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Electrical conductivity and pH of the substrate solution in gerbera cultivars under fertigation

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ABSTRACT

The quality and the profitability on floriculture are intimately linked to the adequate plant nutrition. In the present research we aimed to evaluate the electrical conductivity (EC) and pH of the substrate solution on four different gerbera cultivars subjected to fertigation, with two nutritive solutions. The experiment was carried out in a greenhouse, from May to July 2006, on the Universidade Estadual Paulista, Botucatu, São Paulo state, Brazil. The experiment was carried out under an experimental design of random blocks, in 4×2 factorial arrangement, with four Gerbera cultivars (Cherry, Golden Yellow, Salmon Rose and Orange) and two nutritive solution concentrations: 0.92 and 1.76 dS m^{-1} EC) during the vegetative stage, and 1.07 and 2.04 dS m^{-1} during the reproductive stage (S_1 and S_2, respectively). The nutrients were applied through fertigation, manually performed every day. The EC and pH values of the substrate solution were evaluated weekly, using the 'pourthru' method. Orange and Cherry cultivars had, respectively, the highest and the lowest electrical conductivity of the substrate solution, and Cherry was the most efficient on the nutrient uptake. The solution S_2 showed a trend to accumulate salts in the substrate, but without visual symptoms of plant toxicity, leading to the lowest pH values. The 'pourthru' method was efficient when compared to the 1:2 method and can be adopted for substrate solution analysis in gerbera culture.

Keywords: *Gerbera jamesonii*, floriculture, 'pourthru' method.

RESUMO

Condutividade elétrica e pH da solução do substrato em cultivares de gérbera fertirrigadas

A qualidade e rentabilidade na floricultura estão intimamente relacionadas com adequada nutrição de plantas. O presente trabalho teve por objetivo avaliar a condutividade elétrica e o pH da solução do substrato em quatro diferentes cultivares de gérbera fertirrigadas com duas soluções nutritivas. O experimento foi conduzido em casa de vegetação, de maio a julho de 2006, na Universidade Estadual Paulista, em Botucatu-SP. O mesmo foi instalado sob delineamento experimental em blocos casualizados em esquema fatorial 4×2, sendo quatro cultivares de gérbera (Cherry, Golden Yellow, Salmon Rose e Orange) e duas concentrações de solução nutritiva com condutividade elétrica de 0,92 e 1,76 dS m^{-1} no período vegetativo, e 1,07 e 2,04 dS m^{-1} no período reprodutivo (S_1 e S_2, respectivamente). Os nutrientes foram aplicados via fertirrigação, realizada manualmente, uma vez ao dia. Semanalmente avaliou-se a condutividade elétrica e pH da solução do substrato utilizando a metodologia do 'pourthru'. A solução do substrato nas cultivares Orange e Cherry apresentou maior e menor condutividade elétrica, respectivamente, e Cherry foi a mais eficiente na absorção de nutrientes. A solução 2 apresentou tendência de acúmulo de sais no substrato, mas sem sintomas visuais de fitotoxidez e, nesta solução foram registrados os menores valores de pH. A metodologia do 'pourthru' mostrou-se eficiente quando comparada ao método de diluição 1:2 e pode ser adotada para análise da solução do substrato na cultura da gérbera.

Palavras-chave: *Gerbera jamesonii*, floricultura, método 'pourthru'.

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Fertigation has been increasingly employed in the production of flowers and ornamental plants, enabling to improve the plants yield and quality through the adequate nutrients provision. According to Ludwig *et al.* (2008), the plant nutrients demand is different for gerbera cultivars, and thus an individualized management is needed to express their genetic potential. This management is eased by fertigation.

Maintenance of adequate nutrient levels in the growing medium is a common goal in container plant production, as the supply is directly related to nutrient uptake and plant growth (Cabrera, 1998). It is important to monitor the chemical properties of substrates, as well as the electrical conductivity (EC) and the pH solution. Regular monitoring helps to eliminate problems associated with fertilization, showing the nutrient availability to the crops.

The physical and chemical characterization of substrates is necessary to correct the formulations, to recommend, and to monitor the fertilizer application in greenhouse. However, to date, there is no method fully accepted to chemically characterize substrates (Abreu *et al*., 2007).

Nowadays, most producers do not follow a plan to prevent nutritional imbalances; they only remediate them after the symptoms appear. The 'pourthru' method helps to avoid these problems, easing the maintenance of quality characteristics. 'Pourthru' is a technique based on the substrate solution displacement, is easy to perform and not destructive (Cavins *et al.*, 2004). The

major limitation for its use is the lack of recommendations for floriculture.

The technique most employed by producers is the 1:2 soil/water solution analysis (ratio expressed in a volume basis), because it presents a well developed and readily available protocol. However, it is a destructive analysis, and less accurate due to differences in the substrate humidity.

Due to the lack of information on ornamental plants fertilization and nutrition, as gerbera (*Gerbera jamesonii*) cultivated in pots, this study aimed to evaluate the EC and pH of the substrate solution extracted according to the 'pourthru' method, in four different gerbera cultivars.

MATERIAL AND METHODS

The experiment was carried out from May to July 2006, in a greenhouse at the Universidade Estadual Paulista, county of Botucatu (22°50'S, 48°26'W), São Paulo state, Brazil.

The greenhouse has a bow roof covered with transparent plastic film, lateral surfaces with white screen, and concrete floor. Its total area was 168 m², with a lateral and central heights of 2.6 and 3.0 m, respectively. The internal upper environment was managed according to light intensity, with a 50% thermal screen (Aluminet®), rolling it out from 10:30 a.m. to 4:00 p.m. and exposing the plants at the remaining times when light intensity was lower than 50,000 lux.

The experiment was carried out under a random blocks experimental design and a 4×2 factorial arrangement (four cultivars and two nutritive solutions), with 5 replicates and 6 plants per plot. The plants were put on individual pots spaced 30 cm apart, totalizing a useful area of 21.6 m², with a length of 14.4 m and a width of 1.5 m. They were placed over bricks on the greenhouse floor, in order to facilitate leaching.

The used cultivars were from F_1 generation of the Festival group (Sakata® Company), highly acceptable in the market. Cherry and Golden Yellow belong to the Dark Eyes series (dark center); Salmon Rose and Orange belong to the Light Eyes series (light center).

The nutritive solutions consisted of two electrical conductivities in the vegetative phase: 0.92 dS m^{-1} (S_1), which had the following composition, in mg dm^{-3}: 71.0 NO_3^-, 50.75 NH_4^+, 52.5 K, 12.6 P, 25.65 Ca, 3.15 Mg, 14.0 S, 0.1 B, 0.15 Cu, 1.95 Fe, 0.7 Mn, 0.05 Mo, 0.15 Zn and 1.76 dS m^{-1} (S_2), which had the double of S_1 salt content. When the plants began their reproductive stage, at 41 days after acclimation (DAA), the solutions were reformulated due to changes in the crop demand. S_1 had 1.07 dS m^{-1} EC, and the following composition, in mg dm^{-3}: 55.15 NO_3^-, 33.4 NH_4^+, 142.5 K, 28.3 P, 13.15 Ca, 8.59 Mg, 38 S, 0.2 B, 0.2 Cu, 2.2 Fe, 0.85 Mn, 0.05 Mo, and 0.25 Zn. Similarly to the vegetative phase, S_2 had the double of S_1 salt concentrations.

In both the stages, vegetative and reproductive, the nutritive solutions had their pH adjusted to 5.0, adding phosphoric acid (52% P_2O_5) at the preparation, whenever necessary.

The gerbera seedlings were pre-acclimated during 30 days and subsequently used for pot cultivation. The plants were grown in pots number 15 (1.3 L, 11.5 cm of height, 14.8 cm of superior base and 9.8 cm of inferior base), which were filled with substrate composed of 70% of thin pine bark and 30% of subsoil.

The plants received nutrients through fertigation on a daily frequency. The irrigation depth corresponded to the water amount required to raise the pot substrate humidity to the maximum water retention.

The substrate solution EC (dS m^{-1}) and pH were weekly analyzed by the 'pourthru' method, adapted from Cavins *et al.* (2004). One pot per plot was saturated with its respective nutritive solution; after one hour, plastic bags were placed in the lower part of each pot and 75 mL deionized water were added to their upper part, so that the easily available solution could be leached into the plastic bags. EC was determined immediately after solution extraction with a portable EC meter (Digimed DM-3), and the pH was determined with a portable pH meter (Gehaka PG 1400).

After the harvest, EC was analyzed by the 1:2 method. Part of the substrate in the central region of the pot was removed to be read in suspensions of substrate: deionized water at 1:2 (v:v) proportion, 30 minutes after homogenization.

The results were subjected to the analysis of variance, through the F test. The means were compared by the Tukey test at 5% significance using the statistical program Sisvar (Ferreira, 2000).

RESULTS AND DISCUSSION

The variations on the electrical conductivity were significant at all evaluated dates, except for 28 DAA.

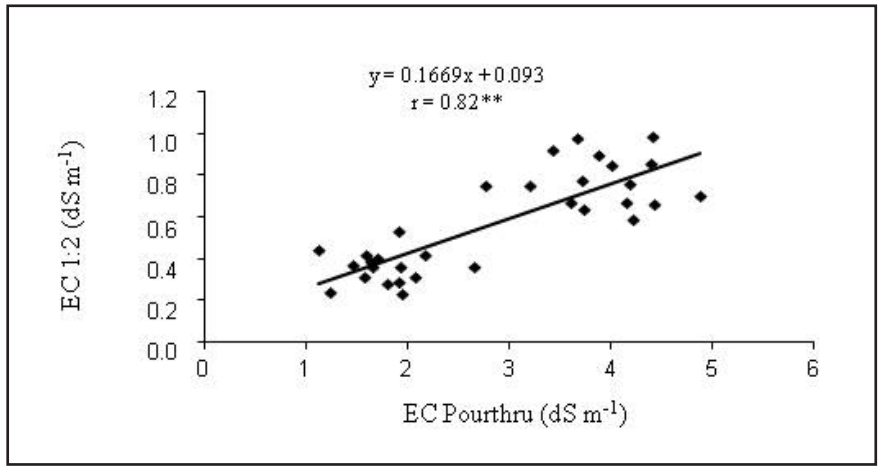

Figure 1. Electrical conductivity (EC) using the 'pourthru' and 1:2 methods (condutividade elétrica avaliada pelos métodos 'pourthru' e 1:2). Botucatu, UNESP, 2006.

Table 1. Mean values of substrate solution EC (dS m^{-1}), obtained by the 'pourthru' method, according to the gerbera cultivars and nutritive solutions [valores médios de EC (dS m^{-1}) da solução do substrato, obtidas pelo método 'pourthru', em função das cultivares e soluções nutritivas]. Botucatu, UNESP, 2006.

	Days after acclimation							
	7	**14**	**21**	**28**	**35**	**42**	**49**	**56**
Cultivars	**EC (dS m^{-1})**							
Cherry	2.2	2.5	2.2	2.7	2.7 a	2.8	3.2	3.8 a
Golden Yellow	2.2	2.4	1.9	2.4	2.3 ab	2.3	2.6	2.8 b
Salmon Rose	2.3	2.6	2.2	2.7	2.4 ab	2.3	2.8	2.9 b
Orange	1.8	1.9	1.6	2.2	2.1 b	2.1	2.3	2.7 b
Solutions								
S_1	1.9	1.9	1.4	1.8 B	1.6 B	1.5	1.6	1.7 B
S_2	2.4	2.9	2.5	3.2 A	3.2 A	3.3	3.9	4.4 A
C	**	**	**	ns	*	**	**	**
S	**	**	**	**	**	**	**	**
C*S	*	**	*	ns	ns	*	*	ns
CV (%)	11.9	11.5	14.8	21.6	19.9	16.2	14.8	18.6

C: cultivars; S: solutions; S_1: solution 1 ($EC_{vegetative}$: 0.92 dS m^{-1} and $EC_{reproductive}$: 1.07 dS m^{-1}); S_2: solution 2 ($EC_{vegetative}$: 1.76 dS m^{-1} and $EC_{reproductive}$: 2.04 dS m^{-1}). Means followed by the same letter did not differ by the Tukey test at 5%. ns: not significant. **significant at 1%; *significant at 5% [C: cutivares; S: soluções; S_1: solução 1 ($EC_{vegetativo}$: 0.92 dS m^{-1} e $EC_{reprodutivo}$: 1.07 dS m^{-1}); S_2: solução 2 ($EC_{vegetativo}$: 1.76 dS m^{-1} e $EC_{reprodutivo}$: 2.04 dS m^{-1}). Médias seguidas pela mesma letra não diferem, Tukey 5%. ns: não significativo. **significativo a 1%. *significativo a 5%].

The solutions were affected in all dates and interaction between cultivars and nutritive solutions, at 7, 14, 21, 42 and 49 DAA (Tables 1 and 2).

The solutions had higher EC on S_2 treatment. This response occurred because such solution had a nutrient concentration higher than that required by the crop; therefore, the plant did not absorb all the nutrients, tending to concentrate salts in the substrate. According to Van Iersel (1999), an EC increase in the growth medium solution indicates that fertilization occurs more rapidly than the uptake, whereas an EC decrease to levels lower than the applied solution EC suggests that the nutrient levels are not enough for the plant optimal growth.

According to Sonneveld *et al.* (1999), gerbera is classified as moderately sensitive to the nutritive solution EC, which varies with the environment and the cultivar. The obtained results corroborate this information, as Orange solution showed lower EC, relative to the remaining cultivars, mainly in S_2, and was thus characterized as a high-uptake cultivar (Tables 1 and 2). Differences in this variable among gerbera cultivars were reported by Baas *et al.* (1995), Nowak & Gabryszewska (2001) and Paradiso *et al.* (2003).

EC values of Cherry's solution at 35, 42, 49 and 56 DAA, were significantly different at 56 DAA (Tables 1 and 2). According to Noordegraaf (1994), during the cultivation period, salts can concentrate when the plant water consumption rises more than the plant nutrient consumption, damaging roots when a critical salt content is reached. Cherry cultivar had a higher leaf area (1116.6 cm^2) than Orange (901.7 cm^2), possibly indicating that evapotranspiration, as well as water demand, was higher in the first cultivar.

At the end of the productive cycle, Cherry cultivar had mean dry matter of 11.9 g, and Orange, 10.4 g. Thus, the first one was more efficient in using the nutrients. From a nutritional point of view, a superior genotype is the one that, under unfavorable fertility conditions, is capable of developing, has appropriate production, can absorb the needed nutrients at lower levels, and distribute them more efficiently to the several plant components without compromising productivity (Furlani *et al.*, 1984). Cultivars efficient in using nutrients are important for nutrient economy and lead to a possible cost reduction.

S_2 had a trend to EC increase along the experimental period (Table 1). This solution had higher nutrient levels than gerbera needs and was not totally absorbed. Daily fertigations led to an increase in the substrate salt concentration, consequently increasing the EC. The trend to EC increase was not observed in S_1 as it had lower concentration, and the plant absorbed almost all daily supplied nutrients. A similar result was obtained by Van Iersel (1999), who used nutritive solutions of 0.6, 1.2, 1.8, 2.4, 3.0, and 3.6 dS m^{-1} EC for *Viola tricolor* culture. This author observed that the substrate solution EC obtained by the 'pourthru' method increased over the cycle in solutions with higher EC, justifying the above-mentioned explanations.

In both the solutions used, there were EC decreases from 14 to 21 DAA, due to previously cloudy days, higher relative humidity and low mean temperature, thus decreasing the plant evapotranspiration and the fertigation need. After this date, the climatic conditions requested daily fertigation, consequently increasing the EC. Baas *et al.* (1995) studied *Dianthus caryophillus* culture and verified EC increases during high transpiration periods. Van Iersel (1999) reported that efficiency in water

Table 2. Values of substrate solution EC (dS m^{-1}), obtained by the 'pourthru' method, according to the gerbera cultivars and nutritive solutions at 7, 14, 21, 42 and 49 DAA [valores médios de EC (dS m^{-1}) da solução do substrato, obtidas pelo método 'pourthru', em função das cultivares e soluções nutritivas aos 7, 14, 21, 42 e 49 DAA]. Botucatu, UNESP, 2006.

Cultivars	Days after acclimation					
	7		14		21	
	Solutions (dS m^{-1})					
	S_1	S_2	S_1	S_2	S_1	S_2
Cherry	1.8 aB	2.6 aA	1.8 aB	3.3 aA	1.5 aB	3.0 aA
Golden Yellow	2.0 aB	2.4 aA	2.0 aB	2.8 aA	1.4 aB	2.5 aA
Salmon Rose	2.0 aB	2.7 aA	2.0 aB	3.2 aA	1.6 aB	2.8 aA
Orange	1.6 aA	1.9 bA	1.7 aB	2.3 bA	1.3 aB	1.9 bA
			42		49	
			Solutions (dS m^{-1})			
			S_1	S_2	S_1	S_2
Cherry			1.6 aB	3.9 aA	1.8 aB	4.7 aA
Golden Yellow			1.4 aB	3.2 abA	1.7 aB	3.6 aA
Salmon Rose			1.5 aB	3.2 abA	1.7 aB	3.9 aA
Orange			1.5 aB	2.7 bA	1.3 aB	3.3 bA

C= cultivars; S= solutions; S_1: solution 1 ($EC_{vegetative}$: 0.92 dS m^{-1} and $EC_{reproductive}$: 1.07 dS m^{-1}); S_2: solution 2 ($EC_{vegetative}$: 1.76 dS m^{-1} and $EC_{reproductive}$: 2.04 dS m^{-1}). Means followed by the same lowercase letter in the column and uppercase in the line did not differ by the Tukey test at 5% [C: cutivares; S: soluções; S_1: solução 1 ($EC_{vegetativo}$: 0.92 dS m^{-1} e $EC_{reprodutivo}$: 1.07 dS m^{-1}); S_2: solução 2 ($EC_{vegetativo}$: 1.76 dS m^{-1} e $EC_{reprodutivo}$: 2.04 dS m^{-1}) Médias seguidas pela mesma letra minúscula na coluna e, maiúscula na linha não diferem, Tukey 5%].

Table 3. Mean values of substrate solution pH, obtained by the 'pourthru' method, according to the gerbera cultivars and nutritive solutions (valores médios de pH da solução do substrato, obtidos pelo método 'pourthru', em função das cultivares e soluções nutritivas). Botucatu, UNESP, 2006.

Cultivars	Days after acclimation							
	7	14	21	28	35	42	49	56
Cherry	7.4 a	7.4	7.5 a	7.4 a	7.3 a	7.2 a	7.2	7.2 a
Golden Yellow	7.4 a	7.4	7.5 a	7.4 a	7.3 a	7.2 a	7.2	7.1 a
Salmon Rose	7.3 a	7.4	7.5 a	7.4 a	7.3 a	7.2 a	7.3	7.2 a
Orange	7.2 b	7.2	7.3 b	7.2 b	7.0 b	6.9 b	6.9	6.9 b
Solutions								
S1	7.4 A	7.5	7.6 A	7.5 A	7.5 A	7.3 A	7.4	7.4 A
S2	7.3 B	7.3	7.3 B	7.1 B	7.0 B	6.9 B	6.9	6.8 B
C	**	**	**	**	**	**	**	**
S	**	**	**	**	**	**	**	**
C*S	ns	*	ns	ns	ns	ns	*	ns
CV (%)	1.2	0.8	1.2	1.9	1.7	1.7	1.8	2.2

C: cultivars; S: solutions; S_1: solution 1 ($EC_{vegetative}$: 0.92 dS m^{-1} and $EC_{reproductive}$: 1.07 dS m^{-1}); S_2: solution 2 ($EC_{vegetative}$: 1.76 dS m^{-1} and $EC_{reproductive}$: 2.04 dS m^{-1}). Means followed by the same lowercase letter in the column and uppercase in the line did not differ by the Tukey test at 5%. ns: not significant. **significant at 1%; *significant at 5% [C: cutivares; S: soluções; S_1: solução 1 ($EC_{vegetativo}$: 0.92 dS m^{-1} e $EC_{reprodutivo}$: 1.07 dS m^{-1}); S_2: solução 2 ($EC_{vegetativo}$: 1.76 dS m^{-1} e $CE_{reprodutivo}$: 2.04 dS m^{-1}). Médias seguidas pela mesma letra maiúscula na linha e minúscula na coluna não diferem entre si pelo teste de Tukey a 5%. ns: não significativo. **significativo a 1%. *significativo a 5%].

use mainly depends on the environmental conditions; the range of plant response within a fertilizer concentration can be affected by climatic factors.

In the cultivars and the nutritive solutions used, there were pH variations in all evaluated periods. Orange solution had lower pH values (Tables 3 and 4). Significant interaction between cultivars and solutions were observed at 14 and 49 DAA.

The pH of S_1 treatment was higher than S_2 treatment in all cultivars (Tables 3 and 4). Several studies showed this trend to pH increase with EC decrease of the nutritive solution (James & Van Iersel, 2001; Van Iersel, 1999; Zheng *et al.,* 2004). It must be emphasized that the pH values measured in the substrate solution were higher than those applied (5.0). Syros *et al.* (2001) also observed

Table 4. Values of substrate solution pH, obtained by the 'pourthru' method, according to the gerbera cultivars and nutritive solutions at 14 and 49 DAA (valores médios de pH da solução do substrato, obtidos pelo método 'pourthru', em função das cultivares e soluções nutritivas aos 14 e 49 DAA). Botucatu, UNESP, 2006.

Cultivars	Days after acclimation			
	14		49	
	Solutions			
	S_1	S_2	S_1	S_2
Cherry	7.5 aA	7.3 aB	7.4 aA	7.0 aB
Golden Yellow	7.5 aA	7.3 aB	7.4 aA	6.9 aB
Salmon Rose	7.5 abA	7.3 aB	7.5 aA	7.0 aB
Orange	7.4 bA	7.1 bB	7.3 aA	6.5 bB

C= cultivars; S= solutions; S_1: solution 1 ($EC_{vegetative}$: 0.92 dS m^{-1} and $EC_{reproductive}$: 1.07 dS m^{-1}); S_2: solution 2 ($EC_{vegetative}$: 1.76 dS m^{-1} and $EC_{reproductive}$: 2.04 dS m^{-1}). Means followed by the same lowercase letter in the column and uppercase in the line did not differ by the Tukey test at 5% [C: cutivares; S: soluções; S_1: solução 1 ($EC_{vegetativo}$: 0.92 dS m^{-1} e $EC_{reprodutivo}$: 1.07 dS m^{-1}); S_2: solução 2 ($EC_{vegetativo}$: 1.76 dS m^{-1} e $EC_{reprodutivo}$: 2.04 dS m^{-1}). Médias seguidas pela mesma letra minúsculas na coluna e maiúsculas na linha não diferem entre si pelo teste de Tukey a 5%].

pH increase although the solution was adjusted to pH 6.0.

There was a decrease in pH along the cycle, which was more evident in S_2 treatment (Figure 1). A similar result was reported by Van Iersel (1999) in *Viola tricolor*. This author observed a reduction in pH along the cycle, especially with high EC values (1.2-3.6 dS m^{-1}). James & Van Iersel (2001) observed this same trend for *Petunia* sp. and *Begonia* sp.

Several authors reported the decreases of gerbera production with pH higher than 6.0 (Savvas & Givas, 2002; Sonneveld & Voogt, 1997) and lower than 5.5 (Ludwig *et al.*, 2010). However, Stinson (1953) verified that gerbera had equal production when the soil pH was kept within 5.0 and 7.2. The latter value is similar to the mean obtained in the present experiment.

There was a positive linear correlation to EC (r: 0.82**), between 'pourthru' and 1:2 methods, and the former had higher values (Figure 1). Cavins *et al.* (2004) found r = 0.98** when EC values obtained by 'pourthru' were correlated to those observed with saturated media extract (SME). The lower values from 1:2 are due to greater sample dilution.

Scoggings & Van Iersel (2006) verified that the 'pourthru' method allowed EC values higher than those obtained with 1:2 dilution. Those authors justified that, in 'pourthru', water is added on the substrate top, displacing the solution at the lower part of the pot, without dilution. In the 1:2 method, greater amount of water is frequently mixed to the substrate and the nutrients are also diluted, resulting in lower EC.

The results allow to conclude that Cherry was more efficient as to nutrient uptake due EC of solutions is higher than Orange cultivar. The S_2 treatment showed salt accumulation in the substrate, without visual symptoms of phytotoxicity, and the lowest pH values. The 'pourthru' method was efficient and can be employed in the analysis of the substrate solution in gerbera culture.

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