*Advances in Research*

*20(6): 1-7, 2019; Article no.AIR.54298*
*ISSN: 2348-0394, NLM ID: 101666096*

# Behaviour of *Salicornia neei* Cultivated in Different Spacing and Irrigated with Desalinizer Tailings

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author CFVF performed the experiment as a master's thesis, performed the statistical analysis and wrote the first draft of the manuscript. Authors JGF and EWFG managed the analysis of the study. Author ASM designed the study and wrote the Protocol. All authors have read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/AIR/2019/v20i630174
Editor(s):
(1) Dr. Paola Deligios, Department of Agriculture, University of Sassari, Italy.
Reviewers:
(1) Manuel Cezar Macedo Barbosa Nogueira de Souza, Universidade Federal do Rio Grande, Brazil.
(2) Jackson Akpojaro, University of Africa, Nigeria.
(3) Benjawan Chutichudet, Mahasarakham University, Thailand.
Complete Peer review History: http://www.sdiarticle4.com/review-history/54298

***Original Research Article***

***Received 01 December 2019***
***Accepted 03 February 2020***
***Published 10 February 2020***

## ABSTRACT

The objective of this work was to evaluate the influence of line and row spacing on biomass yield and minerals absorbed by *Salicornia neei* irrigated with desalination reject. The experiment was conducted in beds at the headquarters of the Agronomic Institute of Pernambuco-IPA, Recife, Pernambuco, Brazil. The experimental design was randomized blocks with treatments consisting of six spacings between plants and rows: 5x5, 10x10, 15x15, 20x20, 30x30 and 40x40 cm, with three repetitions and 30 *Salicornia neei* plants per repetition. After six months, the aerial part of the plant was collected and analyzed bromatologically. It was statistically noticed that the 15x15 cm spacing between plants favored where most bromatological determinations: dry matter weight - DMW (9,353.0 kg/ha); total nitrogen - NT (3.09%); total protein - PT (19.31%); acid detergent fiber - ADF (30.50%); neutral detergent fiber - NDF (38.15%); total fiber - FT (26.71%) and ethereal extract - EE (1.91%). Regarding the phytoextraction by *Salicornia neei*, the most efficient spacing were: 20x20 cm for sodium - Na (15.5%); 30x30 cm for potassium - K (3.00%) and 40x40 cm for calcium - Ca (4.18%) and magnesium - Mg (3.90%), showing the potential use of *Salicornia neei* in soils affected by salts.

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*Keywords: Halophyte; saline water; plant growth; Amaranthaceae.*

## 1. INTRODUCTION

Salinity is a major problem in Pernambuco semiarid region. In view of this, producers are obliged to use waters with high salt concentrations for irrigation and food production [1]. Therefore, salinity tolerant halophyte plants, even beyond seawater concentrations, can bring a great deal of benefit to communities: controlling salinity and improving saline land.

Moreover, there is no competition for land or water use between lucrative conventional attitudes and high salt tolerant plants [2,3]. Among these species is *Salicornia,* which has broad development in saline areas associated with shorelines, tidal floodplains and salty lakes. They are distributed worldwide and found on all continents except Antarctica [4,5].

*Salicornia neei* halophyte is a native South American species and was formerly called *Salicornia gaudichaudiana* Moq. and *Sarcocornia ambigua* (Michx.) M.A. Alonso & M.B. Crespo. It is a coastal halophyte that grows in soils with high interstitial salinity (16 to 55 dS / m) [6,7,8].

This halophyte belongs to the class *Equisetopsida*, subclass *Magnoliidae*, order *Caryophyllales*, family *Amaranthaceae*, genus *Salicornia* and species *Salicornia neei* [9].

*Salicornia neei* is an example of halophyte used for phytoremediation of saline reject / effluents, production of plant biomass for different purposes and restoration of coastal environments. The *Salicornia neei* species has aroused great interest in recent years [10], hence the proposal of this experiment to verify its behaviour in different cultivation spacing.

## 2. MATERIALS AND METHODS

### 2.1 Seedling Production

The vegetative propagation of *Salicornia neei* was performed on a black sombrite screen with partial retention (50%) of sunlight, located at the headquarters of the Agronomic Institute of Pernambuco (IPA), in Recife, Pernambuco. The 10 cm-long stem fragments (cuttings) with preserved nodes and bevelled bottom were removed from the parent plants. These cuttings were placed in polystyrene sowing trays with 128 cells with saline soil, and maintained for 15 days for rooting. Throughout the period, the plants were irrigated with water and sprayed with acclimatization tailings every three days.

### 2.2 Planting and Experimental Design

The seedlings of *Salicornia neei* were planted in the cultivation beds (720 cm x 90 cm) according to Fig. 1, at the headquarters of the Agronomic Institute of Pernambuco (IPA), with soil from its São Bento do Una Experimental Station, with the following attributes: sandy texture, soil density = 1.34 g/cm$^3$, pH = 7.60, P = 209 mg/dm$^3$ and Ca, Mg, Na and K = 33.60, 6.00, 12.00 and 0.70 cmolc/dm$^3$ respectively. According to Köeppen's classification, the region has an As' climate (Tropical Humid).

*Salicornia neei* beds were irrigated with waste from the desalinator located in Riacho das Almas, Pernambuco, with the following characteristics: Electrical conductivity = 11.54 mS/cm at 25ºC, Ca = 403 mg/l, Mg = 393.09 mg/l, Na = 200 mg/l and K = 40 mg/l, Sodium Adsorption Ratio (SAR) = 23.67, pH = 7.9, Irrigation rating = C4S4 (Very high salinity water and high sodium concentration).

The experimental design was in randomized blocks with three repetitions, whose treatments consisted of different planting spacings (5x5, 10x10, 15x15, 20x20, 30x30 and 40x40cm between plants and rows) with 30 *Salicornia neei* seedlings and daily irrigation with 10 liters of desalinator tailings per repetition. After one week of planting, the seedlings that did not adapt (only 10) were replaced by other equivalents and the experiment was maintained daily until collection.

### 2.3 Collection and Laboratory Tests

After six months of experiment, the aerial parts of *Salicornia neei* were collected, separated at a height of 5 cm from the soil surface and washed with deionized water. To evaluate the yield of fresh matter, green matter weight (GMW) on the day of collection was determined. Then, all the material was placed in paper bags, dried in air circulating oven at 60ºC for 72 hours to determine the yield of dry matter (DMW).

Immediately after drying, the aerial part was ground in a Wiley mill with a 42 mm aperture screen to determine the contents of the absorbed elements (K, Na, Ca and Mg) by

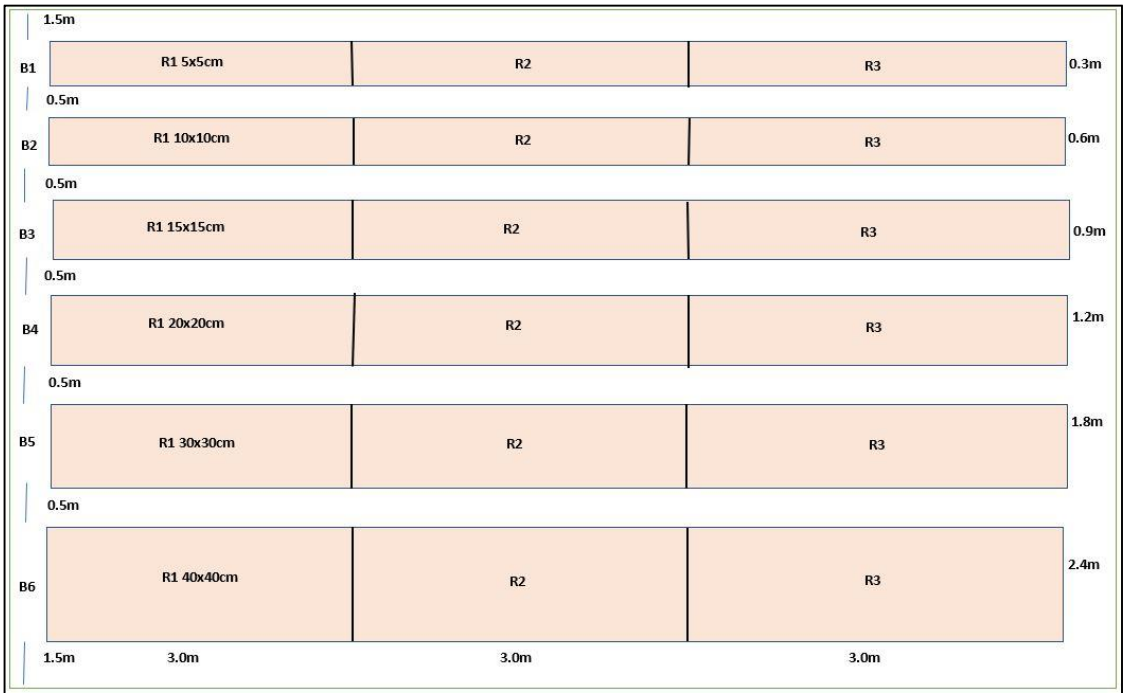


**Fig. 1. Sketch of the planting sites of *Salicornia neei* depending on the spacings**

nitroperchloric digestion [11] and total nitrogen by micro Kjedahl method, in addition to mineral matter, total protein, acid detergent fiber, neutral detergent fiber, non-nitrogen extract, total fiber and ethereal extract, according to Official Methods of Analysis [12].

## 2.4 Statistical Analysis

The data obtained were evaluated by analysis of variance (ANOVA) and means compared by Tukey test at 5% probability, using the GLM (General Linear Model) procedure and regression analysis using SAS® 2002 [13].

## 3. RESULTS AND DISCUSSION

The results of bromatological analysis and production of *Salicornia neei* are shown in Table 1, showing significant difference ($P < 0.05$) due to plant spacing.

It can be seen from Table 1 and Fig. 2 that the Green Matter Weight (GMW) presented a quadratic regressive effect, with its peak in the 10x10 cm (46,816.0 kg / ha) spacing with $R^2$ of 0.6329 and the lowest average in the 40x40 cm spacing (11,638.3 kg / ha). Therefore, a reduction of 75% in GMW is observed as the spacing between plants increased.

Alves [14] in a field experiment with plant spacing of 40x40 cm in cultivation of saline effluent irrigated *Sarcocornia ambigua* found a fresh biomass yield after 24 weeks of 12,540.0 kg/ha, similar to the lowest value found in this experiment (11,638.3 kg/ha), in the same spacing.

On the other hand, Dry Matter Weight (DMW), according to Table 1 and Fig. 3, presented quadratic regressive effect in the 5x5 cm (9,356.0 kg / ha), 10x10 cm (9,400.0 kg / ha) and 15x15 cm (9,353.0 kg / ha) spacing with $R^2$ of 0.8963 and the lowest averages were presented in the 30x30 cm (5,731.0 kg / ha) and 40x40 cm (5,412.0 kg / ha) spacing. Thus, there was a 42% reduction in DMW as plant spacing increased.

These results for Green Matter Weight and Dry Matter Weight may have been due to the intraspecific competition for water, light and nutrients among plants, established by the management of spacing / population density.

Debez et al. [15] in cultivation of the halophyte *Batis maritime* had yield of 17 t / ha of dry mass. These results are inferior to the dry mass productivity obtained in this research.

According to Priesnitz et al. [16], working with pearl millet (*Pennisetum glaucum*) biomass productivity, they observed that biomass production decreased due to the increase in line spacing. The spacing of 20 cm between lines showed, on average, the highest production of green mass and dry mass in the pasty grain stage, with 50.84 t/ ha and 17.60 t/ ha, respectively. There was significant interaction between cultivar and spacing factors for dry matter production at physiological maturation.

Table 1 and Fig. 4 show the results of Mineral Matter (MM), Total Protein (PT), Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), Total Fiber (FT) and Ethereal Extract (EE).

It is noticed that the values for MM presented superior quadratic regressive effect in the 20x20 cm (37.61%) and 30x30 cm (36.29%) spacings and lower in the 10x10 cm (18.33%) spacing. For PT the quadratic regressive effect presented the highest value in the 15x15 cm spacing (19.31%) and the lowest value in the 20x20 cm spacing (13.05%). The ADF presented quadratic regressive effect whose best results were in the 5x5 cm (29.40%) and 15x15 cm (30.50%) spacing and the least favourable result in the 20x20 cm (13.24%) spacing. For NDF the 15x15 cm spacing (38.50%) was the best and the 20x20 cm spacing (19.20%) was the one that presented unsatisfactory results in the quadratic regressive effect. FT presented linear regressive

**Table 1. Results of bromatological analysis (%) and production (kg/ha) of *Salicornia neei* in different crop spacing. Averages of three repetitions**

| Determination | Spacing between plants and rows, cm | | | | | |
|---|---|---|---|---|---|---|
| | **5x5** | **10x10** | **15x15** | **20x20** | **30x30** | **40x40** |
| GMW, kg/ha | 29.742,0c | 46.816,0a | 36.050,8b | 12.761,0d | 11.670,0e | 11.638,3f |
| DMW, kg/ha | 9.356,0a | 9.400,0a | 9.353,0a | 8.834,0b | 5.731,0c | 5.412,0c |
| MM, % | 21,33b | 18,33d | 21,12b | 37,61a | 36,29a | 19,14c |
| NT, % | 2,38d | 2,68b | 3,09a | 2,08e | 2,31d | 2,42c |
| PT, % | 14,87d | 16,75b | 19,31a | 13,05e | 14,48d | 15,12c |
| ADF, % | 29,40a | 27,78b | 30,50a | 13,24d | 14,12c | 14,35c |
| NDF, % | 35,16b | 36,20b | 38,15a | 19,20d | 20,35c | 21,12c |
| FT, % | 24,61b | 25,34a | 26,71a | 12,14d | 13,21c | 12,30d |
| EE, % | 1,76b | 1,81a | 1,91a | 0,95d | 0,92d | 1,02c |
| Na, % | 1,6d | 4,2c | 1,0e | 15,5a | 14,5a | 5,09b |
| K, % | 1,9c | 1,5d | 0,9f | 2,30b | 3,00a | 1,32e |
| Ca, % | 0,8c | 0,7d | 0,8c | 1,5b | 1,7b | 4,18a |
| Mg, % | 1,4c | 1,5c | 1,5c | 2,1b | 2,4b | 3,90a |

*Different letters in the line differ from each other by Tukey's test at 5% probability; Where: GMW = green matter weight; DMW = dry matter weight; MM = mineral matter; NT = total nitrogen; PT = total protein; ADF = acid detergent fiber; NDF = neutral detergent fiber; FT = total fiber; EE = ethereal extract; Na = sodium; K = potassium; Ca = calcium; Mg = magnesium; Source: Plant, Feed and Water Analysis Laboratory-LAPRA, Agronomic Institute of Pernambuco - IPA, Recife, Pernambuco, Brazil (2019)*

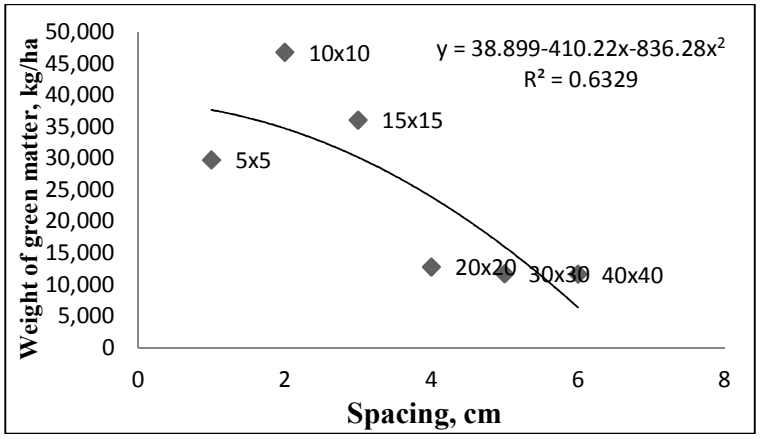


**Fig. 2. Log-normal regression between weight of green matter averages (kg/ha) of *Salicornia neei* as a function of spacing, after six months of cultivation**

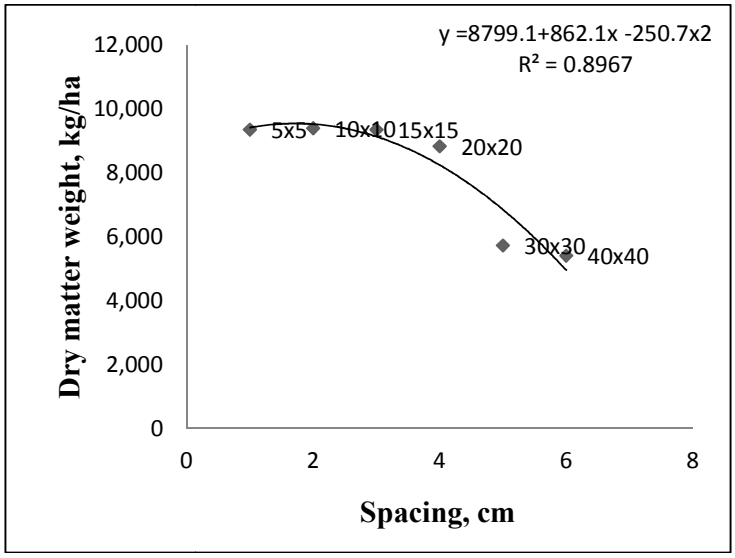


**Fig. 3. Log-normal regression between dry matter weight averages (kg/ha) of *Salicornia neei* as a function of spacing, after six months of cultivation**

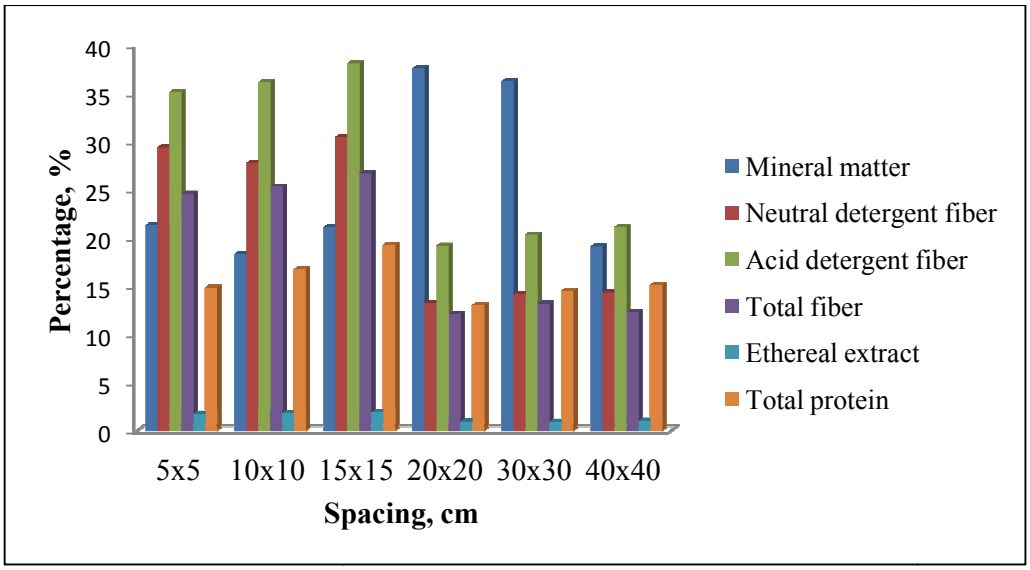


**Fig. 4. Mineral Matter (MM), Total Protein (PT), Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), Total Fiber (FT) and Extract Ethereal (EE) of *Salicornia neei* depending on spacings, after six months cultivation**

effect and the 10x10 cm (25.34%) and 15x15 cm (26.71%) spacing presented satisfactory results, and the 40x40 cm spacing (12.30) was less indicated. EE presented linear regressive effect being more efficient in the 10x10 cm (1.81%) and 15x15 cm (1.91%) spacing than in the 20x20cm (0.95) and 30x30 cm (0.92) spacing.

Barreira et al. [17] working with *Salicornia perennis alpini*, *Sarcocornia perenis perenis* and *Salicornia ramosissima* found total protein (PT) values of 8.10%, 6.90% and 5.20% respectively, and for neutral detergent fiber (NDF) 20.8%, 34.1% and 22.5%, well below those of this experiment.

Table 1 and Fig. 5 show the results of Total Nitrogen (NT), Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg).

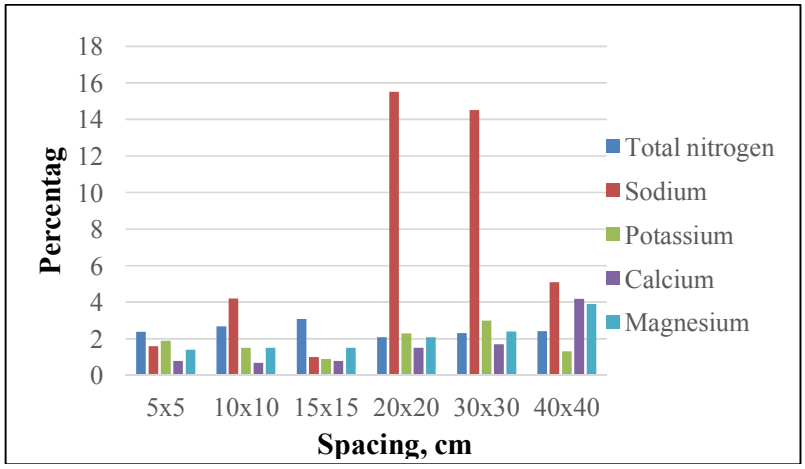


**Fig. 5. Results of Total Nitrogen (NT), Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg) of *Salicornia neei* as a function of spacings, after six months of cultivation**

NT presented the most significant value in the 15x15 cm spacing (3.09%) and the lowest value in the 20x20 cm spacing (2.08%). For Na the 20x20 cm (15.5%) and 30x30 cm (14.5%) spacing were the best results and the 15x15 spacing (1.0%) the lowest result. The 30x30 cm spacing (3.0%) presented the highest K content and the 15x15 cm spacing (0.9%) presented the lowest content. For Ca the highest value was found in the 40x40 cm spacing (4.18%) and the lowest value was in the 10x10 cm spacing (0.7%). Mg content was higher in the 40x40 cm spacing (3.90%) and lower in the 5x5 cm (1.4%), 10x10 cm (1.5%) and 15x15 cm (1.50%) spacing.

Barreira et al. [17] working with *Salicornia perennis alpini, Sarcocornia perenis perenis* and *Salicornia ramosissima* found values for Na equal to 6.43%, 6.41% and 8.99%, for K equal to 1.03%, 1.39% and 0.89%, for Ca equal to 0.26%, 0.23% and 0.49%, for Mg equal to 0.70%, 0.67% and 0.94%, respectively.

Julião [18] found Na (18.19 g / 100 g), K (1.06 g / 100 g) and Ca (0.27 g / 100 g) content in the evaluation of the potential of *Salicornia ramosissima* (halophyte) for use in fresh or powdered salads (green salt).

## 4. CONCLUSION

According to the results obtained, it can be concluded that the development and productivity of *Salicornia neei* was influenced by the cultivation spacing, where most bromatological determinations presented more efficient values in the 15x15 cm spacing: dry matter weight-DMW (9,353.0 kg/ha); total nitrogen-NT (3.09%); total protein-PT (19.31%); acid detergent fiber-ADF (30.50%); neutral detergent fiber-NDF (38.15%); total fiber-FT (26.71%) and Ethereal Extract-EE (1.91%). Regarding the phytoextraction by *Salicornia neei*, the most efficient spacing were 20x20 cm for sodium-Na (15.5%); 30x30 cm for potassium-K (3.00%) and 40x40 cm for calcium-Ca (4.18%) and magnesium -Mg (3.90%).

## ACKNOWLEDGEMENT

The authors are grateful to the Coordination of Improvement of Higher Education Personnel (CAPES) for the master's scholarship, to the Foundation for the Support of Science and Technology of the State of Pernambuco (FACEPE) for the research aid, to the Agronomic Institute of Pernambuco (IPA) for the physical space, to the Consortium Universitas for the research aid and to the Analytical Chemistry Laboratory of Catholic University of Pernambuco for the support in the experiments.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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