



(RESEARCH ARTICLE)



## Biological mixture of brown algae extracts influences the microbial community of *Lobivia arachnacantha*, *Lobivia aurea*, *Lobivia jojoiana* and *Lobivia grandiflora* in pot cultivation

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### Abstract

**Research goal:** Based on the information found in the literature, it has been verified that the use of biofertilizing algae can definitely improve plant quality, growth, and blooms. In this work, studies were conducted to evaluate whether the use of algae in the cultivation of ornamental cacti in pots can improve the growth, ornamental qualities and resistance to salt stress of plants that normally grow in environmental conditions different from our latitudes.

**Materials and Methods:** The experiments, started in September 2020, were conducted in the greenhouses of CREA-OF in Pescia (PT), Tuscany, Italy (43°54'N 10°41'E) on *Lobivia arachnacantha*, *Lobivia aurea shaferi*, *Lobivia jojoiana* and *Lobivia grandiflora herzogli*. The experimental groups were: i) group control, irrigated with water and substrate previously fertilized; ii) group control1, irrigated with water and substrate previously fertilized + 50 mM of NaCl once every 7 days; iii) group with algae, irrigated with water and substrate previously fertilized; iv) group with algae, irrigated with water and substrate previously fertilized + 50 mM of NaCl once every 7 days. On July 28, 2021, plant height and circumference, suckers' number, number and length of thorns, vegetative and roots weight, flowers number, flowers life, plants dead from salinity stress, substrate microbial count, pH were analysed.

**Results and Discussion:** The test showed a significant increase in agronomic and quality parameters analyzed in plants treated with algae extracts on *Lobivia arachnacantha*, *Lobivia aurea shaferi*, *Lobivia jojoiana* and *Lobivia grandiflora herzogli*. In fact, the trial showed in agronomic terms an increase in plant height and circumference, number of new suckers, vegetative and roots growth, number and length of thorns and flowers number. In qualitative terms, these treated with algae extracts have shown a significant increase in the flower's life and greater resistance to salt stress. The trial also showed an increase in the microorganism's number in the theses treated with algae and a lowering of the pH in the substrate. The results therefore suggest the presence of additional sources of carbon and energy in particular nitrogen and phosphorus that ensure the increase of microbial populations and influence their behavior.

**Conclusions:** This research paper highlights the potential of biofertilizer technology in terms of cost, environmental sustainability, and saline soil improvement. As in other experiments in the literature, the application of algae not only resulted in significant effects on plant growth but also influenced the development of microbial communities in the soil.

**Keywords:** Cactus plants; Sustainable agriculture; Biofertilizers; Algae; *Lobivia*

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## 1. Introduction

### 1.1. *Lobivia*: Characteristics and environment

*Lobivia* is a genus of cactaceae whose name was obtained of the anagram of Bolivia, the country from which most of the species in the genus originate. It is a genus that is now included in *Echinopsis*. *Lobivia* are small, globular or cylindrical South American cacti with several ribs thickly covered with spines, from Argentina, Peru and of course Bolivia [1,2]. They are plants characterized by a globular shape, by an extreme easiness to grow and by very abundant flowerings, large and with beautiful and vivid colors which come out abundantly if the plant has been kept at rest in winter, without watering in a cool environment [3]. Summer flowers, with a hairy peduncle, funnel-shaped, diurnal, long-lasting, red, orange, carmine, yellow, white, produced in quantity and never on top. The minimum winter temperature is 4°C. A low temperature predisposes to a copious flowering. In summer do not exceed 30°C [4]. Repotting will be done annually. Pay attention to mealybugs, mites and humidity. Light misting serves to avoid attacks by the red spider mite. Fertilize three times during the growing season, also adding trace elements [5].

### 1.2. Role of algae as Biofertilizer

The development of organic agriculture and the growing demand for healthy food and long-term sustainability has led to the increasing development of new alternatives to synthetic fertilizers [6].

A biofertilizer is generally characterized by the presence of living microorganisms, which when applied to the soil, colonize the rhizosphere, plant roots, and seed surfaces to promote growth and improve uptake of key nutrients needed by the plant. Biofertilizers usually feature microorganisms in their composition, such as fungi, bacteria, cyanobacteria and algae or even their metabolites that are capable of improving soil fertility, plant growth, flowering and yields. Biofertilizers can include nitrogen-fixing symbionts such as *Rhizobium spp.* associated with legumes, non-symbiotic fixers such as *Azotobacter*, generally used in growing vegetables and industrial crops, while *Azospirillum* is usually used in cereals and in quality improvement of ornamental species. Some biofertilizers such as *Nostoc sp.* and *Anabaena sp.* also have the ability to fix atmospheric nitrogen. Some products contain mycorrhizae, fertilizers and phosphate solubilizing bacteria [7, 8]. The application of biofertilizers in plant breeding can result in numerous benefits for improving plant and soil quality and productivity, as they can enhance nutrient transfer from soil to plants, improve soil microbial biodiversity, stabilize soil aggregates, and reduce fossil fuel use [9].

The use and effect of cyanobacteria was first studied in 1950 in Japan. In the research, an improved ability by *Cyanobacteria* to fix nitrogen under flooding conditions was identified, providing improved soil fertility and increased rice growth and productivity [10].



**Figure 1** Detail of *Lobivia* plants in pots in the greenhouses of CREA-OF in Pescia

Algae possess several properties: increase soil porosity and production of adhesive substances that aggregate soil particles; presence of hormones (auxin, gibberellin), vitamins, and amino acids; ability to retain water in their gelatinous structures; increase in biomass as a result of their desiccation and decomposition; decrease soil salinity; reduce weed development; and increase in soil phosphorus as a result of excretion of organic acids [11,12,13,14]. Benefits from the use of biofertilizing algae have been reported in several cereal, vegetable, and ornamental crops [15,16,17, 18].

Based on the information found in the literature, it has been verified that the use of bio fertilizing algae can definitely improve plant quality, growth, and blooms. In this work, studies were conducted to evaluate whether the use of algae

in the cultivation of ornamental cacti in pots can improve the growth, ornamental qualities and resistance to salt stress of plants that normally grow in environmental conditions different from our latitudes.

## 2. Material and methods

### 2.1. Greenhouse experiment and growing conditions

The experiments, started in September 2020, were conducted in the greenhouses of CREA-OF in Pescia (PT), Tuscany, Italy (43°54'N 10°41'E) on *Lobivia arachnacantha*, *Lobivia aurea shaferi*, *Lobivia jojoiana* and *Lobivia grandiflora herzogli*. The plants were placed in pots ø 12 cm; 30 plants per thesis, divided into 3 replicas of 10 plants each. Plants in the control thesis, were fertilized with a controlled release fertilizer (3 kg m<sup>-3</sup> Osmocote Pro®, 9-12 months with 190 g/kg N, 39 g/kg P, 83 g/kg K) mixed with the growing medium before transplanting. The experimental groups were:

- group control (CTRL) (acid peat 40% + pumice 2-4 mm 30% + non-calcareous sand 2-4 mm 30% ), irrigated with water and substrate previously fertilized;
- group control1 (CTRL1) (acid peat 40% + pumice 2-4 mm 30% + non-calcareous sand 2-4 mm 30% ), irrigated with water and substrate previously fertilized; 50 mM of NaCl once every 7 days;
- group with algae (ALG) (acid peat 35% + biochar 5% + pumice 2-4 mm 30% + non-calcareous sand 2-4 mm 30%), irrigated with water and substrate previously fertilized; dilution algae: 20 ml of product every 2 liters of water (50 ml of the dilution per plant). Treatment every 10 days;
- group with algae (ALG1) (acid peat 30% + biochar 10% + pumice 2-4 mm 30% + non-calcareous sand 2-4 mm 30%), irrigated with water and substrate previously fertilized; 50 mM of NaCl once every 7 days; dilution algae: 20 ml of product every 2 liters of water (50 ml of the dilution per plant). Treatment every 10 days.

The product ALGATRON used in the experimentation is a natural specialty obtained from the brown seaweed *Macrocystis Integrifolia*. The exclusive production process allows to keep intact all the natural biologically active substances such as carbohydrates, vitamins, essential amino acids, polyphenols. ALGATRON, thanks to the natural substances of which it is composed, in the tests carried out can positively influence the germination and the development of roots, intensifying the natural defenses against biological stresses (frost, drought, nutritional imbalances, etc..) and physiological, also promoting the growth and ripening of fruits and vegetables (Table1).

The plants were watered 1 time per day, 3 days a week and grown for 12 months. The plants were irrigated with drip irrigation. The irrigation was activated by a timer whose program was adjusted weekly according to climatic conditions and the fraction of leaching. On July 28, 2021, plant height and circumference, suckers' number, number and length of thorns, vegetative weight, root weight, number of flowers, flowers life, plants dead from salinity stress, substrate microbial count, pH were analyzed.

### 2.2. Statistics

The experiment was carried out in a randomized complete block design. Collected data were analysed by one-way ANOVA, using GLM univariate procedure, to assess significant ( $P \leq 0.05$ , 0.01 and 0.001) differences among treatments. Mean values were then separated by LSD multiple-range test ( $P = 0.05$ ). Statistics and graphics were supported by the programs Costat (version 6.451) and Excel (Office 2010).

**Table 1** Characteristics of the Algatron product used in the test

Parameter	Value
Organic nitrogen	0.2 %
Organic carbon of biological origin	0.7 %
Organic carbon of biological origin pH (10% w/v in water)	4.5 %

## 3. Results

The test showed a significant increase in agronomic and quality parameters analyzed in plants treated with algae extracts on *Lobivia arachnacantha*, *Lobivia aurea shaferi*, *Lobivia jojoiana* and *Lobivia grandiflora herzogli*. In fact, the

trial showed in agronomic terms an increase in plant height and circumference, number of new suckers, vegetative and roots growth, number and length of thorns and flowers number. In qualitative terms, these treated with algae extracts have shown a significant increase in the flowers life and greater resistance to salt stress. The trial also showed an increase in the microorganism's number in the theses treated with algae and a lowering of the pH in the substrate.

In detail in (Table 2) on *Lobivia arachnacantha*, it is shown that treatment (ALG) significantly improved plant height with 7.68 cm, compared to (ALG1) and (CTRL) with 6.12 cm and 6.03 cm respectively and to (CTRL1) with 5.19 cm (Figure 2).

The use of algae extracts added to the growing medium significantly increased plant girth, in fact, the best treatment was (ALG) with 13.06 cm, followed by (CTRL) with 10.86 cm, (ALG1) with 10.34 cm, and (CTRL1) with 9.04 cm. It also shows an increase in the number of new suckers in (ALG) 6.61, compared to 4.42 in (ALG1), 3.40 in (CTRL) and 2.42 in (CTRL1). It also shows an increase in vegetative weight 28.65 g (ALG), 24.11 g (CTRL), 23.22 g (ALG1), 20.89 g (CTRL1). Root weight also increased with the use of algae extracts, in fact thesis (ALG) showed a weight of 23.55 g, followed by (CTRL) with 18.80 g, (ALG1) with 18.64 g, and (CTRL1) with 16.30 g. The number of spines significantly increased in the (ALG) thesis with 72.40, compared to 56.21 and 54.62 in (ALG1) and (CTRL) respectively and 47.61 in (CTRL1). Plug length also increased in the (ALG) thesis with 4.28 mm, compared with 3.31 mm in the (CTRL) control, 2.96 mm in (ALG1), and 2.66 in (CTRL1). There was also an increase in the number of flowers in the (ALG) thesis with 6.41, compared to 3.62 in (CTRL), 2.62 in (ALG1) and 1.43 in (CTRL1).

In (Table 3) we show how the use of algae extracts can influence the flower life in treated plants, in fact in (ALG) flower life was 35.00 hours, in (CTRL) 24.60 hours, in (ALG1) 24.00 hours and in (CTRL1) 20.00 hours. The application of algae in the cultivation substrate of *Lobivia arachnacantha* resulted in an increase in the number of microorganisms, in fact it increased from  $2.7 \times 10^2$  cfu/g (ALG), to  $2.3 \times 10^2$  cfu/g in (CTRL and ALG1) and  $2.1 \times 10^2$  cfu/g in (CTRL1). No significant pH differences were evident in the growing medium of this plant.

In (Table 4) on *Lobivia aurea shaferi* it is shown that treatment (ALG) significantly affected plant height with 5.82 cm, followed by (ALG1) and (CTRL) with 4.26 cm and 4.21 cm respectively and 3.62 cm of (CTRL1). Algae extract also resulted in a significant increase in plant circumference in thesis (ALG) with 6.47 cm, followed by (CTRL) with 5.63 cm, (ALG1) with 5.26 cm and (CTRL1) with 4.09 cm. There is also a significant increase in the number of new suckers in (ALG) 3.61, compared to (ALG1) with 1.40, (CTRL) with 0.80 and (CTRL1) with 0.60. The test also showed an increase in vegetative weight in (ALG) with 20.76 g, compared to (CTRL) with 18.10 g, (ALG1) with 17.99 g, and (CTRL1) with 15.90 g (Figure 3). In terms of root weight, the (ALG) treatment was also the best with 17.15 g, followed by (CTRL) and (ALG1) with 14.84 g and 14.58 g, respectively, finally (CTRL1) with 12.83 g. Same trend in the number of spines, where (ALG) was the best treatment with 49.80, followed by (CTRL) and (ALG1) with 43.00, finally (CTRL1) with 38.61. In terms of spines length and number of flowers, the (ALG) thesis was also the best with 3.44 cm and 6.40 respectively.

In (Table 5) on *Lobivia aurea shaferi*, the (ALG) treatment prolonged flower life with 37.00 hours, compared to 28.20 hours and 28.00 hours of (CTRL) and (ALG1) respectively. In addition, the (ALG) treatment significantly reduced plant mortality following salt stress, 0.00 plants compared to 0.40 of (CTRL) and (ALG1) and 2.61 (CTRL1). There is also a significant increase in the number of microorganisms in the substrate treated with (ALG)  $2.8 \times 10^2$  compared to the other experimental theses. There is a slight lowering of pH in the theses treated with algae extracts compared to the control theses.

In (Table 6) on *Lobivia jojoiana*, it is shown that treatment (ALG) significantly affected plant height with 7.42 cm, followed by (ALG1) and (CTRL) with 6.06 cm and 5.93 cm respectively and 5.06 cm of (CTRL1). Algae extract also resulted in a significant increase in plant circumference in thesis (ALG) with 12.98 cm, followed by (CTRL) with 10.79 cm, (ALG1) with 10.21 cm and (CTRL1) with 8.60 cm. There was also a significant increase in the number of new suckers in (ALG) 5.40, compared to (CTRL), (ALG1) and (CTRL1) with 2.00 and 1.60 respectively. The trial also showed an increase in vegetative weight in (ALG) with 28.78 g, compared to (CTRL) with 24.63 g, (ALG1) with 23.05 g and (CTRL1) with 20.09 g (Figure 4). In terms of roots weight, the (ALG) treatment was also the best with 22.89 g, followed by (CTRL) and (ALG1) with 18.31 g and 17.70 g, respectively, and finally (CTRL1) with 16.77 g. Same trend regarding the number of thornes, where (ALG) was the best treatment with 68.20, followed by (CTRL) with 47.00 and (ALG1) with 40.12, finally (CTRL1) with 36.21. Also with regard to the thornes lenght and flowers number, the (ALG) thesis was the best with 4.00 cm and 4.80 respectively.

In (Table 7) on *Lobivia jojoiana*, the (ALG) treatment prolonged flowers life with 33.80 hours, compared to 23.41 hours and 20.44 hours of (CTRL) and (ALG1) respectively and 18.38 hours of (CTRL1). In addition, the (ALG) and (ALG1) treatment reduced, but not significantly, plant mortality following salt stress compared to (CTRL) and (CTRL1). There

was also a significant increase in the number of microorganisms in the substrate treated with (ALG),  $2.6 \times 10^2$  compared to the other experimental theses. It showed also in this experiment a slight lowering of the pH in the theses treated with algae extracts compared to the control theses.

In (Table 8) on *Lobivia grandiflora herzogli*, it was noted that treatment (ALG) significantly affected plant height with 6.99 cm, followed by (ALG1) and (CTRL) with 5.83 cm and 5.82 cm respectively and 4.86 cm of (CTRL1). The application of algae to the growing medium also resulted in a significant increase in plant circumference in thesis (ALG) with 13.46 cm, followed by (CTRL) with 11.09 cm, (ALG1) with 10.65 cm and (CTRL1) with 8.50cm. There was also a significant increase in the number of new suckers in (ALG) 4.21, compared to (CTRL), (ALG1) and (CTRL1) with 2.22, 1.61 and 1.23 respectively. The trial also showed an increase in vegetative weight in (ALG) with 25.44 g, compared to (CTRL) with 22.68 g, (ALG1) with 21.90 g, and (CTRL1) with 19.68 g (Figure 5). In terms of roots weight, the (ALG) treatment was also the best with 22.09 g, followed by (ALG1) and (CTRL) with 16.83 g and 16.31 g, respectively, and finally (CTRL1) with 15.51 g. Same trend regarding the number of thornes, where (ALG) was the best treatment with 68.41, followed by (ALG1) with 54.42 and (CTRL) with 52.00, and finally (CTRL1) with 45.81. Also, in terms of thornes length and flowers number, the (ALG) thesis was the best with 4.14 cm and 6.00 flowers, respectively.

**Table 2** Evaluation of algae extracts on agronomic characters of *Lobivia arachnacantha*

Groups	PH (cm)	PC (cm)	SN (n°)	VW (g)	RW (g)	NT (n°)	LT (mm)	NF (n°)
CTRL	6,03 b	10,86 b	3,40 c	24,11 b	18,80 b	54,62 b	3,31 b	3,62 b
CTRL1	5,19 c	9,04 d	2,42 d	20,89 d	16,30 c	47,61 c	2,66 d	1,43 d
ALG	7,68 a	13,06 a	6,61 a	28,65 a	23,55 a	72,40 a	4,28 a	6,41 a
ALG1	6,12 b	10,34 c	4,42 b	23,22 c	18,64 b	56,21 b	2,96 c	2,62 c
ANOVA	***	***	***	***	***	***	***	***

One-way ANOVA; n.s. – non significant; \*,\*\*,\*\*\* – significant at  $P \leq 0.05$ , 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test ( $P = 0.05$ ). Legend: (CTRL): control; (CTRL1): control + 50 mM NaCl; (ALG): Algatron; (ALG1): Algatron + 50 mM NaCl; PH: plant height; PC: plant circumference; SN: suckers number; VW: vegetative weight; RW: roots weight; NT: thornes number; LT: thornes length; NF: flowers number

**Table 3** Evaluation of algae extracts on quality characters of *Lobivia arachnacantha*

Groups	FL (hours)	PS (n°)	MC (cfu/g)	pH
CTRL	24,60 b	0,40 c	$2,3 \times 10^2$ b	6,6
CTRL1	20,00 c	3,20 a	$2,1 \times 10^2$ c	6,3
ALG	35,00 a	0,00 c	$2,7 \times 10^2$ a	6,4
ALG1	24,00 bc	1,20 b	$2,3 \times 10^2$ b	6,6
ANOVA	***	***	***	-

One-way ANOVA; n.s. – non significant; \*,\*\*,\*\*\* – significant at  $P \leq 0.05$ , 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test ( $P = 0.05$ ). Legend: (CTRL): control; (CTRL1): control + 50 mM NaCl; (ALG): Algatron; (ALG1): Algatron + 50 mM NaCl; FL: flowers life; PS: plants dead from salinity stress; MC: microbial count; pH: measurement of soil acidity or basicity

In (Table 9) on *Lobivia grandiflora herzogli*, the (ALG) treatment prolonged flower life with 34.81 hours, compared to 22.64 hours, 21.23 hours and 17.21 hours of (CTRL), (ALG1) and (CTRL1) respectively. In addition, the (ALG) treatment significantly reduced plant mortality after salt stress compared to all other treatments. There was also a significant increase in the number of microorganisms in the substrate treated with (ALG),  $2.7 \times 10^2$  compared to the other experimental theses, as already found on the other types of *Lobivia*. Also in this experiment there was a slight lowering of pH in the theses treated with algae extracts compared to the control theses.

**Table 4** Evaluation of algae extracts on agronomic characters of *Lobivia aurea shaferi*

Groups	PH (cm)	PC (cm)	SN (n°)	VW (g)	RW (g)	NT (n°)	LT (cm)	NF (n°)
CTRL	4,21 b	5,63 b	0,80 b	18,10 b	14,84 b	43,00 b	2,52 b	2,81 b
CTRL1	3,62 c	4,09 d	0,60 b	15,90 c	12,83 c	38,61 c	2,34 b	0,42 d
ALG	5,82 a	6,47 a	3,61 a	20,76 a	17,15 a	49,80 a	3,44 a	6,40 a
ALG1	4,26 b	5,26 c	1,40 b	17,99 b	14,58 b	43,00 b	2,52 b	1,64 c
ANOVA	***	***	***	***	***	***	***	***

One-way ANOVA; n.s. – non significant; \*, \*\*, \*\*\* – significant at  $P \leq 0.05$ , 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test ( $P = 0.05$ ). Legend: (CTRL): control; (CTRL1): control + 50 mM NaCl; (ALG): Algaltron; (ALG1): Algaltron + 50 mM NaCl; PH: plant height; PC: plant circumference; SN: suckers number; VW: vegetative weight; RW: roots weight; NT: thornes number; LT: thornes length; NF: flowers number

**Table 5** Evaluation of algae extracts on quality characters of *Lobivia aurea shaferi*

Groups	FL (hours)	PS (n°)	MC (cfu/g)	pH
CTRL	28,20 b	0,40 b	$2,1 \times 10^2$ b	6,6
CTRL1	20,20 c	2,61 a	$1,7 \times 10^2$ c	6,0
ALG	37,00 a	0,00 b	$2,8 \times 10^2$ a	5,8
ALG1	28,00 b	0,40 b	$1,9 \times 10^2$ b	5,9
ANOVA	***	***	***	-

One-way ANOVA; n.s. – non significant; \*, \*\*, \*\*\* – significant at  $P \leq 0.05$ , 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test ( $P = 0.05$ ). Legend: (CTRL): control; (CTRL1): control + 50 mM NaCl; (ALG): Algaltron; (ALG1): Algaltron + 50 mM NaCl; FL: flowers life; PS: plants dead from salinity stress; MC: microbial count; pH: measurement of soil acidity or basicity

**Table 6** Evaluation of algae extracts on agronomic characters of *Lobivia jojoiana*

Groups	PH (cm)	PC (cm)	SN (n°)	VW (g)	RW (g)	NT (n°)	LT (cm)	NF (n°)
CTRL	5,93 b	10,79 b	2,00 b	24,63 b	18,31 b	47,00 b	2,68 b	2,61 b
CTRL1	5,06 c	8,60 d	1,60 b	20,09 d	16,77 c	36,21 d	1,84 d	0,62 c
ALG	7,42 a	12,98 a	5,40 a	28,78 a	22,89 a	68,20 a	4,00 a	4,80 a
ALG1	6,06 b	10,21 c	1,60 b	23,05 c	17,70 b	40,12 c	2,26 c	1,42 c
ANOVA	***	***	***	***	***	***	***	***

One-way ANOVA; n.s. – non significant; \*, \*\*, \*\*\* – significant at  $P \leq 0.05$ , 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test ( $P = 0.05$ ). Legend: (CTRL): control; (CTRL1): control + 50 mM NaCl; (ALG): Algaltron; (ALG1): Algaltron + 50 mM NaCl; PH: plant height; PC: plant circumference; SN: suckers number; VW: vegetative weight; RW: roots weight; NT: thornes number; LT: thornes length; NF: flowers number

**Table 7** Evaluation of algae extracts on quality characters of *Lobivia jojoiana*

Groups	FL (hours)	PS (n°)	MC (cfu/g)	pH
CTRL	23,41 b	1,10 ab	2,3 x 10 <sup>2</sup> b	6,2
CTRL1	18,38 c	2,00 a	2,0 x 10 <sup>2</sup> c	6,1
ALG	33,80 a	0,42 b	2,6 x 10 <sup>2</sup> a	5,8
ALG1	20,44 bc	0,61 b	2,1 x 10 <sup>2</sup> c	5,9
ANOVA	***	*	***	-

One-way ANOVA; n.s. – non significant; \*, \*\*, \*\*\* – significant at  $P \leq 0.05$ , 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test ( $P = 0.05$ ). Legend: (CTRL): control; (CTRL1): control + 50 mM NaCl; (ALG): Algatron; (ALG1): Algatron + 50 mM NaCl; FL: flowers life; PS: plants dead from salinity stress; MC: microbial count; pH: measurement of soil acidity or basicity

**Table 8** Evaluation of algae extracts on agronomic characters of *Lobivia grandiflora herzogii*

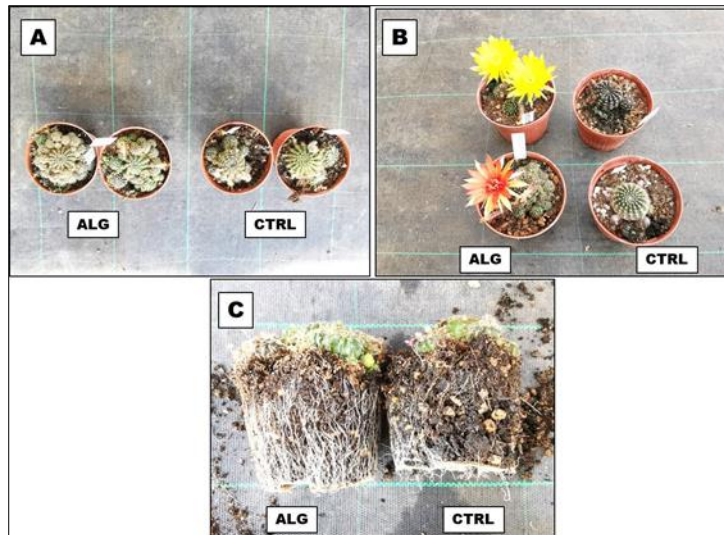
Groups	PH (cm)	PC (cm)	SN (n°)	VW (g)	RW (g)	NT (n°)	LT (cm)	NF (n°)
CTRL	5,82 b	11,09 b	2,22 b	22,68 b	16,38 b	52,00 b	3,14 b	3,00 b
CTRL1	4,86 c	8,50 c	1,23 c	19,68 c	15,51 b	45,81 c	2,34 d	1,00 c
ALG	6,99 a	13,46 a	4,21 a	25,44 a	22,09 a	69,41 a	4,14 a	6,00 a
ALG1	5,83 b	10,65 b	1,61 bc	21,90 b	16,83 b	54,42 b	2,76 c	2,20 b
ANOVA	***	***	***	***	***	***	***	***

One-way ANOVA; n.s. – non significant; \*, \*\*, \*\*\* – significant at  $P \leq 0.05$ , 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test ( $P = 0.05$ ). Legend: (CTRL): control; (CTRL1): control + 50 mM NaCl; (ALG): Algatron; (ALG1): Algatron + 50 mM NaCl; PH: plant height; PC: plant circumference; SN: suckers number; VW: vegetative weight; RW: roots weight; NT: thornes number; LT: thornes length; NF: flowers number

**Table 9** Evaluation of algae extracts on quality characters of *Lobivia grandiflora herzogii*

Groups	FL (hours)	PS (n°)	MC (cfu/g)	pH
CTRL	22,64 b	1,00 bc	2,3 x 10 <sup>2</sup> b	6,5
CTRL1	17,21 b	3,42 a	1,9 x 10 <sup>2</sup> d	6,4
ALG	34,81 a	0,23 c	2,7 x 10 <sup>2</sup> a	6,1
ALG1	21,23 b	1,22 b	2,1 x 10 <sup>2</sup> c	6,2
ANOVA	***	***	***	-

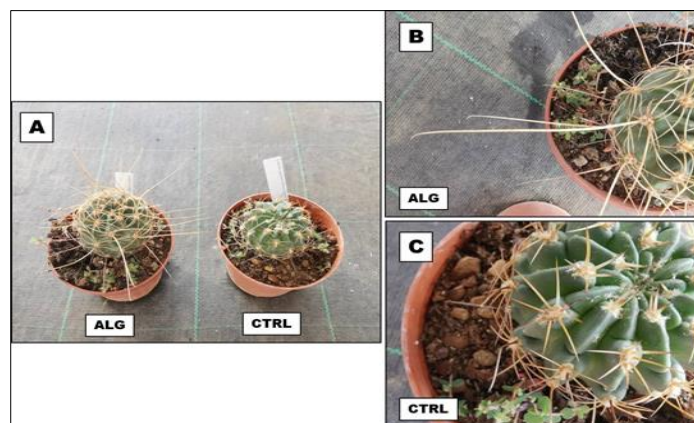
One-way ANOVA; n.s. – non significant; \*, \*\*, \*\*\* – significant at  $P \leq 0.05$ , 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test ( $P = 0.05$ ). Legend: (CTRL): control; (CTRL1): control + 50 mM NaCl; (ALG): Algatron; (ALG1): Algatron + 50 mM NaCl; FL: flowers life; PS: plants dead from salinity stress; MC: microbial count; pH: measurement of soil acidity or basicity



**Figure 2** Effect of algae extracts on vegetative biomass and flowering (A-B) and roots biomass (C) of *Lobivia arachnacantha*. Legend: (CTRL) control; (ALG) algalatron

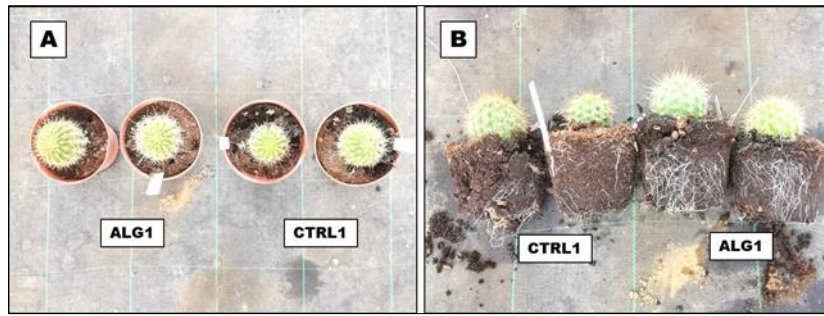


**Figure 3** Effect of algae extracts on vegetative biomass *Lobivia aurea shaferi* Legend: (CTRL) control; (ALG) algalatron



**Figure 4** Effect of algae extracts on vegetative biomass (A) and on the thorns length (BC) of *Lobivia jojoiana* Legend: (CTRL) control; (ALG) algalatron





**Figure 5** Effect of algae extracts on vegetative biomass (A) and roots biomass (B) of *Lobivia grandiflora herzogli* in saline soil conditions. Legend: (CTRL1) control + 50 mM of NaCl once every 7 days; (ALG1) algatron + 50 mM of NaCl once every 7 days

#### 4. Discussion

*Cyanobacteria* have multiple capabilities and can be used as biofertilizers, as renewable fuel sources, in bioremediation for the degradation of various metal pollutants, in saline and pesticide-affected soils [19]. A fundamental role played by cyanobacteria is the ability to improve soil fertility with consequent effects on plant growth and production. Aspects found in several experiments on ornamental and vegetable plants and in this test on cactus plants of the genus *Lobivia* [16,18]. The improvements found in the cultivation of plants and more specifically of cacti in pots are related to the ability of algae to excrete substances that promote the production of phytohormones such as (auxins and gibberellins), vitamins and amino acids [11]; the ability to retain water due to their gelatinous structure that can increase the availability of water and minerals for plants in times of stress [12]; increased biomass in the soil as a result of their decomposition with an increase in mineral sources that can be absorbed by the roots; possible decrease in soil salinity, in fact in this experiment the addition of algae to the substrate irrigated with saline water resulted in an average growth comparable to that of the control without saline water. The control treatment with saline water, on the other hand, proved to be the worst in the experiment [13,14,15]. Apte and Thomas [20] highlighted the possibility of improving moderately saline soils following the application of the halotolerant *Cyanobacterium Anabaena torulosa*. In the laboratory, it was found that algalization can result in a reduction in pH, electrical conductivity, and exchangeable Na.

*Cyanobacteria* also proved to be useful in preventing weed development and resulted in increased phosphates in the soil. Application of algae to growing media can result in decreased soil pH, hydraulic conductivity, and soil aggregation as found by Subhashini and Kaushik and also evidenced in this experiment [21]. *Cyanobacteria* are capable of releasing trace elements into the soil and solubilizing and chelating mineral elements such as Fe, Mn, Cu, Mo, and Zn. The gelatinous sheaths of *Cyanobacteria* are able to reduce particle erosion and adsorb cations [22].

Some research has addressed the effect of algal biofertilizer on soil microflora. Rao and Burns [23] reported an eight-fold increase in bacterial members in columns inoculated with BGA, while the increase in fungal population was not significant. In this experiment on *Lobivia*, there was an increase in the number of microorganisms in these treated with algae with significant effects found on plant development and flower and thorn production. The results therefore suggest the presence of additional sources of carbon and energy in particular the presence of nitrogen and phosphorus that ensure the increase of microbial populations and influence their behaviour [16]. The changes found in soils following the application of algal biofertilizers thus improve the chemical properties of salt-affected soils and enhance crop vigor and yield [18].

#### 5. Conclusion

This research paper highlights the potential of biofertilizer technology in terms of cost, environmental sustainability, and saline soil improvement. The secretion of exopolysaccharides and bioactive substances by algae and cyanobacteria has demonstrated its role in recovering soil nutrients and mobilization of insoluble forms of inorganic phosphates.

The experimentation carried out at CREA-OF of Pescia has demonstrated how the application of algae extracts to the cultivation substrate of *Lobivia arachnacantha*, *Lobivia aurea shaferi*, *Lobivia jojoiana* and *Lobivia grandiflora herzogli* can significantly improve plant growth and quality and resistance to abiotic stresses, in particular saline stress.

As in other experiments in the literature, the application of algae not only resulted in significant effects on plant growth but also influenced the development of microbial communities in the soil. This effect was likely mediated by the presence of carbon and mineral sources in the algae that not only directly stimulate plant growth, but also directly interact with the microbial communities.

Interesting results were also the increase in the number of spines, flowers and flower duration, and production of new suckers in plants grown with algae. Other investigations are currently underway to study the biostimulant capacities of different algal types and the influence they can have on different species of fruit cacti and edible succulents and on the microbial communities present in soils.

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## Compliance with ethical standards

### *Acknowledgments*

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### *Disclosure of conflict of interest*

The author declares no conflict of interest.

### *Statement of ethical approval*

The present research work does not contain any studies performed on animals/humans subjects.

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