Article

Mineral nutrition with nitrogen, phosphorus and potassium in the production of blue barrel in greenhouse

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Abstract

In the biznaga 'blue barrel' (*Ferocactus glaucescens* (DC.) Britton and Rose) 12 treatments were evaluated considering nutrient concentrations (100, 200, 400 and 800 mg L^{-1}) of soluble fertilizers in interaction with three nitrogen levels (N), phosphorus (P) and potassium (K) (100-50-50, 100-50-100 and 50-50-100), these were compared with the nutrient solution of Steiner at 25% and 50% and two commercial controls (triple 17 and triple 20). The variables evaluated were plant height, stem diameter, fresh and dry weight of stem and root, and concentration of N, P and K. An ANOVA and Tukey's mean test ($p \leq 0.05$) were performed, indicating that the 50% Steiner nutrient solution and the solution prepared with 800 mg L^{-1} with the balance of 100-50-100 of NPK generated at 153 DDT plants with higher biomass and commercial size with stem height and diameter greater than 6 cm referring that in early stages the N:K relationship influence this process.

Keywords: cacti, nutrition, ornamental.

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Introduction

The species *Ferocactus glaucescens* (DC.) Britton and Rose. taxonomically it is located in the subfamily Cactoideae and Tribe Cacteae (Trópicos, 2017). According to Guzmán *et al*. (2003), *F. glaucescens* is an endemic plant that is distributed in the center of Mexico, being in natural conditions a species that presents solitary habits and that does not produce shoots in a natural way. This species is not mentioned in NOM-059-SEMARNAT-2010; however, it is included in CITES Appendix II (Trópicos, 2017; Cites, 2019).

Due to its rarity, morphological characteristics and beauty, these plants are considered ornamental and are used in gardening as an indoor and outdoor pot plant as referred by Guzmán *et al*. (2003); Villavicencio *et al*. (2010). In the market the production of globose semicolumnar type species, as in this case, does not exceed 5% of said volume, so there is interest in increasing the production of this type of species that has ecological and commercial importance among the producers and nurserymen with record of environmental management unit (UMA) (Granada, 2014; Villavicencio, 2015; Gámez *et al.*, 2016). In ornamental plants, fertigation has been applied in cultivars of cut flowers, foliages and pot plants produced in greenhouse or in the open sky (Cabrera, 1999). Pot plants require periodic contributions of liquid or solid fertilizers, but in cactus and succulent plants, these must be special considering that they are xerophytic plants; however, studies are scarce (Flores, 2009; Arredondo, 2016).

Trinidad and Aguilar (1999) report that in vascular plants nutrients can penetrate through the stem and roots, so a chemical analysis both leaf and root are important to assess absorption and nutrimental assimilation. In this regard there are references in, yellow pitahaya (*Cereus triangularis* L.) (Orrico, 2013), golden biznaga or golden barrel (*Echinocactus grusonii* Hildm.) (Tanaka *et al*., 1983), donkey biznaga or large barrel (*Echinocactus platyacanthus* Link & Otto) (Arredondo, 2016), *Mammillaria carmenae* and *Mammillaria plumosa* (Rodríguez, 2010) and pitahaya (*Stenocereus griseus* Haworth) (Serrano, 1996), so the objective of this research was to determine the needs of this cultivar through a nutrimental solution that promotes plant growth, profitable productivity and good product quality.

Materials and methods

The research was conducted during the spring-summer cycles (S-S) of 2017 and 2018 at the facilities of the Vegetable Tissue Cultivation Laboratory (LCTV) and greenhouse of the Saltillo Experimental Field CIRNE-INIFAP, located in the municipality of Saltillo, Coahuila, Mexico.

Vegetal material

A batch of plants of this 4-month-old species was used in 2.5” plastic pots using a mixture of sand, peat and agrolite substrate described by Villavicencio *et al*. (2013), which recorded a pH of 6.5 and electrical conductivity of 4.2 dS m^{-1}. This mixture was previously sterilized in an autoclave (Marca Sumi) at a temperature of 120 °C and 1.5 pounds of pressure.

Vegetative growth

12 treatments were evaluated by means of a randomized block design with factorial arrangement, considering as factor A four nutrient concentrations (100, 200, 400 and 800 mg L^{-1}) of soluble fertilizers and as factor B the balance of elements, considering three levels of nitrogen (N), phosphorus (P) and potassium (K) (100-50-50, 100-50-100 and 50-50-100), using as fertilizer source urea (46-00-00), phosphate monoammonium (12-61-00) and potassium nitrate (12-00-46). Two treatments were also evaluated considering Steiner's nutrient solution (Steiner, 1984), at 25% and 50% and two commercial controls (triple 17 and triple 20) which are the fertilizers used by growers in nurseries or greenhouses of ornamental cacti.

In total, seventeen treatments were evaluated in a greenhouse at a temperature of 28 °C, considering as an experimental unit 5 plants and 5 repetitions per treatment. The fertilization treatments were adjusted considering a pH of 6.5 with phosphoric acid and an electrical conductivity of 2 dS m^{-1}. These treatments were provided by a fertigation system making the application every 15 days alternating with an irrigation without fertilization, the variables were recorded from 30 and up to 153 days after transplantation (DDT), these were: height of the plant (At, cm) measured from the base of the stem to the terminal apex of the plant, with a digital vernier, equatorial and polar diameters, with which the average diameter was calculated (Dp, cm).

At the end of the evaluation (153 DDT), the weight of fresh and dry matter of the aerial part and root was determined, drying was done in an oven (Brand Felisa) for 72 h at 70 °C until constant weight in grams (g). To determine the concentration of nitrogen (N), phosphorus (P) and potassium (K), one plant of each treatment was selected, the concentration of N was determined by the Kjeldahl method, P and K were read in vegetable material digestate with sulfuric acid, perchloric acid and hydrogen peroxide in a 2:1:1 ratio (v:v:v), in an ICP-OES (Agilent, 725-AES).

Statistical analysis

The evaluated variables were statistically analyzed by means of the GLM procedure of the SAS statistical analysis system (Version 9.3), performing an analysis of variance (Anova) and a comparison test of Tukey means at a 95% probability.

Results and discussion

The results show that the growth of this species is a function of the concentration of nutrients applied in the fertigation and that this cultivar requires a specific nutritive solution to reach its commercial size. In this stage the plants of this species responded to the effect of the treatments by absorbing the ions present in the chemical composition of the nutrient solution.

Effect of nutrient concentrations

Height of the plants (At)

The results of the Anova showed highly significant differences ($p\leq$ 0.01) in the plant height between concentrations, being the concentration of the Steiner nutrient solution at 50%, the commercial control triple 20 and the concentration of 800 mg L^{-1} equal statistically. These concentrations exceeded the rest of the concentrations evaluated, with an average height (At) of 6.28 cm, which represents an increase in height of 35.5% (2.23 cm) with respect to the control (Figure 1a). The concentrations of the Steiner solution at 25%, the commercial control triple 17, 400 and 200 mg NPK L^{-1} had the same behavior registering an average height of 5.88 cm.

Average diameter (Dp)

Among the evaluated concentrations there were highly significant differences ($p\leq$ 0.01) in the average diameter from the 60 days of evaluation, being the concentration of the Steiner nutrient solution at 50% which exceeded the rest of the evaluated concentrations, registering an average in this variable of 6.45 cm, which exceeded in 1.79 cm (27.75%) the average diameter of plants of the control without fertilizing.

Commercial fertilizers used as controls (triple 17 and triple 20) together with the 25% Steiner solution and the 800 and 400 mg concentrations of NPK L^{-1} were statistically equal, registering an average diameter of 5.95 cm, which is 1.29 cm higher (21.68%), to the diameter of unfertilized plants. Concentrations of 100 and 200 mg NPK L^{-1} had the lowest effect on this variable with a mean value of 5.56 cm (Figure 1b).

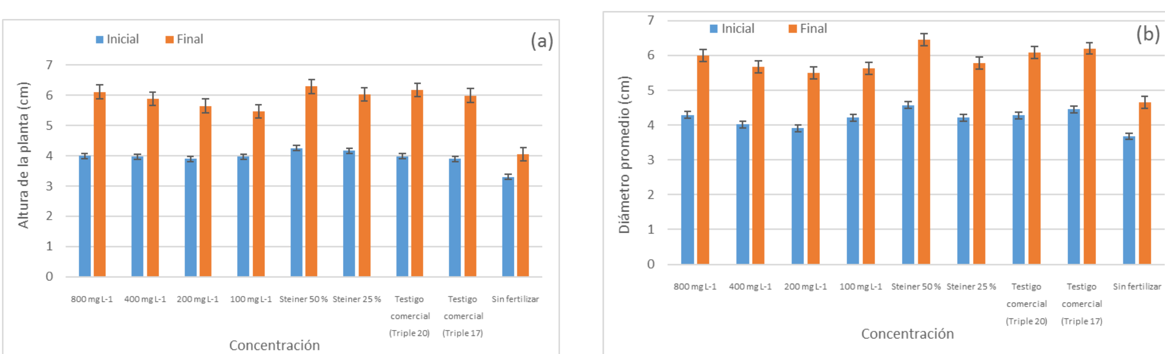

Figure 1. Concentration of nitrogen (N), phosphorus (P) and potassium (K) in fertigation at the height of plant (a) and average diameter (b) of the biznaga blue barrel (*Ferocactus glaucescens* (De Candolle). Britton and Rose, in the greenhouse.

Effect of nutritional balance

Height of the plants (At)

At the end of the evaluation (153 DDT) the results of the ANOVA showed highly significant differences ($p\leq$ 0.01), between nutrient balances in plant height. From 90 days it was observed that, the Steiner solution at 50 and 25% together with the commercial control Triple 20 were statistically equal with an average height of 6.16 cm. These nutritional balances exceeded the plant height of the unfertilized control at 2.11 cm, which represented an increase in size of 34.25% (Figure 2a).

The commercial indicator triple 17 and balances 50-50-100, 100-50-100 and 100-50-50 of NPK were equal statistically registering a height of plant of 5.82 cm, which was superior in 1.77 cm to the size of the plants with respect to the control without fertilizer, which represented an increase in size of 30.45% (Figure 2b).

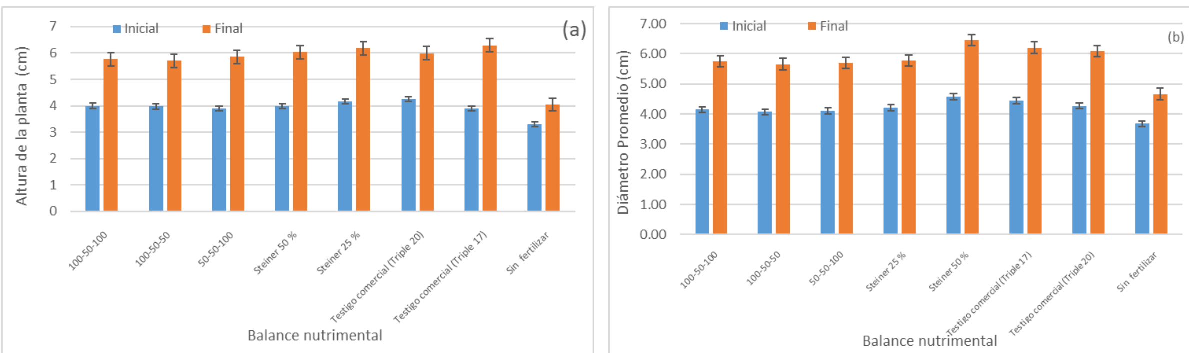

Figure 2. Nutritional balance in fertigation at plant height (a) and average diameter(b) of the biznaga blue barrel (*Ferocactus glaucescens* (DC.) Britton and Rose, in greenhouse.

Average diameter (Dp)

Plants treated with the Steiner solution at 50% exceeded in diameter the rest of the evaluated balances, registering an average value of 6.45 cm. With this nutritional balance, the diameter increased by 1.79 cm with respect to the control without fertilizer, which represented an increase of 27.75%.

The commercial fertilizers used as commercial controls (triple 17 and triple 20) together with the 25% Steiner solution and the nutritional balances 50-50-100 and 100-50-100 of NPK were statistically equal, registering on average a diameter of 5.75. cm. With these balances the plants increased their diameter by 1.09 cm with respect to the control without fertilizer, which represented an increase of 18.95%. The nutritional balance 100-50-50 of NPK was the one that generated the least response of the three NPK nutritional balances evaluated (Figure 2b).

Effect of treatments

Height of the plants (At)

When performing Tukey's means test ($p \leq 0.05$) considering the interaction of the concentration and nutrient balance of NPK, 50% Steiner nutritive solution were selected and 800 mg L^{-1} treatment with nutritional balance 100-50-100 NPK as fertigation treatments that promote greenhouse growth in stage 1 of this species registering, at 153 DDT, plants with a height greater than 6.29 cm statistically exceeding ($p \leq 0.01$) the rest of the evaluated treatments including commercial controls (triple 17 and triple 20), obtaining an increase in plant height of 35.5% with respect to the treatment without fertilization (Figure 3).

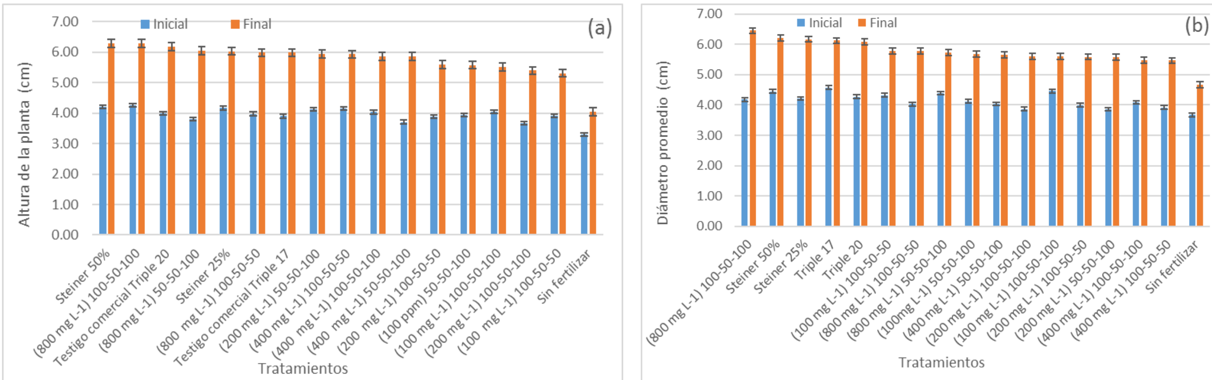

Figure 3. Concentration and nutritional balance of NPK in fertigation in plant height (a) and average diameter (b) of the biznaga blue barrel (*Ferocactus glaucescens* (DC.) Britton and Rose, in greenhouse.

Plant height is one of the most important characteristics for this cultivar, due to the presentation in a pot plant for marketing purposes. Plants with smaller size than those obtained with the previous treatments are difficult to market, they lose quality and price in the sales centers. In this regard, Langton *et al*. (1999); Flores (2009) report that the height of the plant is also a good indicator of a sufficient or deficient nutrition. For the case of this type of cactaceae the quality variables are the size of the plant (height and diameter), color of the stem, stiffness and firmness of the spines.

In order of importance they were followed by the treatments where the Steiner solution was applied at 25% and the treatments with 800 mg L^{-1} with nutritional balances 100-50-100 and 50-50-100 of NPK registering a height of 5.99 cm. From these treatments, the results showed that as the concentration of mg L^{-1} decreases from 400 to 100 mg L^{-1} in the three NPK nutritional balances evaluated (100-50-50, 100-50-100 and 50-50-100) the height decreases, finding the least response with the treatment of 100 mg L^{-1} that was elaborated with the nutritional balance 100-50-50 of NPK registering a height of 5.31 cm, which represented a difference with respect to the unfertilized control of 1.26 cm.

Average diameter (Dp)

After the 153 DDT, the 50% Steiner nutrient solution and the 800 mg L^{-1} treatment with the nutritional balance 100-50-100 of NPK were the fertigation treatments that promote the largest diameter of the plants, registering a value medium of 6.45 cm, which exceeded the rest of the treatments evaluated. The commercial controls triple 17 and triple 20 and the control without fertilizing recorded an average diameter of 6.14 cm.

The Steiner nutrient solution at 25% registered the same trend as the commercial control Triple 20 together with the treatments with a concentration of 800 mg L^{-1} prepared with the nutritional balances 50-50-100 and 100-50-50 of NPK registering an average diameter of 6.24, cm being statistically equal ($p \leq 0.01$). From these treatments, the results showed that as the concentration of mg L^{-1} decreases from 400 to 100 mg L^{-1} in the three NPK nutritional balances evaluated (100-50-50, 100-50-100 and 50-50-100) the average diameter is reduced, finding the lowest response with the treatment of 400 mg L^{-1} that was elaborated with the nutritional balance 100-50-50 of NPK registering a diameter of 5.46 cm, which represented a negative difference with regarding the control without fertilization of 0.7 cm.

The Steiner nutrient solution at 50% showed to be a balanced nutritive solution, with respect to the nutritive elements that it contributed to the water that was used, where the radicular system of branched type of the plant could absorb the nutrients. With this solution the contribution of nitrogen was 84 mg L^{-1}, phosphorus of 15.5 mg L^{-1} and potassium of 136.5 mg L^{-1}, the latter element being of higher concentration. Likewise, this nutrient solution provided other secondary macroelements such as calcium (90 mg L^{-1}) magnesium (24.5 mg L^{-1}) and sulfur (56 mg L^{-1}), while the concentration of 800 mg L^{-1} with the balance nutrimental 100-50-100 of NKP provided a nitrogen (N) concentration of 25.4 mg L^{-1}, phosphorus (P) of 14.9 mg L^{-1} and potassium (K) of 39.6 mg L^{-1}.

These results show that the fertilization system together with the integrated management of the cultivar (MIC) are important to obtain plants of commercial size.

Fresh and dry matter of the stem and root

The results of the Anova showed highly significant differences ($p \leq 0.01$) in weights of fresh and dry matter of stem and root being the treatments with the Steiner solution at 50% and the treatment of 800 mg L^{-1} with the nutritional balance 100-50-100 of NPK those that generated greater biomass in fresh and dry matter of the stem and root, surpassing the commercial controls (triple 17 and triple 20) and the rest of the evaluated treatments, reason why the nutrimental solutions applied had an effect in the production of biomass (Table 1).

These results coincide with those reported by Trejo *et al*. (2013); Villanueva *et al*. (2010) who report that fertilization with N and K in each phenological phase differentially influences biomass production.

Table 1. Concentration of nitrogen (N), phosphorus (P) and potassium (K) in blue barrel plants (*Ferocactus glaucescens* (DC.) Britton and Rose in greenhouse after 153 DDT with different concentrations and nutritional balances.

Treatment	Stem fresh matter	Stem dry matter	Root fresh matter	Root dry matter	N	P	K
	(g)*				(g kg^{-1} of dry matter)		
1 (100 mg L^{-1}) 100-50-50	38.14 f	4.85 f	2.14 ef	0.22 d	5.6	2.164	20.759
2 (100 mg L^{-1}) 100-50-100	73.71 c		3.46 d		9.1	1.255	10.977
3 (100 mg L^{-1}) 50-50-100	73.71 c		3.59 d		4.9	1.719	16.37
4 (200 mg L^{-1}) 100-50-50	71 cd	8.88 d	1 f	0.23 d	8.4	1.686	17.626
5 (200 mg L^{-1}) 100-50-100	38.12 f		4.42 c		7	1.329	13.81

Treatment	Stem fresh matter	Stem dry matter	Root fresh matter	Root dry matter	N	P	K
	(g)*				(g kg^{-1} of dry matter)		
6 (200 mg L^{-1}) 50-50-100	49.11 e		2.96 e		8.7	1.107	13.692
7 (400 mg L^{-1}) 100-50-50	49 e	7.31 e	4 d	0.9 c	12.2	0.684	6.644
8 (400 mg L^{-1}) 100-50-100	42.49 e		2.28 ef		5.6	1.633	13.536
9 (400 mg L^{-1}) 50-50-100	68.17 cd		0.86 f		5.2	1.304	14.599
10 (800 mg L^{-1}) 100-50-50	78 c	9.6 d	1 f	0.14 d	4.5	1.678	25.164
11 (800 mg L^{-1}) 100-50-100	80 b	19.65 ab	3 b	1.13 b	4.2	1.665	20.032
12 (800 mg L^{-1}) 50-50-100	59.73 d		4.81 c		5.6	1.077	9.838
13 Triple 17	49 e	17.9 b	0.5 g	0.95 cd	7.7	2.168	14.425
14 Triple 20	67 cd		1 f		7.35	3.296	16.963
15 Steiner 25%	43 ef	11.06 c	1 f	0.84 cd	8.05	1.451	11.08
16 Steiner 50%	92 a	22.91 a	6 a	1.77 a	5.6	1.759	9.286

*= Means with different letters in each column indicate significant statistical differences (Tukey, $p\leq 0.05$) between treatments.

Total concentration of N, P and K in the plant

With the 50% Steiner nutrient solution, an N concentration of 5.6 g kg^{-1} of dry matter was registered, similar to the nutrient solution of 800 mg L^{-1} with the balance of 100-50-100 of NPK (N= 4.2 g kg^{-1} dry matter). Although other treatments exceeded these values, the size of the plants in height and diameter was lower than that registered in the commercial controls (triple 17 and triple 20) where the concentration of N was statistically equal with a value of 7.35 g kg^{-1} of dry matter (Table 1).

With the 50% Steiner nutrient solution, the phosphorus concentration (P) was 1.75 g kg^{-1} of dry matter, exceeding in dry matter the plants where the nutrient solution was applied with 800 mg L^{-1} with the balance of 100-50-100 of NPK registering 1.66 g kg^{-1} of dry matter. The commercial controls triple 17 and triple 20 registered a phosphorus concentration (P) greater than 2.16 kg of dry matter, surpassing the rest of the treatments evaluated.

The highest concentration of potassium (K) in the plants was obtained with nutrient solution prepared with 800 mg L^{-1} with the balance of 100-50-100 of NPK registering 20.03 g kg^{-1} of dry matter, this concentration doubled to that obtained with 50% Steiner nutrient solution (Table 1).

In general, the 50% Steiner nutrient solution provides the plant with a higher concentration of dry matter in nitrogen (N) and potassium (P) than the one elaborated with 800 mg L^{-1} with the balance of 100-50-100 of NPK having an opposite effect with potassium (K) where the plants of the second treatment referred duplicated the dry matter of potassium (K). In contrast, commercial controls (Triple 17 and Triple 20) exceeded these treatments in nitrogen (N) with a concentration higher than 7.35 g kg^{-1} of dry matter, in phosphorus (P) (2.1 g kg^{-1} of dry matter).) and potassium (K) (14.42 g kg^{-1} dry matter) without showing symptoms of toxicity. With these treatments the plants were smaller and it is estimated that they require at least six additional months in the greenhouse to reach their commercial size, this implies the investment of time and increase in the cost of production, for which the producers have to consider other fertilization options to promote the growth of this type of plants.

Pineda *et al*. (1998); Enríquez *et al*. (2005) report that the universal nutrient solution proposed by Steiner (1984), greater than 25%, records a concentration of N in the foliage of the plant between 3 and 5 g kg^{-1} of dry matter. This interval is similar to that obtained with 50% Steiner nutrient solution and that elaborated with 800 mg L^{-1} with the balance of 100-50-100 NPK. In this stage, the demand for K in the plant was higher than in N. Rueda *et al*. (2016) mentions that the N is lost more quickly in the substrate than the K and that with the risks increases the K:N ratio in early stages of the crop, a relationship that favors the increase in size and the quality of the pot plant, this same effect was obtained with the referred treatments, so these nutritive solutions are adequate within the sufficiency ranges.

Also, Arredondo (2009); Trejo *et al*. (2013); Spurway and Thomas (2001) report that the main nutrients absorbed by the plant in early stages are the N and K and that a deficiency of these will drastically affect the development, production and quality of the product, an effect that was also registered with this species.

This same response was obtained with *Echinocactus grusonii* (Tanaka *et al*., 1983) and in cactus (Lara, 1990, Serrano, 1996) where not only the length and width of the cladode increased, but also the number of bud/plant. These results show that nutrition is one of the most important factors, where there is no standard solution for all cultivars, so it is necessary to determine the needs of each cultivar to promote profitable productivity and good product quality.

Conclusions

The 50% Steiner nutrient solution and the solution prepared with 800 mg L^{-1} with the balance of 100-50-100 of NPK generated the 153 DDT plants with higher biomass and commercial size with stem height and diameter greater than 6 cm referring that in early stages the N:K relationship influence this process.

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