Colegio de Postgraduados

Adaptability of sugarcane (*Saccharum* spp.) clones, introduced by exchange to southeastern Mexico

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ABSTRACT

Objective: To evaluate sugarcane (*Saccharum* spp.) clones in the adaptability phase and select those with high field and factory yields that significantly exceed the commercial control clones.

Design/Methodology/Approach: Fourteen sugarcane clones were evaluated in a crop established for the first time and to which no cut has been made. The experimental design consisted of randomized complete blocks with four repetitions. The following agricultural characteristics were evaluated: stalk weight, population, and yield. The following industrial characteristics were likewise assessed: sucrose content, juice purity, and theoretical sugar production. Both values were compared with the values of the local clones MEX 69-290 and CP 72-2086 that were used as control.

Results: Statistical differences were found in agricultural and industrial characteristics between clones. In terms of stalk weight, the LTMEX 94-02 clone stood out, while, in population terms, the Mex 95-35 clone recorded the highest number of stalks per ha. Regarding field yield, the COLPOSCTMEX 09-1433 clone obtained significantly higher tonnage per hectare than the two control clones. Among the factory characteristics, the MEX 96-10 clone stood out with a significantly higher concentration of sucrose and with the highest juice purity. Finally, the COLPOSCTMEX 09-1433 clone had the highest theoretical sugar production value, which was statistically superior to the two control clones.

Study Limitations/Implications: The data were obtained from a crop established for the first time.

Findings/Conclusions: At least four clones showed high field and factory yields: COLPOSCTMEX 09-1433, LTMEX 94-02, MEX 95-59, and MOTZMEX 00-1192. All four showed a field performance that had better statistics than the control MEX 69-290; therefore, it would be appropriate to pursue its evaluation and multiplication during the semi-commercial test phase. However, since they were introduced, their evaluation should continue under the environmental conditions of the region.

Keywords: Selection, yield, sucrose, production, theoretical sugar.

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INTRODUCTION

The genetic improvement of sugarcane is carried out through the sowing of the hybrid seed, its subsequent evaluation, selection, and multiplication (at the beginning of the process), and the evaluation of the selected clones in 10 successive phases (Valdez *et*

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al.,1998). When the outstanding genetic material reaches advanced phases of evaluation, it is exchanged with other sugarcane regions of the country. It takes 10 to 13 years of continuous evaluation before a clone is finally recommended as a promising product (Valdez *et al.*, 1998).

The adaptability phase of sugarcane clones aims to determine the agricultural and industrial behavior of the selected materials in the experimental field (Flores, 2001). In the southeast of Mexico, sugarcane is grown in approximately 121,657 ha, 70% of whose surface is covered with three clones: Mex 69-290, CP 72-2086, and MEX 79-431 (MAM, 2022). The national average field yield is 67 t ha^{-1} (ATAM, 2021), while in the southeast of Mexico it is only 54.19 t ha^{-1} (COLPOS, 2021). Additionally, many sugarcane fields are old fields (with discontinued clones and low population densities), show disease problems, and have high percentages of clone mixing. This problem causes losses that harm producers and industrialists. In 2006, the Colegio de Postgraduados-Campus Tabasco began the Programa de Mejoramiento Genético for the improvement of sugarcane, with the objective of selecting clones with better field yields and sucrose content than currently cultivated clones. Sugarcane clones are the backbone of the supply area of sugar mills; however, they have an average useful life of 25 years, as a consequence of the appearance of new pests and diseases, among other causes (Martínez, 2017). The ideal sugarcane clone meets the needs of producers, field workers, and industrialists (Climaco and Ranjel, 1995). To solve the abovementioned problems, 14 sugarcane clones that have excelled in the selection process in other sugarcane regions of Mexico were evaluated during the adaptability phase.

MATERIALS AND METHODS

Experimental site location

The present work was carried out on a plot of the Unión Local de Productores de Caña de Azúcar C.N.C. of the Ingenio Benito Juárez, A. C., located in Poblado C-27, Cárdenas, Tabasco (18° 00' 37" N and 93° 34' 56" W).

Sugarcane clones evaluated

The clones were exchanged and selected in the Experimental Field of the Colegio de Postgraduados-Campus Tabasco in the Strain, Plot, and Furrow phase, according to the methodology recommended by this institution. The sugarcane clones to be evaluated in this research work are included in Table 1.

Table 1. Sugarcane clones introduced for exchange purposes and evaluated in the adaptability phase.

No.	Clone	No.	Clone	No.	Clone
1	MEX 95-03	6	EMEX 91-917	11	LTMEX 94-02
2	MEX 95-59	7	MEX 09-82	12	MEX 96-10
3	COLPOSCTMEX 09-1433	8	M 1658-78	13	MEX 69-290 (t)
4	EMEX 96-35	9	EMEX 91-117	14	CP 72-2086 (t)
5	MEX 95-35	10	MOTZMEX 00-1192		

Control clones 13 and 14 (MEX 69-290 and CP 72-2086) occupy the largest sugarcane cultivation area in southeastern Mexico.

Experimental design

A randomized complete block (RCB) experimental design with four repetitions was used, considering the clones as treatments, obtaining a total of 14 treatments: 12 clones from the selection process and two as control treatments. The experimental units consisted of twenty-four 12-m long furrows. The agricultural variables were evaluated in 4 central furrows of the useful plot, while the industrial variables were evaluated in the 12 lateral furrows.

Establishment and monitoring of the crop (experimental plot)

To guarantee the homogeneity between the clones, the material used came from the multiplication phase III in a 9-month-old crop established for the first time. The land preparation consisted of two fallowings, two harrowings, and one furrowing with 1.4 m between furrows and a depth of 40 cm. After planting and establishment, the technological package recommended to sugarcane producers from the southeastern region was applied.

Variables

The data of the variables were obtained when the crop established for the first time reached 15 months of age.

Agricultural variables

Population

The existing 2-m stalks from the central furrows of the experimental units were counted. The population of sugarcane clones were classified as very good (>80,000 stalks per hectare), good (79,000 to 60,000), regular (59,000 to 40,000), and poor (40,000) (IMPA, 1988).

Five repetitions of each of the abovementioned agricultural variables were taken in each of the experimental units and in each of the four blocks.

Stalk weight

The stalks of the four central furrows of each experimental unit in the four blocks were harvested and weighed. Less than 1 kg of stalk weight is considered light, 1 to 1.5 kg of stalk weight is considered medium, and more than 1.5 kg stalk weight is classified as heavy (IMPA, 1988).

Field yield

The averages of the stalk weight (tons of sugarcane per hectare) and population (number of stalks per meter) variables were used to estimate field yield. More than 130 t ha^{-1} is classified as an excellent yield clone, from 100 to 130 t ha^{-1} as a high-yield clone, 70 to 100 t ha^{-1} as a medium-yield clone, and less than 70 t ha^{-1} is classified as a low-yield clone (IMPA, 1988). The methodology recommended by IMPA (1988) was used to evaluate the agricultural variables.

Industrial variables

Samples were taken from the lateral furrows of each experimental unit and 20 stalks were sent to the laboratory of the Pdte. Benito Juárez, S. A. sugar mill. They were analyzed with the pol formula, from 11 to 15 months of age, and the following variables were determined in the stalk juice: sucrose content, purity, fiber content, reducing sugar content, and theoretical sugar yield. The last variable was calculated with the field yield and sucrose content values and was expressed in tonnes of sugar per hectare.

Statistical analysis

The information obtained for the evaluated response of both the agricultural and industrial variables was systematized and organized. The experimental information was subjected to an analysis of variance with the R ver. 4.1.1 statistical software for Windows.

RESULTS AND DISCUSSION

Stalk weight

There were statistical differences between the 14 clones evaluated regarding this variable (Figure 1). Clone 4 (EMEX 96-35) was the lightest and clone 11 (LTMEX 94-02) was the heaviest. Clones 11 (LTMEX 94-02), 3 (COLPOSCTMEX 09-1433), 2 (MEX 95-59), 10 (MOTZMEX 00-1192), and 9 (EMEX 91-117) were classified as heavy (>1.5 kg). The stalk weights of the first three were statistically equal to each other, with clone 11 being significantly heavier than clones 10 and 9 (Figure 1). The rest of the clones had statistically similar values and were classified as medium (1 to 1.5 kg) (IMPA, 1988) (Figure 1).

The stalk weight of sugarcane depends on the clone, the environmental conditions, and the follow-up given to the crop (IMPA, 1988).

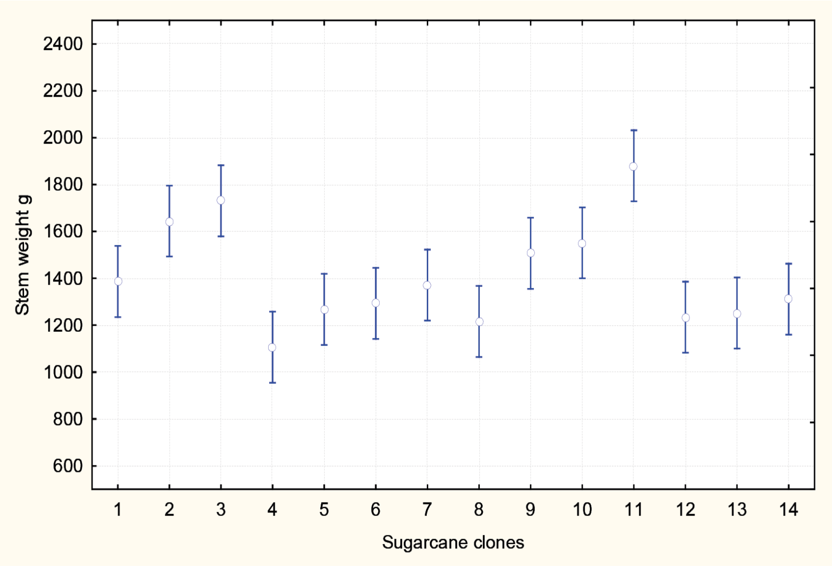

Figure 1. Stalk weight of 14 clones evaluated in the adaptability phase (vertical bars indicate the 95% confidence interval).

Population

Figure 2 shows statistical differences between the clones evaluated regarding the stalk population per hectare variable. Based on the IMPA measurement scale (1988), clone 5 (MEX 95-35) was classified as very good (>80,000 stalks per hectare), although its values were statistically equal to the other clones, with the exception of clone 12 (MEX 96-10), which recorded a significantly lower value. The rest of the clones fall within the good category (from 60,000 to 79,000 stalks per hectare) and clone 12 (MEX 96-10) belongs to the regular category (from 40,000 to 59,000 stalks per hectare).

Clones with more than 120,000 grinding stalks per hectare are not desirable. Overall, their thin and shorter stalks result in poor field yields.

Field yield

There were statistical differences between the 14 clones evaluated. Clones 3 (COLPOSCTMEX 09-14339), 11 (LTMEX 94-02), and 2 (MEX 95-59) had the highest yield, although their values were statistically equal to those observed in the 10 clones with the highest yield (Figure 3).

It is important to note that all the clones evaluated in this research work exceeded the average yield of the national mean (67 t ha^{-1}), as well as the average yield in southeastern Mexico (54.19 t ha^{-1}) (MAM, 2022). On the one hand, the field yield of clone 3 (COLPOSCTMEX 09-1433) statistically exceeded the yield of the two control clones (CP 72-2086 and MEX 69-290). On the other hand, five of the evaluated clones statistically exceeded the field yield of control clone 13 (MEX 69-290): clones 3 (COLPOSCTMEX 09-1433), 11 (LTMEX 94-02), 2 (MEX 95-59), 9 (EMEX 91-117), and 10 (MOTZMEX 00-1192), with yields of 136,225, 130,850, 126,300, 119,225, and 114,775 t ha^{-1}, respectively.

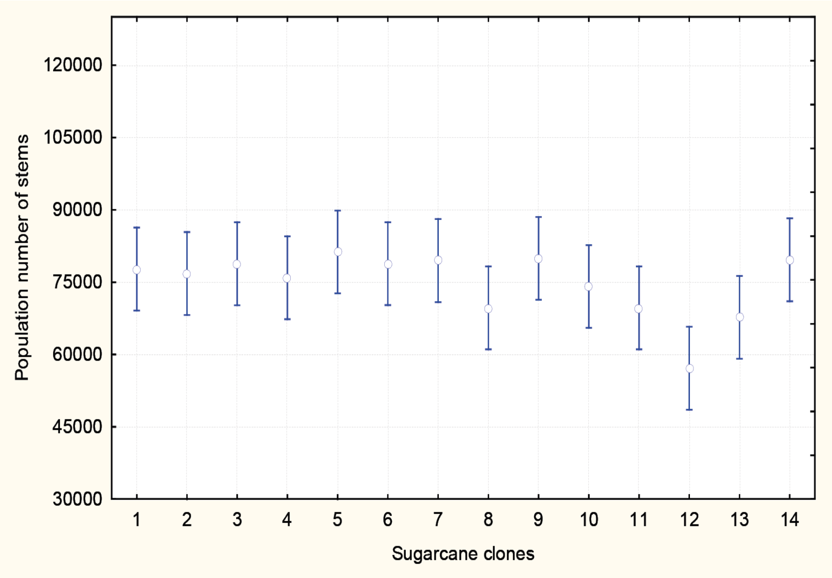

Figure 2. Stalks population per hectare in 14 clones evaluated in the adaptability phase (vertical bars indicate the 95% confidence interval).

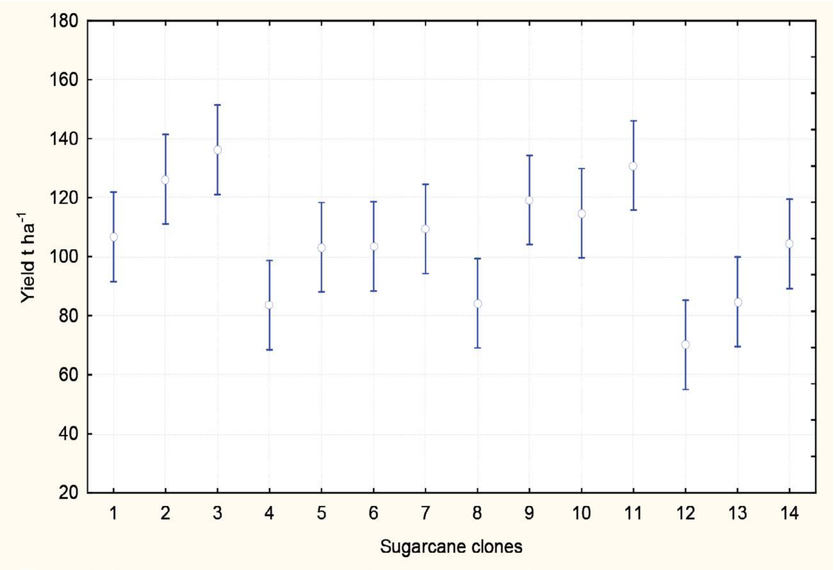

Figure 3. Yield in t ha^{-1} of the 14 clones evaluated in the adaptability phase (vertical bars indicate the 95% confidence interval).

Yield is a compound variable in which substantial changes can occur from one cycle to another (first cycle to second regrowth), mainly influenced by the environment, the genetic characteristics of the clone, and crop management. In sugarcane fields, yield is expressed in tons of sugarcane per hectare (García, 1981).

Industrial parameters

Sucrose

There were statistical differences regarding the sucrose percentage between the 14 clones evaluated (Figure 4). Clone 12 recorded the highest percentage of sucrose concentration (MEX 96-10), which was significantly higher than the others. Clones 2 (MEX 95-59), 6 (EMEX 91-917), 7 (Mex 09-82), and 9 (EMEX 91-117) showed the lowest concentration, with values which were statistically equal between each other and significantly lower than those found in the other clones. Both clones 12 (MEX 96-10) and 3 (COLPOSCTMEX 09-1433) recorded higher sucrose contents than the two control clones.

Sugarcane is considered mature or adequate for industrial processing, as long as its juice has a $\geq$13% concentration of sucrose (Larrahondo and Villegas, 1995). Ripening is the process by means of which sucrose accumulates in the stalk and it requires a decrease in the speed of growth to favor the accumulation of the sugars produced during the photosynthetic activity (Larrahondo, 1995). Martínez (2012) pointed out that the harvest of the clone must take into account its maturity, in order to take advantage of the maximum concentration of sucrose in the stalk and transform it into a greater amount of sugar. García (1981) mentions that sucrose is the sugar in sugarcane juice and other vegetables: it is a disaccharide (chemical formula: $C_{12}H_{22}O_{11}$) produced by condensation of equimolecular amounts of glucose and fructose. Clones with low levels of sucrose have high contents of reducing sugars (Larrahondo, 1995).

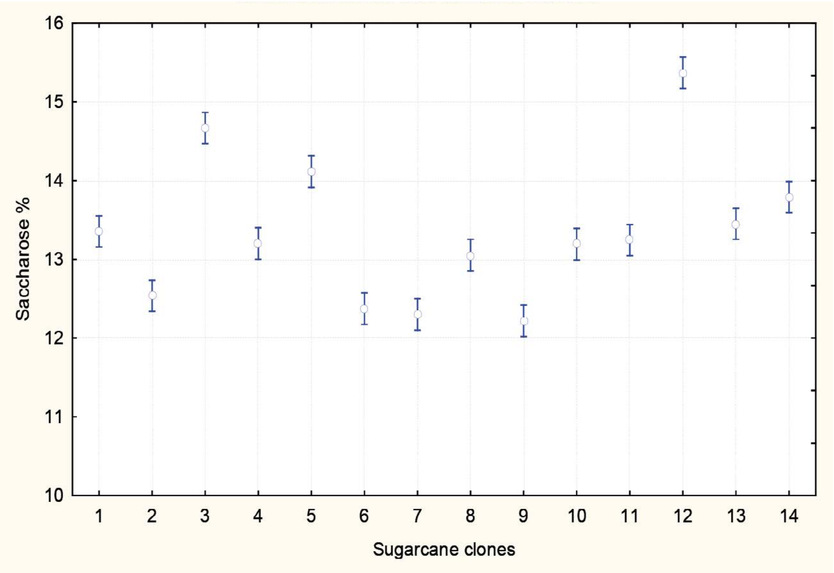

Figure 4. Sucrose concentration of 14 clones evaluated in the adaptability phase (vertical bars indicate the 95% confidence interval).

Juice purity

Statistical differences were recorded in juice purity between the clones evaluated. Clone 12 obtained the highest results (MEX 96-10), with a statistically similar value to clone 3 (COLPOSCTMEX 09-1433); both had significantly higher values than the rest (Figure 5). Clones 7 (MEX 09-82), 9 (EMEX 91-117), and 6 (EMEX 91-917) showed significantly lower juice purity.

García (1981) indicated that juice purity is the percentage of solids dissolved in the sugarcane juice. For his part, Larrahondo (1995) defines it as the percentage ratio between

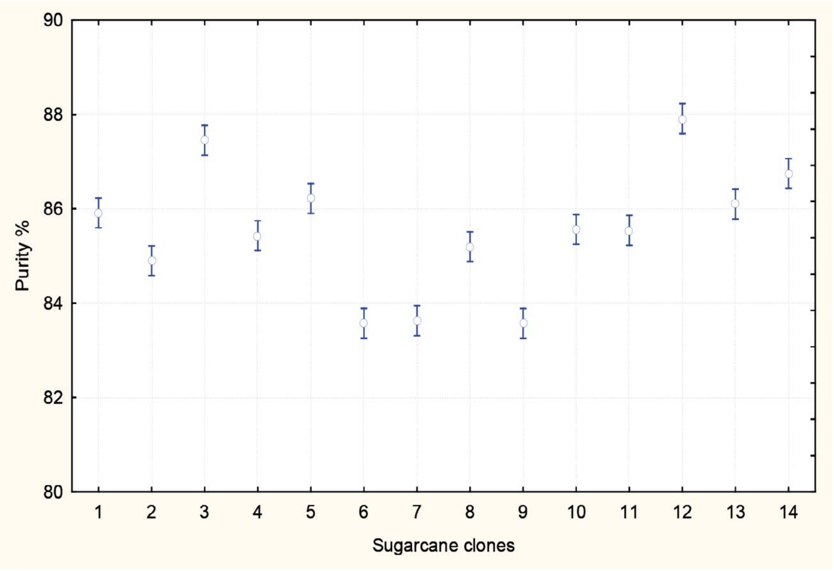

Figure 5. Juice purity in 14 clones evaluated in the adaptability phase (vertical bars indicate the 95% confidence interval).

the sucrose in the juice and the °Brix. The selection and genetic improvement program must discard individuals whose juice purity is below 85%.

Theoretical sugar production

Statistical differences were found among the 14 clones when the theoretical sugar production was determined (Figure 6). Clone 3 (COLPOSCTMEX 09-1433) showed a significantly higher theoretical sugar content (19.99 t ha-1), which was statistically different from the others, except for clones 2 (MEX 95-59) and 11 (LTMEX 94-02) (Figure 6). Clone 12 (MEX 96-10) showed the lowest production (10.77 t ha^{-1}); however, it had a statistically similar value to the other clones (1, 4, 5, 6, 7, 8, 9, 13, and 14) (Figure 6).

García (1981) indicates that theoretical sugar production is the amount of sugar that the factory can recover from a clone, based on the specific weight of the sugarcane stalks, as well as the extracted juice, whose sucrose concentration is known. Larrahondo (1995) mentions that the quality of a clone is determined at the time of milling, based on the amount of recoverable sugar obtained per tonne of milled sugarcane. The theoretical sugar production is made up of two parameters: the agricultural (yield) and the industrial (sucrose) parameters. As the basis on which sugarcane producers paid, it is extremely important for the recommendation of a clone for commercial cultivation. Clones 3 (COLPOSCTMEX 09-1433) and 11 (LTMEX 94-02) showed a statistically higher theoretical sugar yield than control clone 13 (MEX 69-290). The theoretical sugar concentration in clone 3 was significantly higher than in the two controls (MEX 69-290 and CP 72-2086). However, the values found for all clones are within the acceptable range (IMPA, 1988).

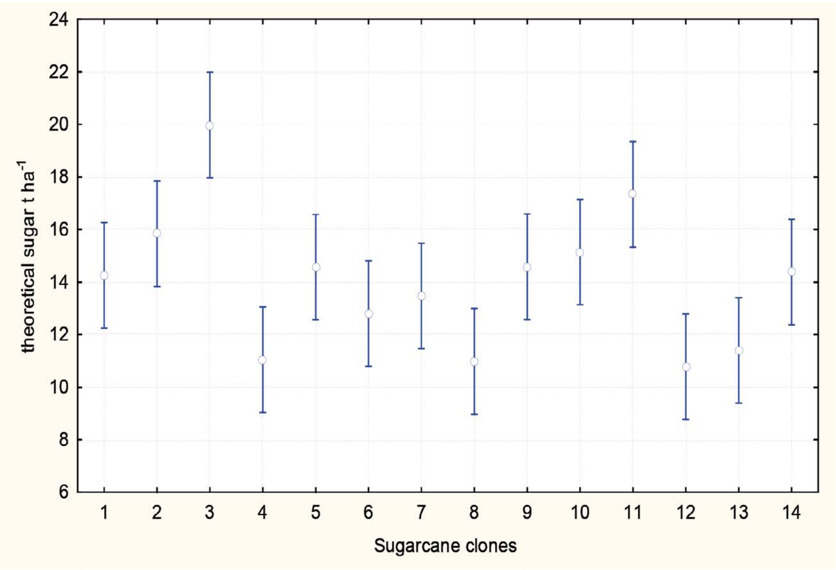

Figure 6. Theoretical sugar production of 14 clones evaluated in the adaptability phase (vertical bars indicate the 95% confidence interval).

CONCLUSIONS

Four of the sugarcane clones evaluated in this research work showed high field and factory yields: COLPOSCTMEX 09-1433, LTMEX 94-02, MEX 95-59, and MOTZMEX 00-1192. The COLPOSCTMEX 09-1433 clone significantly outperformed the two control clones (MEX 69-290 and CP 72-2086) in theoretical sugar production. The LTMEX 94-02 clone significantly outperformed the control clone MEX 69-290 in the said variable. In terms of field yield, the clone COLPOSCTMEX 09-1433 significantly outperformed the two control clones. All four clones produced statistically higher values than those observed in the MEX 69-290 clone. Consequently, the evaluation and multiplication of the four clones must be continued during the semi-commercial test phase, along with their observation in the field. However, since they were introduced to the area, their ongoing evaluation should continue under the usual environmental conditions of the region.

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