AP AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Agro-industrial evaluation of new sugarcane (*Saccharum* spp.) hybrids in the dry tropic under no watering conditions

Cervantes–Preciado, J.F.[1*]**; Alcaraz-Tapia, P.A.**[2]**; Reyes-Castillo, A.**[1]**; Orozco-Gutiérrez, G.**[1]

[1] Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP), Campo Experimental Tecomán, Carretera Colima-Manzanillo km 35, Tecomán, Colima, México, C. P. 28930.
[2] Ingenio Quesería S.A. de C.V., Grupo Azucarero Beta San Miguel (BSM), Juan M. Cárdenas # 1, Quesería, Colima, México, C.P. 28510.
* Correspondence: cervantes.jeovani@inifap.gob.mx

ABSTRACT
Objective: To select new sugarcane (*Saccharum* spp.) hybrids with better adaptability and higher field and industrial performance, within the supply area of the Quesería Sugar Mill of the Beta San Miguel group (BSM).
Design/methodology/approach: We set up a group of 11 new hybrids in the agro-industrial phase in order to compare their adaptability and their field and industrial performance, using the Mex 69-290 commercial hybrid as control.
Results: The obtained results indicated that during the soca cycle and under local soil conditions, the ColMex 05-484, ColMex 05-38 (C9), and ColMex 05-627 hybrids produced the highest estimated field yields, with values of 154, 149, and 143 t/ha^{-1}, respectively. The highest percentages of sucrose in cane (Pol) in 12-month-old plants were observed in the ColMex 05-147 (16.8%), ColMex 08-38 (C8) (16.5%), and ColMex 05-897 (16.1%) hybrids, according to their intermediate stage maturity curve.
Study limitations/implications: The limitations that could affect the results of the research were the abundance of stones on the topsoil and the poor distribution of rainfall during crop development (1,203 mm).
Findings/conclusions: After analyzing the agricultural and industrial performance of several hybrids, we can conclude that ColMex 05-484 was the best, surpassing the Mex 69-290 commercial control.

Keywords: Sugarcane, Field Yield, Sucrose, Dry Tropic.

Citation: Cervantes–Preciado, J.F., Alcaraz-Tapia, P.A., Reyes-Castillo, A., & Orozco-Gutiérrez, G. (2022). Agro-industrial evaluation of new sugarcane (*Saccharum* spp.) hybrids in the dry tropic under no watering conditions. *Agro Productividad*. https://doi.org/10.32854/agrop.v15i2.2079

Editor in Chief: Dr. Jorge Cadena Iñiguez

Received: July 7, 2021.
Accepted: January 23, 2022.
Published on-line: March 1, 2022.

Agro Productividad, 15(2). February. 2022. pp: 41-48.

INTRODUCTION

Sugarcane (*Saccharum* spp.) is the main source of sugar among developing countries (Rodríguez, Castillo, and Flores, 2005). Most of the world's sugarcane is produced in the Americas (54% of the world total). Mexico is the sixth largest producer, with an average of 55 million tons (FAOSTAT, 2017). Over 164,000 Mexican producers grow sugarcane in 15 states (CONADESUCA, 2016). Annually, the sugarcane agro-industry benefits over two million people, both directly and indirectly. During the 2018/19 sugar harvest, a surface of approximately 805,000 ha was cultivated, with an average production of 70.81 t ha^{-1} (CONADESUCA, 2019). Although Colima does not stand out as one of the largest sugarcane producer states, it has better yields than the national average (for both rainfall and irrigation agriculture), with 80 t ha^{-1}.

Image by Joseph Mucira at Pixabay

Creating new varieties is one of the main technological priorities of sugarcane producers and industrialists in the country (Moreno, 2010). Hence the need to expand and/or renew the number of commercial varieties. The currently grown varieties have been used for over 30 years, which makes them more vulnerable to plagues and diseases, incapable of adapting to edaphoclimatic changes, prone to have a low productivity and, as a result, to present decreased crop yields.

In this context, following an experimental process —that comprised the variety hybridization and selection stages, during an evaluation period of 14 and 15 uninterrupted years (Sentíes *et al.*, 2016)—, the national genetic improvement program obtained high agro-industrial yield cultivars for some sugarcane areas of the country. In Campeche, through the agro-industrial evaluation of new varieties, Vera *et al.* (2016) found that CP 94-1674 and SP 83-5073 achieved a better cane and sucrose production than commercial varieties. Likewise, after evaluating a group of new varieties in Guatemala, Ronald (2015) found that CP 73-1547 was the highest yielding variety across four altitudinal strata. Therefore, the objective of this research was to select new sugarcane hybrids with better adaptability and field and industrial performance, in Ocotillo, municipality of Cuauhtémoc, Colima, Mexico, located within the supply area of the Ingenio Quesería S.A. de C.V. (Quesería Sugar Mill) of the Beta San Miguel group (BSM).

MATERIALS AND METHODS

Study area. The study was conducted within the supply area of the Quesería Sugar Mill, in Ocotillo, Cuauhtémoc, Colima, Mexico. The plot is located at 19° 19' 33" N and 103° 40' 15" W, at 839 meters above sea level (masl). The edaphoclimatic conditions of the site are: sandy loam soil; light stoniness at a depth of no more than 30 cm; warm and humid weather with summer rains; average annual temperature of 23.7 °C; and an approximate annual rainfall of 1,200 mm (Figure 1).

Figure 1. Geolocation of the new sugarcane hybrids trial site, at Ocotillo, Colima.

Study phase. We evaluated the agro-industrial phase —*i.e.*, the last research stage in the selection of new sugarcane hybrids. In this phase, a small number of hybrids —with their respective regional control(s)— are evaluated in trials under experimental design.

Evaluated hybrids. We established a group of 11 new sugarcane hybrids derived from Fuzz seeds (generation 2005) which we compared to the Mex 69-290 commercial control during the soca cycle (Table 1). We suggested the new hybrids included in this study based on their outstanding agro-industrial characteristics. These features had been observed during the previous ten years of evaluation at the INIFAP's Campo Experimental Tecomán and Sitio Experimental Costa de Jalisco.

Experimental design. We chose a randomized block design with four repetitions. The experimental unit or plot had five 8 m (long) × 1.20 m (wide) furrows. The useful plot had three 8-m long furrows.

Evaluated variables. Using the Pol ratio method, the sucrose percentage and the theoretical sugar estimate were determined in the laboratory for each variety in 10 to 12-month-old plants. This method was designed and implemented in late 1959 at the Los Mochis Sugar Mill, in Sinaloa, by Mr. R. P. Humbert, and was adopted by the IMPA for its research work. The main objective of this method is to determine, based on a sample of milling stalks, the sucrose percentage in cane, the fiber percentage, and the moisture and reducing sugars percentages in section 8-10, in order to evaluate the sucrose and fiber contents of each treatment (Rodríguez, 2005). The sampling was done in the two lateral furrows of the experimental plot. Subsequently, the maturity curve of each hybrid was traced. Following IMPA's methodology, the population of milling stalks per hectare was evaluated in the field with 12-month-old plants. This was done by sampling three 8-m long furrows. The field yield estimate was also obtained, as were the local climatic conditions (annual v. historical rainfall).

Statistical analysis. The SAS statistical program was used to carry out an analysis of variance (ANOVA) of the treatments (hybrids). A Tukey test (5%) was used to compare means and the hypothesis were tested using the F test.

RESULTS AND DISCUSSION

Characterization of rainfall: historical and during the study. A large part (77.45%) of the Quesería Sugar Mill's supply area is classified as rainfall zone (12,313 ha); it is mainly located in northern Colima and in some municipalities of southern Jalisco. Another

Table 1. List of new sugarcane hybrids evaluated at Ocotillo, Colima, within the supply area of the Quesería Sugar Mill.

Hybrid and clone	Origin	Hybrid and clone	Origin
ColMex 05-542 (C1)	Fuzz	ColMex 05-484 (C3)	Fuzz
ColMex 05-627 (C10)	Fuzz	ColMex 05-147 (C9)	Fuzz
ColMex 05-89 (C1)	Fuzz	ColMex 05-38 (C8)	Fuzz
ColMex 05-129 (C3)	Fuzz	ColMex 05-897 (C6)	Fuzz
ColMex 05-437 (C1)	Fuzz	ColMex 05-977 (C7)	Fuzz
ColMex 05-38 (C9)	Fuzz	Mex 69-290	Testigo

17.90% of the surface is cultivated using deep irrigation (2,846.9 ha); this area is located in the central and southern part of Colima and its water sources are the Peñitas and Ámela irrigation units. Therefore, only 4.65% of the surface is cultivated with auxiliary irrigation (740 ha): approximately two or three rounds of surface irrigation are applied during the most critical periods of the crop cycle (March-May).

Figure 2 shows the behavior of historical monthly rain precipitation (2007-2019) as compared to rainfall during the months when the crop was developed. Historically, the rainiest months were June-October, with an average water volume of 1,123.6 mm: 92% of the rain precipitation during those months. Figure 2 also shows that rainfall during the development of the crop and the evaluation of the new sugarcane hybrids behaved similarly to the historical data: the rainiest months were June-October, with a water accumulation of 1,094 mm (90%) during the said period. Additionally, compared with the consumptive use and/or water requirements of the sugarcane crop for the different months of its productive development (1,712.2 mm per year), the remaining months (November-May) had a rain shortage of 926 mm. Meanwhile, a 417 mm rain excess (non-usable water) took place only during the months of June-October. Therefore, according to the calculations, 785.6 mm of usable water was available during the study: *i.e.*, 926.6 mm of water were needed. This could have affected the agro-industrial crop yields for each of the evaluated hybrids.

Milling stalk population. This is one of the most relevant variables, as a result of its direct impact on the field yield potential. As Hernández (2004) points out, in addition to stalk population, components such as plant height and stalk diameter have an impact on the field yield, and they must be considered as distinctive characteristics of the varieties in the late stages of selection. Meanwhile, Viveros *et al.* (2014) used path analysis to show that sugarcane tons per hectare have a high correlation with stalk population and diameter; in other words, high plant populations and thick stalk diameters are required to achieve a large sugarcane production. The analysis of variance (ANOVA) results for this variable (Table 2) shows a highly significant difference between treatments, although not for repetitions,

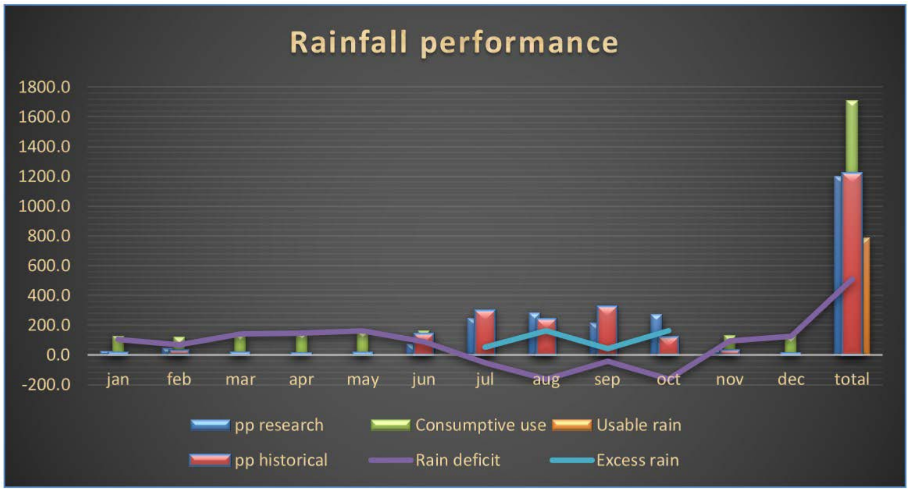

Figure 2. Monthly rainfall averages at the Quesería Sugar Mill, historically and during the sugarcane hybrid study.

Table 2. Analysis of variance of milling stalks and field yield estimate for the new sugarcane hybrids trial at Ocotillo, Colima, Mexico.

Variation source	DF	Calculated F		Table F		Pr>F	
		Population	Yield	0.05	0.01	Population	Yield
Treatment	11	7.01	19.35	2.10	2.87	0.0001 **	0.0001 **
Repetition	33	0.68	1.06	2.89	4.44	0.5714 NS	0.3812 NS
Error	33						
Total	47						
C.V.		9.87	9.90				

DF : Degrees of freedom; C.V. : Coefficient of variation.
When the value of F calc. (calculated F) is lower than F tabla (tabulated F) (5%), there is no Significant Difference (NS).
When the value of F calc. is equal to or higher than F tabla (5%), but lower than (1%), there is a Significant Difference (*).
When the value of F calc. is higher than or equal to F tabla (1%), there is a Highly Significant Difference (**).

with values of 0.0001 and 0.5714, respectively. The 9.87% Coefficient of Variation (CV) indicates that the trial data are reliable.

In the mean grouping based on the Tukey test (5%) of the milling stalk population (Figure 3), the ColMex 05-129 and ColMex 05-38 (C8) hybrids stand out with values of over 109,000 and 108,000 stalks/ha, respectively. However, based on the Least Significant Difference (DMS) (22,327 stalks), the five subsequent hybrids are statistically equal, with an average of 95,000 stalks. The remaining evaluated hybrids (41.66%) are statistically inferior to the abovementioned, which include the Mex 69-290 commercial control, whose nearly 85,000 stalks/ha are lower than the 24,000 and 23,000 stalks of the ColMex 05-129 and ColMex 05-38 (C8) hybrids, respectively, which were the most outstanding hybrids (Figure 3).

Field yield. In the case of this trial and under the edaphoclimatic conditions of Ocotillo, Colima, Table 2 shows a significant difference between treatments, although not for repetitions, with values of 0.0001 and 0.3812, respectively. The coefficient of variation yielded a result of 9.90%, which indicates that the experiment results are good and reliable. Figure 4 shows that three groups (A, B, and C) were formed according to

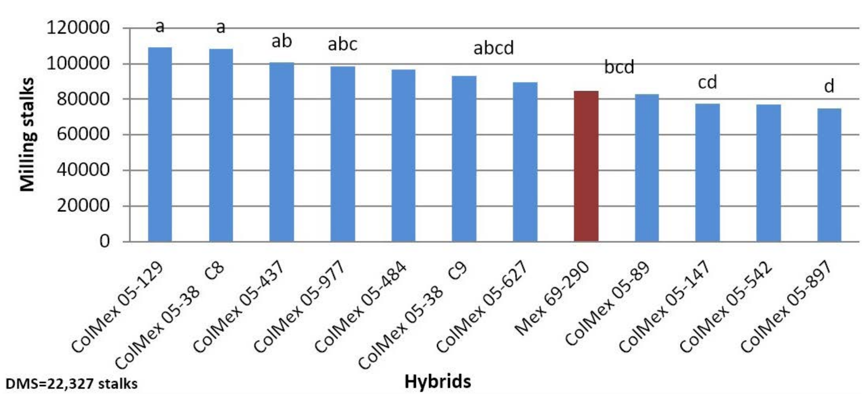

Figure 3. Milling stalks population per hectare for 12-month-old plants at Ocotillo, Colima.

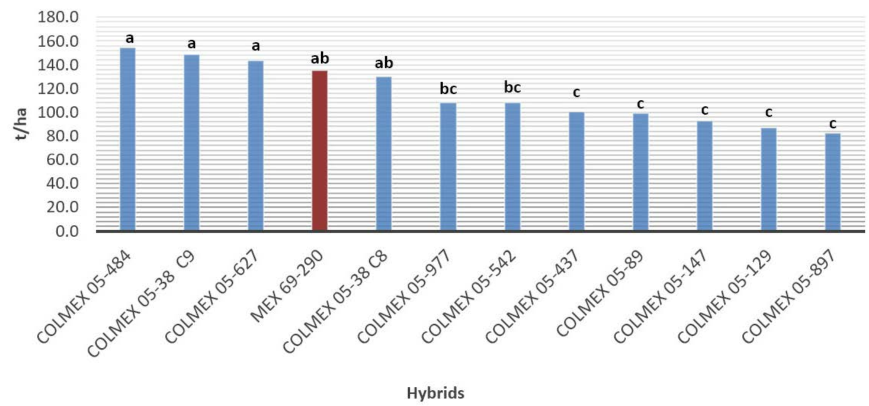

Figure 4. Estimated yield per hectare in 12-month-old plants at Ocotillo, Colima.

the mean grouping by the Tukey test (5%), with 12-month-old plants. The ColMex 05-484, ColMex 05-38 (C9), and ColMex 05-627 hybrids stand out with values of 154, 149, and 143 t ha^{-1}, respectively. However, based on the DMS that resulted from the analysis (28.49 t), the subsequent two hybrids are statistically equivalent; one of them is the Mex 69-290 commercial control, with a value of 135 t ha^{-1}. The remaining evaluated hybrids (41.66%) are statistically lower than the aforementioned, with a field yield average of 96.97 t/ha, although their value surpasses the national yield by 25 t ha^{-1}. Cervantes *et al.* (2017) reported that the new varieties include a group of weather, soil, and management variables that have a noticeable influence on the behavior of field and factory yields.

Sucrose percentage (Pol). The sucrose content in cane is one of the most important components during the harvest: it is associated with high field yields and a high factory efficiency. The larger the amount of sugar obtained in the agro-industry, the higher the price offered to the producer per ton of sugarcane. Figure 5 shows the sucrose percentages of the new hybrids studied for the trial at Ocotillo, Colima, among which the ColMex 05-147, ColMex 05-38 (C8), and ColMex 05-897 hybrids stand out; their values increased

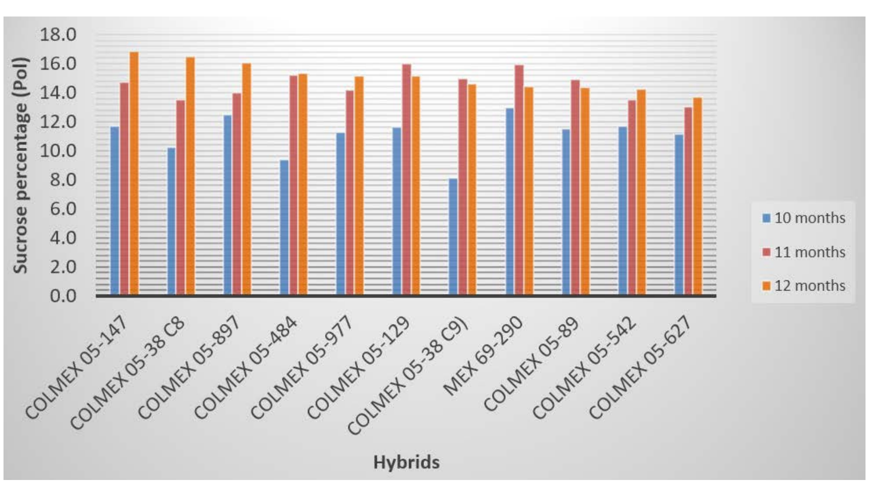

Figure 5. Industrial analysis (Pol) of 10- to 12-month-old plants for the new sugarcane hybrids, agro-industrial phase, at Ocotillo, Colima.

during the 10th to 12th months of plant growth, reaching >16% sucrose in cane values during the last month. Meanwhile, the sucrose content of the Colmex 05-129, ColMex 05-38 (C9), Mex 69-290, and ColMex 05-89 hybrids clearly decrease in month 12, which means that the hybrids of this study area have an early to late-intermediate maturity stage. The remaining evaluated hybrids have an intermediate to late maturity stage behavior, where the harvest is usually carried out in March-June (depending on the calendar of each of the country's sugar mills). Studies conducted in the Jalisco region by García-Preciado *et al.* (2017), which included two evaluation cycles, showed that the sucrose content of some new hybrids match the content of some of the materials shown in Figure 3. In this respect, Chávez (1982, quoted by García *et al.* (2017)) mentions that sucrose in sugarcane presents an inverse linear correlation with the moisture content. Therefore, further evaluations are necessary to determine maturity curves (Delgado *et al.*, 2012). In addition, considering the interaction of edaphic, climatic, and management aspects of the behavior or response of a new material to a specific environment (Cervantes *et al.*, 2017) is vital for the distribution of the new hybrids.

CONCLUSIONS

After analyzing the agricultural and industrial behavior of the new hybrids during the soca cycle and under the local edaphoclimatic conditions, the ColMex 05-484, ColMex 05-38 (C9), and ColMex 05-627 hybrids had the highest estimated field yields, with values of 154, 149, and 143 t ha^{-1} respectively. The hybrids with the highest sucrose percentage in cane (Pol), in 12-month-old plants, were: ColMex 05-147 (16.8%), ColMex 08-38 (C8) (16.5%), and ColMex 05-897 (16.1%), according to their intermediate-stage maturity curve. Finally, a well-distributed annual rainfall is an important factor that has a direct impact on field yield.

REFERENCES

Cervantes P. J.F., Milanés R.N y García P. J.C. (2017). Trabajo en extenso "Evaluación de rendimiento de campo de 11 nuevos híbridos de caña de azúcar en la región central del estado de Veracruz". Boca del Rio, Veracruz, México. Pág. 113-118.

Comité Nacional para el Desarrollo Sustentable de la Caña de Azúcar (CONADESUCA). 2016. Nota informativa sobre innovaciones en materia de productividad del sector. junio de 2016. Nuevas variedades de caña de azúcar. México D.F. 16 p.

Comité Nacional para el Desarrollo Sustentable de la Caña de Azúcar (CONADESUCA). 2019. Reportes Balance de caña cosechada y de molienda. Zafra: 2018-2019. Disponible en: 28/12/2019. campo,datoacumulado.https://www.siiba.conadesuca.gob.mx/infocana/Consulta/Reporte.aspx?cr=64&lstZaf=2019+++&mZafra=1&numero=0&mNumeno=1&recorrer=1&mSector=1&mIngenio=1&limitI=75&lstEst=14&mEstado=1&f=2&acu=1.

Delgado-Mora I, Suárez H. J., García-Pérez H., Bernal-Liranza N., Díaz-Mujica F. R., Bernal-Villegas A., Gómez-Pérez J. R., Aday-Díaz O., González-Gallardo H., Buedo-Domínguez M., Reyes-Pérez S., Núñez- Jaramillo D., Barroso-Medina J. y Machado-Toledo L. F. (2012). Potencialidades de familias de variedades de caña de azúcar para diferentes períodos de zafras en Cuba. *Cultivos Tropicales*, vol. 33, no. 3, p. 5-14.

García-Preciado J.C.; Álvarez-Cilva M.; Guzmán-Martínez M.; Cervantes-Preciado J.F.; Bermúdez-Guzmán M.J. (2017). Evaluación de variables de calidad en híbridos de *Saccharum* spp. en diferentes ambientes agroecológicos de Jalisco, México. Agroproductividad. 10, (11). 105-111.

Moreno T., V. M. 2010. Nuevas variedades de caña de azúcar. Programa de Documentación de Casos de Éxito. Fundación Produce Colima A. C., IICACOFUPRO 2010. Colima Col. 57p.

Rodríguez-H., A. M, Castillo-C., M. A., & Flores-B., E. P. (2005). Diversidad genética de los cultivos de caña más importantes de México. e-Gnosis, 3, 1-10.

Rodríguez, R. F. (2005). Métodos y sistemas aplicados en el laboratorio de campo del ingenio José María Martínez de Tala, Jalisco. Guía didáctica. Centro universitario de Ciencias Biológicas y Agropecuarias. Universidad de Guadalajara. 62p.

Ronald-Gamaliel, R. G. (2015). Evaluación del rendimiento comercial de variedades de caña de azúcar (*Saccharum officinarum*) según estratos altitudinales y tipos de suelo, Ingenio Pantaleón, Guatemala. E.A.P. Zamorano Honduras. 37 p.

Sentíes H., H.E., F.C. Gómez M. y R. Loyo J. 2016. El Mejoramiento Genético de la Caña de Azúcar (*Saccharum* spp.) en México: una Historia de Éxito con Nuevos Desafíos. Agroproductividad. 9 (2): 9-15.

Vera-Espinosa, Carrillo Á. E., Flores Cáceres. S., Arreola E. J., Osnaya G.M. y Castillo A.C.D.C. (2016). Evaluación agroindustrial de diez variedades de caña de azúcar (*Saccharum* spp) Articulo en revista Agroproductividad. 9(3). 21-26.

Viveros, V. C. A., Baena, G. D., Fredy Salazar, V. F., López, L. O. y Victoria, K. J. I. (2014). Características de la caña de azúcar asociadas con toneladas de caña por hectárea y sacarosa (% caña). Mejoramiento Genético Vegetal y Recursos Fitogenéticos / Plant Breeding and Plant Genetic Resources. Colombia. Acta Agronómica. 642015, p 268-272. Doi: 10.15446/acag.v64n3.44494