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Description of cultivar

Dulcina: a new variety of sweet sorghum for Tamaulipas and central Nuevo León

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Abstract

Sweet sorghum is an excellent potential source for bioethanol production due to its hardiness, tolerance to drought and high temperatures and adaptation to marginal regions. It provides renewable energy capable of supplanting fossil fuels. Crosses between contrasting genotypes were made at the Marín *Campus* of the Faculty of Agronomy of the Autonomous University of Nuevo León during the autumn-winter 2009-2010 cycle. Dulcina originated from the cross of SBB-25 x Rox Orange, which was subjected to the method of furrow per panicle or pedigree from the F_2 generation for four generations. The selection (SBB-25 x Rox Orange) 17-1-1-1 was registered with the CNVV on January 21, 2021, under the name Dulcina. It adapted favorably in central Nuevo León and Tamaulipas. The panicles are compact, with small grains, orange in color, of intermediate cycle (74.4 to 87.1 days to flowering), with a bioethanol production between 2 614 to 3 925 L ha^{-1}, higher than the best control by 6.1 to 32.3%, equivalent to 191 to 959 L ha^{-1}. It also had tall plants (221 to 235 cm) and a sugar content of 16.4 to 20.4 °Brix. In southern Tamaulipas, Dulcina was more tolerant of lodging than Keller and RB-Cañero. It was tolerant to leaf blight [*Helminthosporium turcicum* (Pass.) Leo and Suggs] and anthracnose [*Colletotrichum graminicola* (G.E. Wilson)] and was superior ($p \leq 0.05$) to Keller.

Keywords:

bioethanol production, brix, sweet sorghum.

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Mexico has optimal agroecological conditions for the production of sweet sorghum. The states with the largest potential area are Veracruz, Campeche, Tamaulipas, Tabasco, Guanajuato, Sonora, Sinaloa, Nuevo León, Michoacán, Chihuahua, and Quintana Roo (Ramírez-Jaramillo *et al*., 2020). The state of Tamaulipas is the largest producer of sorghum in Mexico; in 2021, it grew 1 000 000 ha, 80% under rainfed conditions (SIAP, 2022).

Rising prices in the global market of fossil fuels and growing demand and its instability make renewable fuels economically viable (Khawaja *et al*., 2014). Another important factor is that oil reserves are finite (Serna *et al*., 2011). To reduce the world's dependence on fossil fuels, renewable fuel alternatives, such as bioethanol production, have been developed. Sweet sorghum is a potential source for bioethanol production.

Compared to other crops, it provides high biomass yield and high sugar/ethanol yield, and it has the ability to grow in marginal areas (Tang *et al*., 2018). The generation of new genetic materials is required for the development of a bioenergy industry that allow the migration towards a more sustainable system in the medium term (Moreno-Hernández *et al*., 2018). Since 2006, the Faculty of Agronomy of the Autonomous University of Nuevo León has carried out research in genetic improvement of sweet sorghum.

During the autumn-winter (A-W) 2009-2010 cycle at the Marín *Campus*. Dulcina was obtained by genetic recombination and selection (Table 1). The germplasm that gave rise to this variety was the fertility-maintaining elite-grain line SBB-25, which was developed in Mexico by the National Institute of Forestry, Agricultural, and Livestock Research (INIFAP, for its acronym in Spanish)-Río Bravo Experimental Field, it is the progenitor of the following commercial hybrids: RB-4000, RB-Patrón, and RB-Huasteco (Williams-Alanís *et al*., 2017). The sweet and forage sorghum variety Rox Orange or Waconia was generated by the Wisconsin Agricultural Experiment Station, USA (Ali *et al*., 2008).

Table 1. Outline of the process for obtaining Dulcina.

Year and cycle	Process
A-W/2009-2010	SBB-25 x Rox-Orange cross. Obtaining F_1 seed
S-S/2010	Sowing F_1 seed and obtaining F_2 seed
A-W/2010-2011, S-S/2011, A-W/2011-2012, and S-S/2012	Sowing F_2, F_3, F_4, and F_5 seed, where the method of selection of furrow per panicle or pedigree was applied
A-W/2012-2013	Seed increase and standardization. Obtaining the experimental variety (SBB-25 x Rox Orange) 17-1-1-1
S-S/2013-2022	Evaluation. This variety was called Dulcina

The F_1 cross of SBB-25 x Rox-Orange was made during the A-W/2009-2010 cycle and the F_2 seed was obtained during the S-S/2010 cycle. During the cycles of A-W/2010-2011, S-S/2011, A-W/2011-2012, and S-S/2012, in the F_2, F_3, F_4 and F_5 generations; the method of selection of furrow per panicle or pedigree was applied by self-fertilizing tall plants with thicker stems without lodging and with tolerance to foliar diseases, with a sugar content in the juice between 15 and 20.5 °Brix.

To complete the formation of the varieties during the A-W/2012-2013 cycle, the seed was increased by self-fertilizing plants with similar phenotypic characteristics. The best 10 varieties (visual selection) were evaluated in experiments, which were planted in four environments in southern Tamaulipas (Cuauhtémoc Station) and four environments in central Nuevo León (Marín), where the commercial varieties Keller (USA) and RB-Cañero (INIFAP) served as controls.

At a later date, a third trial was designed and evaluated in three environments in northern Tamaulipas, which was compared to the INIFAP controls. In the evaluations of the three localities, the experimental variety (SBB-25 x Rox Orange) 17-1-1-1 stood out, which was called Dulcina. It has compact panicles, with small grains, orange in color, 26.2 cm in panicle length, 16 cm in exsertion, with an intermediate cycle (74.4 and 87.1 days to flowering).

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In central Nuevo León, it had a later cycle than Keller, the tall plants (227 to 230 cm) were similar to the commercial controls. Williams-Alanís *et al*. (2017) mentions that the tallest, sweet sorghums are the most productive. The sugar content in the stem juice was 6.6 to 20.4 °Brix, ranging from -3.4 to 13.3% compared to Keller, the best commercial control (Tables 2, 3 and 4). In northern Tamaulipas, Dulcina (20.6) was higher in °Brix than the controls RB-Tehua (17.6) and RB-Cañaveral (18.2). Elangovan *et al*. (2014) states that the characteristics of juice production and °Brix are very important for the production of bioethanol.

Table 2. Agronomic characteristics of sweet sorghum in central Nuevo León (Marín). Averages of four environments from 2014 to 2017.

GEN	DF	PH	°Brix	TPWKH	SWKH	JWKH	BIO
Dulcina	87.1 a	227 a	16.4 a	37 685	29 431	15 300	2 614 a
Keller	82.1 b	230 a	16.3 a	34 514	24 267	13 065	2 174 a
RB-Cañero	79.6 c	215 b	9.9 b	30 119	21 695	11 895	1 140 b
%OBC	6	-1.3	0.06	9.1	21.2	17.1	20.2
CV	1.18	4.49	12.6	22.4	23.79	26.11	27.62

Different literals indicate a statistically significant difference (Tukey, $p \leq 0.05$). %OBC= % over the best control; CV= coefficient of variation; GEN= genotype; DF= days to flowering; PH= plant height; °Brix= soluble solids; TPWKH= total plant weight kg ha^{-1}; SWKH= stem weight kg ha^{-1}; JWKH= juice weight kg ha^{-1}; BIO= production of bioethanol L ha^{-1}.

Table 3. Agronomic characteristics of sweet sorghum in southern Tamaulipas (Cuauhtémoc Station, Las Huastecas Experimental Field). Averages of four environments from 2013 to 2014.

GEN	DF	PH	°Brix	TPWKH	SWKH	JWKH	BIO
Dulcina	75.8 b	221	17 a	44 407	35 203	22 136	3 306 a
Keller	74.8 b	206	17.6 a	49 968	32 425	19 124	3 115 a
RB-Cañero	81.8 a	226	8.6 b	36 252	28 421	18 706	1 278 b
%OBC	-7.3	-2.2	-3,4	-11.1	8.5	15.7	6.1
CV	4.27	14.32	9.7	26.17	27.15	29.44	30.1

Different literals indicate a statistically significant difference (Tukey, $p \leq 0.05$). %OBC= % over the best control; CV= coefficient of variation; GEN= genotype; DF= days to flowering; PH= plant height; °Brix= soluble solids; TPWKH= total plant weight (kg ha^{-1}); SWKH= stem weight (kg ha^{-1}); JWKH= juice weight (kg ha^{-1}); BIO= production of bioethanol (L ha^{-1}).

Table 4. Agronomic characteristics of sweet sorghum in northern Tamaulipas (Río Bravo). Averages of three environments from 2021 and 2022.

GEN	DF	PH	°Brix	TPWKH	SWKH	JWKH	BIO
Dulcina	74.4	225	20.6 a	43 861	34 051	13 943	3 925 a
RB-Cañaveral	74.4	235	18.2 b	38 700	29 579	12 111	2 966 b
RB-Tehua	72	233	17.6 b	37 101	28 217	11 520	2 788 c
%OBC	0	-4	13.1	13.3	15.1	15.1	32.3
CV	2.98	6.9	8.02	19.9	21.63	27	25.35

Different literals indicate a statistically significant difference (Tukey, $p \leq 0.05$). %OBC= % over the best control; CV= coefficient of variation; GEN= genotype; DF= days to flowering; PH= plant height; °Brix: soluble solids; TPWKH= total plant weight (kg ha^{-1}); SWKH= stem weight (kg ha^{-1}); JWKH= juice weight (kg ha^{-1}); BIO= production of bioethanol (L ha^{-1}).

Dulcina presented values of TPWKH between 37 685 and 44 407 kg ha^{-1}, SWKH between 29 431 and 35 203 kg ha^{-1} and JWKH between 15 300 and 22 136 L ha^{-1}. They were above the control

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by 8.5 to 26.1%, except for TPWKH in southern Tamaulipas, which was 11.1% lower. Bioethanol production ranged from 2 614 to 3 925 L ha^{-1}, higher than the best control by 6.1 to 32.3%, equivalent to 191 to 959 L ha^{-1} more.

In norther Tamaulipas, Dulcina (3 925 L ha^{-1}) was higher ($p \leq 0.05$) than the commercial controls, RB-Cañaveral (2 966 L ha^{-1}) and RB-Tehua (2 788 L ha^{-1}), in bioethanol production (Table 4); bioethanol production was estimated according to the formulas described by Rakhmetova *et al*. (2020). Theoretical production of bioethanol L ha^{-1}= (°Brix sugar 100) x (0.65 L bioethanol 1 kg sugar) x (0.85) x (stem weight kg ha^{-1}).

In southern Tamaulipas (Table 5), Dulcina was more tolerant to lodging than Keller and RB-Cañero. Leaf blight [*Helminthosporium turcicum* (Pass.), Leo and Suggs and leaf anthracnose [*Colletotrichum graminicola* (Ces.) G.E. Wilson] occurred, and Dulcina was tolerant and was superior ($p \leq 0.01$) to Keller.

Table 5. Incidence of foliar diseases and classification of lodging in southern Tamaulipas. (Las Huastecas Experimental Field).

GEN	Dulcina	Keller	RB-Cañero	%OBC	CV
Lodging	2.2	3.2	3.7	31.25	23.7
Inc. of foliar diseases	2 a	2.6 b	2 a	14.5	15.4

Different literals indicate a statistically significant difference (Tukey, $p \leq 0.05$). GEN= genotype; %OBC= % over the best control; CV= coefficient of variation. Characteristics were rated visually from highest to lowest on a scale of 1 to 5.

The management of the crop should be carried out in accordance with the regional recommendations for commercial sorghum production of the irrigation technology package. All SNICS indications (sowing, isolation, demixig, etc.) must also be complied with in terms of seed production.

Dulcina is recommended for the lowlands (0-800 masl) of central Nuevo León and Tamaulipas. It was registered on January 13, 2021, with the breeder's title No. 2606 in the National Catalog of Plant Varieties (CNVV, for its acronym in Spanish). UANL has seed available for the increase of the variety.

Conclusions

Dulcina is recommended for the lowlands (0-800 masl) of central Nuevo León and Tamaulipas. The Faculty of Agronomy of the Autonomous University of Nuevo León has seed for the increase of the variety. The variety is part of the growing number of sweet materials available in the country, constituting an important contribution to improve crop productivity.

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