = \frac{Pr.D}{Pr.T} * 100\%$$

Pr. D (damaged propagules), Pr. T (total propagules).

Number of sprouts and length of sprouts

The evaluation was carried out 90 days after sowing, quantifying the number of sprouts per propagule of each species and the length of each of the sprouts in each of the treatments. In the columnar cactus species Armatocereus humilis and Pilosocereus colombianus, two data dates were considered, 30 and 60 days.

Statistical analysis

A simple statistical analysis was performed with an analysis of variance (ANOVA) for each of the variables, shoot length (LR) and number of shoots per propagule (NR) with -F test and a multiple comparisons test of means. Tukey at 95% probability with the STATGRAPHICS centurion version XVII program.

RESULTS AND DISCUSSION

RESPONSE OF PROPAGULES TO THE HEALING METHOD

The cacti evaluated showed differences in the response to the healing process. When considering the percentage of propagule loss as an indication of the healing potential, it was observed that some cacti have good healing represented by the low percentage of loss between 0 to 3%, others presented medium levels around 30% and finally a high loss of 100%.

Species such as A. humilis and O. bella showed low levels of propagule loss between 0 and 3% respectively; the species O. pitteri and P. colombianus obtained similar losses of 33 and 27% respectively, with the highest loss rate in the propagules corresponding to Tm2; Finally, M. curvispinus presented total loss of the evaluated material.In cephaloid type cacti such as the species M. curvispinus, there are no records of vegetative propagation by conventional methods and propagation by micropropagation with adult material is limited, as the material can be easily contaminated.(EMBRAPA 2018). This is consistent with the results obtained with this species where the total loss of material occurred (Figure 1).

Except for the species A. humilis with 0% loss of propagules, the four remaining species showed degradation in the plant tissue exposed during cutting to obtain pieces and stalks. Furthermore, the healing capacity is not related to morphological characteristics or type of growth, thus, the columnar type cacti presented different levels of healing, a similar behavior was observed in species with cladodes as was the case of the opuntias. Despite the variations in behavior, for species of the genus opuntia the propagation is efficient, especially for O. bella and for cacti such as A. humilis. Reproduction by means

of vegetative propagules is known as an important strategy for rapid reproduction and colonization.(PALLEIRO et al., 2006). Thus the loss of propagules for this species was low compared to some of the other cactus species, which makes this type of reproduction viable (Figure 1).

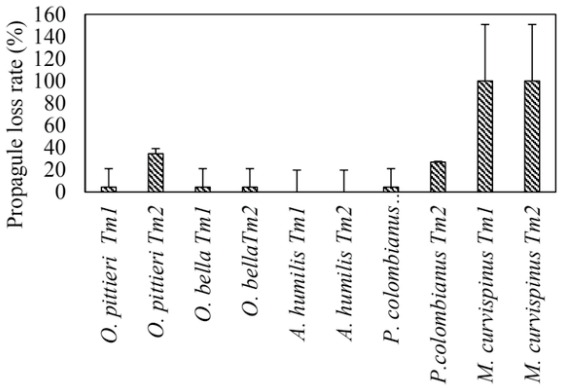

Figure 1: Damage to cactus propagules; On the x axis are the species, the number 1-2 corresponds to propagules at the size of the propagule Tm1- Tm2. On the Y axis is the percentage of propagules lost.

DEVELOPMENT OF COLUMNAR CACTI

The vegetative development of columnar cacti is not related to their morphological and structural characteristics, so it was possible to observe variations in the behavior of the species in the number and length of sprouts. The species P. colombianus showed slow growth during the first 60 days, and reached an average of 2 cm regrowth in 90 days, growth that was favored by larger propagules. Meanwhile, the species A. humilis showed accelerated growth with lengths of 5 cm in 30 days and about 15 cm in 90 days (Figure 2). For both species, the vegetative propagation method is an efficient method, evidencing apical dominance in A. humulis. Similar behaviors have been observed in species of commercial interest such as Stenocereus griseus, compared to Stenocereus stellatus and Escontria chiotilla.(LÓPEZ-GÓMEZ et al., 2000).

RESPONSE OF PROPAGULES TO PROPAGATION CONDITIONS

The number and length of the sprouts vary between the species of cacti and the type of soil where it is cultivated; the size of the propagule is a factor that only the length of the sprouts interferes with. The analysis of variance showed values of $p < 0.0001$ for both variables with the species factor, in addition the plant species explains 90% for the number of sprouts and 76% for the length of the total variance found in the experiment. (Table 1).

The size of the propagule is a factor that only affects the length of sprouts ($p<0.05$) and explains 7.6% of the variance, while the number of sprouts is not conditioned by the size of the propagule. The interactions of the factors species x size (AxC) can explain 52.8% of the variance for the variable sprout length, while the interaction species x soil (AxB) for both variables presents significant differences with values of $p <0.05$ with 52.27% and 37.3% of explained variance.

The vegetative development of each of the species is different, the five cacti were classified into three groups for the variable number of sprouts, where (a) O. bella obtained an average of 1.5, being the highest number of sprouts. The species (b) O. pittieri and A. humilis presented a similar number of regrowths between them with averages of 0.78 and 0.67, lastly (c) P. colombianus and M. cuerviespinus, presented the lowest number of regrowths and a low length of these compared to the other species, with lengths between 0.4 and 1 (Table 2), the low production of sprouts in Melocactus has been reported previously, tropical species of this genus do not have the ability to form sprouts naturally when They suffer physical damage and it is even difficult for them to reproduce sexually.(EMBRAPA, 2018).

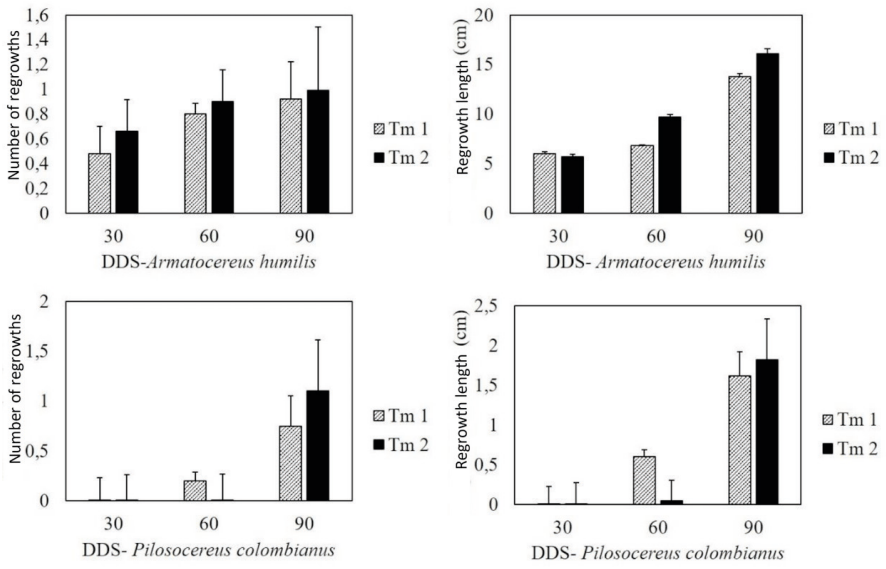

Figure 2: Comparison of the growth of two columnar cacti at 30, 60 and 90 days after DDS sowing with two sizes of propagules. a) Number of regrowth of A. humilis. b) Length of sprouts (cm) of A, humilis. c) Number of regrowth of P. colombianus. d) Length of sprouts (cm) of P. colombianus.

Source	D.F.	Number of sprouts	P-value	Explained variance	Length of shoots	P-value	Explained variance
EFFECTS							
Species (A)	4	6,415	**0.000**	90,313	198,686	**0.000**	76,413
Soil (B)	2	0.502	**0.0084**	7,067	41,543	**0.0004**	15,977
Size (C)	1	0.186	0.171	2,618	19,785	**0.0436**	7,609
INTERACTIONS							
(A) * (B)	8	0.264	**0.0123**	52,277	14,829	**0.0045**	37,320
(A)* (C)	4	0.074	0.5475	14,653	21,004	**0.003**	52,861
(B)* (C)	2	0.115	0.3114	22,772	2,341	0.6073	5,891
(A)* (B)* (C)	8	0.052	0.8178	10,297	1.56	0.949	3,926
WASTE	60	0.096			4,656		

Table 1: Analysis of variance for number of sprouts and length of sprouts of the evaluated cactus species. The mean squares of the – P values are presented.

Species	Number of sprouts		±SD	Regrowth length		±SD
M. curviespinus	0.0453009	to	0.441	0.416429	to	2,662
P. colombianus	0.275301	to	0.284	1.01754	to	2,237
A. humilis	0.67419	b	0.008	**6.20754**	**b**	1,432
O. pitieri	0.781667	b	0.076	**6,315**	**b**	1,508
O. beautiful	**1.58833**	**c**	0.647	**6.95333**	**b**	1959
Floor						
Unsifted	0.5068	to	0.101	2.8273	to	0.902
Enriched	0.7015	ab	0.036	**4.4055**	**b**	0.213
Sifting	**0.7425**	**c**	0.065	**5,076**	**b**	0.688

Table 2: Test of multiple comparisons of means for number of sprouts and length of sprouts of the evaluated cactus species.
(Letters indicate significant differences at 95% reliability for 95% Tukey test)

The length of regrowth in the species O. bella, O. pittieri and A.humuli was greater in sieved soils enriched with organic matter compared to P. colombianus, which presented better results in unsieved soils, and the species M. curviespinus, which did not. I present no variation in any type of soil.*O.bella*presented an increase of 16% for length, in sieved soil and enriched with organic matter, compared to unsieved soil.*O. pitieri*and*A. humilis*They presented better results with soil enriched with organic matter with an increase of 60% compared to unsieved soil and 49% compared to sieved soil. Finally,*P. colombianus*It presented higher values in unsieved soil with an increase of 90% compared to the sieved soil.

The soil conditions favored the growth of cacti, with increases close to 30% on average for the number of sprouts and 40% for sprout length in the sifted soil enriched with organic matter (Table 2). Similar behavior was reported in estudies on cacti at different growth stages that showed significant variations in their development depending on soil compounds (AMMAR et al., 2012). The results showed longer regrowth lengths in sieved and enriched soils for O. bella, and O. pittieri.

The sifted soil favored the production of sprouts of*O. beautiful*with increases of 40% compared to unsieved soil, the enriched soil showed an increase in the number of shoots of 43% and 42.4% for*O. pittieri*and*A. humilis*with respect to the minimum values of the unsieved soil treatment. The low number of outbreaks of*P. colombianus*was favored by unsieved soil with an increase of 75% compared to the sieved soil where the minimum values were obtained, while none of these conditions generated a differential effect for*M. curviespinus*(Figure 3).Other studies indicate that Melocatus plants present a differentiated development between species, such as the case of M. zehntneri, which in soils enriched with agroindustrial and agricultural waste showed growth from micropropagation (GOMES FILHO et al., 2013), being similar for the species M. bahiensis with controlled light intensity presents a viable development(LONE et al., 2009). M. curvispinus did not present differences in relation to the soil in which it was treated, compared to the previously mentioned studies.

The size of the propagules does not generate variations in the development of the propagules in the cacti evaluated. The species of the genus*Opuntia*They were not affected in the size of the cladode, showing variations between 1 to 4% in the sizes evaluated.For the species of the Opuntia genus, asexual reproduction is a considerable alternative due to the optimal results obtained. Some species of this genus are cultivated worldwide in order to be used for livestock feed and medicinally (HUANG et al., 2008) and its propagation is mainly vegetative for food species such as Opuntia ficus-indica(INGLESE et al., 2017). In the species of this genus the ranges of variation of both vegetative and intraspecific reproductive characteristics are high. (PORRAS FLÓREZ et al., 2018).

For A. humilis the size of the propagule affected positively with an increase of 55% in the 20 cm propagules compared to the 10 cm ones. To a lesser extent, close to 13%, P. colombianus was favored by larger propagules (12 cm).

For M. curviespinus, this factor fails to positively influence the low development presented, the different conditions do not generate effects on the behavior of M. curviespinus, revealing the difficulty of this species to be propagated vegetatively, it is known that in other species of the Melocactus genus, its reproduction is exclusively sexual and has reduced seedling survival.(EMBRAPA, 2018). In this study, it was possible to obtain seedlings in a low percentage and more

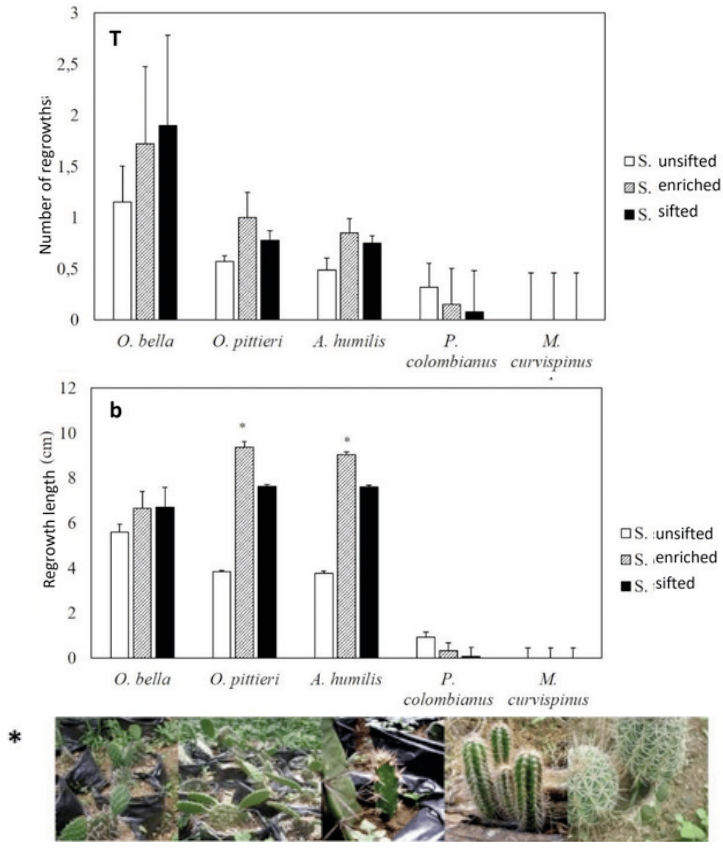

Figure 3: Behavior of cacti to soil type. a) Variation in number of sprouts according to the species and type of substrate (unsieved soil, soil enriched with organic matter and sifted soil), b) length of sprouts for the cactus species in the three types of substrate, note the behavior of Melocactus cuerviespinus (*identifies the soils to which each species behaves best).

conditions need to be evaluated.

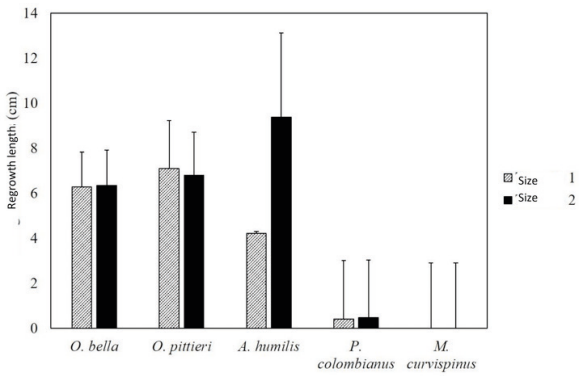

Figure 4: Behavior of the five species of cactus regarding the length of sprouts due to the effect of the size of the propagule.

In general terms, four of the five cacti evaluated responded effectively to vegetative reproduction. Additionally, it was possible to determine the type of soil and the minimum length of the propagule. Thus, O. pittieri, O. bella and A. humilis were the most efficient cacti in multiplication due to their superior growth. Additionally, these cacti are part of the dry forest plant associations of the integrated management district of Atuncela and can be selected for ecological restoration processes, according to the properties of each species and the degree of degradation of the site to be recovered(QUIROGA et al., 2019). Vegetative propagation constitutes a short-term response to the ecological restoration of BS-T relicts, effectively reducing the effects of a wide range of reported threats to cacti, including land conversion for agriculture and aquaculture, harvesting as biological resources and residential use and commercial development GOETTSCH et al., 2015; PILLET et al., 2022).

CONCLUSIONS

The DMI cacti respond differently to biotic conditions, with M. curviespinus showing greater vulnerability, which makes it necessary to continue researching appropriate ways for its healing, in the same way for the management of sectioned cladodes and propagules of P. colombianus.

Cactaceae species present differences in length behavior and number of sprouts that are favored by characteristics of the substrate, whether sifted or enriched soil, the size of the propagule is a relevant characteristic for the propagules in A. humilis.

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