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Registration of 'CI0947bmr' Sorghum

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Registration of 'CI0947*bmr*' Sorghum

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Abstract

The sorghum [*Sorghum bicolor* (L.) Moench] cultivar CI0947*bmr* (Reg. No. CV-137, PI 672153) was jointly developed and released by the Centro Nacional de Tecnología Agropecuaria y Forestal (CENTA) research program in El Salvador and the Texas A&M Agrilife Research sorghum breeding program in 2013. CI0947*bmr* is a brown midrib (*bmr*), dual-purpose sorghum selected for productivity in Central American environments. CI0947*bmr* was developed from a pedigree breeding program, and it was derived from a BC_1F_2 population of the pedigree B03292*bmr*/Tortillero//Tortillero. All generation advancement and selection were completed in San Andres, El Salvador. To confirm performance of the line, CI0947*bmr* was evaluated in replicated yield trials in 10 Central American environments ranging from Panama to Guatemala in 2010 and 2011. Compared with Sureno (a non-*bmr* dual-purpose sorghum cultivar grown in the region), CI0947*bmr* is similar in maturity, dry biomass yield, grain yield, and composition, with lower concentration of lignin and higher in vitro dry matter digestibility and total digestible nutrients. Given these characteristics, CI0947*bmr* can be used for forage production (grazing and silage) or for grain production with the post-harvest plant residue suitable as forage. In addition, producers can save seed for replanting. This cultivar is designed to provide small livestock producers and dairies in Central America with access to sorghum forage with improved forage quality without sacrificing dry matter yield, grain yield, or grain quality.

The productivity of the Central American livestock industry is hindered by issues that include paucity of credit, inadequate infrastructure, and limited quality and quantity of forage or silage. Feed supply and quality are of critical importance; sorghum [*Sorghum bicolor* (L.) Moench] and maize (*Zea mays* L.) play a major role in meeting the feed requirements of dairy cattle in most crop–livestock farming systems in El Salvador, and quantity and quality of feed heavily influence milk productivity (Villacís, 2012). Most livestock producers in this region are small and have limited land resources. Consequently, most Central American countries import some of the dairy and meat products needed to meet the demands of an increasing population.

In addition, the environmental conditions in Central America make the production of high-quality forage challenging. First, the tropical environment hosts significant pest and pathogens that attack and reduce both yield and quality if they are not managed. Second, the seasonality of rainfall limits forage production during the dry season. The rainy period occurs between mid-May and mid-July; this season is the most productive for crops. A second cropping season is completed in the transitional period of August to November as rainfall frequency and amount drop and eventually stop until the following May. While not as productive as the rainy season, forage production is still important in the dry season.

Forage quality in Central America is low, and there remains a real need to improve it. Given the limited resources in the region, any improvement should be inherent to the crop itself. Forage sorghum quality in other regions of the world has been significantly improved through the integration of the brown midrib (*bmr*) trait. The presence of *bmr* results in reduced lignin concentration and improved forage quality (Bout and Vermerris, 2003; Saballos et al., 2008). To date, *bmr* sorghum cultivars have not been developed in Central America, where local adaptation is critical for productivity and their presence in varieties is critical as most producers do not have the economic means to use hybrids.

To meet this need, a breeding initiative to integrate the brown midrib trait into sorghum adapted to Central American was begun at the Centro Nacional de Tecnología Agropecuaria y Forestal (CENTA) in El Salvador in collaboration with the US-AID funded INTSORMIL project. The goal of this program was to develop a *bmr* sorghum cultivar adapted to Central America.

From this program, the sorghum cultivar CI0947*bmr* (Reg. No. CV-137, PI 672153) was identified and released because it possesses the unique combination of agronomic adaptation, biomass and grain yield, and improved forage quality due to the presence of the brown midrib trait. This cultivar is selfpollinated, and seed can be saved by the producer to maintain production. CI0947*bmr* provides Central American crop and livestock producers with a sorghum cultivar with improved forage quality forage and high yield potential.

Methods

CI0947*bmr* was developed at the CENTA research program located at San Andrés, San Salvador, El Salvador. The pedigree of CI0947 is B03292*bmr*/'Tortillero'//Tortillero. Tortillero is a Central America adapted line released by CENTA in 1989; it was a selection from the cultivar S-3. S-3 was a version of 'Sureno' (Meckenstock et al., 1993). B03292*bmr* is an experimental line from the sorghum breeding program of Texas A&M Agrilife research with a pedigree of BTxArg-1//BTx-623*bmr*/BTxArg-1. This line was selected for the presence of the *bmr12* trait and agronomic adaptation in College Station, TX, and Guayanilla, PR. BTx623*bmr* is an unreleased experimental line that was used as a source of the *bmr12* allele. BTx-Arg-1 is a dwarf, whiteseeded line released by Texas A&M Agrilife Research in 1991 (Miller et al., 1992).

The initial cross was made in summer 2005, and the backcross to Tortillero was made in the winter of 2005–2006. Selection and advancement from the F_2 to F_5 generation was completed in San Andres, El Salvador. Selection during each generation was based on the stable expression of the brown midrib trait and agronomic adaptability. Agronomic traits of importance included appropriate maturity and plant height, high grain yield and quality, and lodging and disease resistance. In the F_5 generation, multiple lines of this cross and several others were selected and bulked for advanced testing in the region as $F_{5:6}$ lines.

CI0947*bmr* was one of 15 experimental *bmr* lines evaluated for both grain and biomass yield in 10 environments to identify the most productive and stable line for release. The locations (and years evaluated) were San Andres, El Salvador (2010 and 2011); La Lujosa, Honduras (2010 and 2011); Zacapa, Guatemala (2010 and 2011); Managua, Nicaragua (2010 and 2011); Guanacaste, Costa Rica (2010); and Azuero, Panama (2010). The experimental design in each environment was a randomized complete block design with four replications and 16 genotypes (15 *bmr* genotypes and Sureno). Sureno is a non-*bmr* sorghum cultivar that is widely grown in the region. Trials were managed using local methods for sorghum, including fertilization, cultivation, and herbicide and pesticide applications. All trials were rainfed, and all harvest occurred at grain maturity. In each environment, the agronomic data collected included days to anthesis, plant height, lodging, dry matter yield, and grain yield.

At harvest, biomass and grain samples were collected for compositional analysis. For biomass composition, fiber parameters of acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent lignin (ADL), crude protein (CP) and total digestible nutrients (TDN) were estimated using nearinfrared analysis on a Foss XDS system with and calibration curves developed in the Texas A&M AgriLife Sorghum Breeding Program using a set of 200 forage sorghum samples. In vitro dry matter digestibility (IVDMD) estimates were made using the methodology described by Portillo (2013). Grain composition parameters of protein, starch, fiber, fat and ash content were estimated using near-infrared analysis on a Foss XDS system with and calibration curves developed within the Texas A&M AgriLife Cereal Quality Laboratory.

Statistical analysis was completed for data from each environment using genotypes and replications as independent variables. Data were combined across environments and analyzed using a mixed model with genotypes as a fixed effect and replications and environments as random effects. All statistical analysis was completed in SAS v9.2 (SAS Institute, 2008). When the genotype main effect was significant, differences between CI0947*bmr* and Sureno were tested using contrasts to eliminate variation from unrelated genotypes in the tests.

Characteristics

CI0947*bmr* was significantly different from Sureno in 3 of 10 environments for days to anthesis and 6 of 10 environments for plant height. In the combined analysis, the lines did not differ for either trait (Table 1). For dry biomass yield, CI0947*bmr* was similar to Sureno in the combined analysis; in individual environments, differences between the two cultivars were detected in four environments, with Sureno producing higher dry biomass yield in three of the four environments (Table 1). For grain yield, there was no difference between the two lines in the combined analysis, and Sureno was higher yielding only in Nicaragua 2011 (Table 1). Thus, the data indicate that CI0947*bmr* has similar agronomic productivity to Sureno across this region.

The forage quality of CI0947*bmr* was equal to or better than Sureno (Table 2). In the combined analysis, CI0947*bmr* was higher in IVDMD and TDN and lower in ADL than Sureno, and the two lines were not statistically different for ADF, NDF and CP (Table 2). In the individual environments, differences in ADF between CI0947*bmr* and Sureno were detected in five environments, with CI0947*bmr* lower in three of those environments. For ADL, CI0947*bmr* was lower in all nine environments, and for TDN, CI0947*bmr* was higher in four of five environments where differences were detected (Table 2). Differences in NDF were detected in only 3 of 10 environments, with no clear trend between the parents. Crude protein was higher in CI0947*bmr* in four environments and higher in Sureno in two environments (Table 2). There were no differences in IVDMD for most individual environments, but IVDMD was consistently numerically higher in CI0947*bmr*, which resulted in a significant difference in the combined analysis (Table 2). Other studies have reported similar reductions in ADL, TDN, and IVDMD when comparing *bmr* and normal genotypes (Oliver et al., 2005a).

Because CI0947*bmr* is expected to be used as a dual-purpose cultivar, grain quality is quite important. The grain composition of CI0947*bmr* is very similar to Sureno. In the combined analysis, starch and fiber concentrations were slightly higher in Sureno, whereas fat content was consistently higher in CI0947*bmr*. No differences between the two lines were detected for protein or ash content (Table 3). Given that the *bmr12* mutant affects a lignin biosynthesis pathway (Bout and Vermerris, 2003) and lignin is not a major component in grain composition, any differences in grain composition are probably not associated with the *bmr* trait itself. While grain composition for *bmr* genotypes has not been reported previously, differences in grain test weight among *bmr* isolines were minimal (Oliver et al., 2005b). In addition to composition, there was essentially no difference in the appearance of grain between CI0947*bmr* and Sureno (Fig. 1).

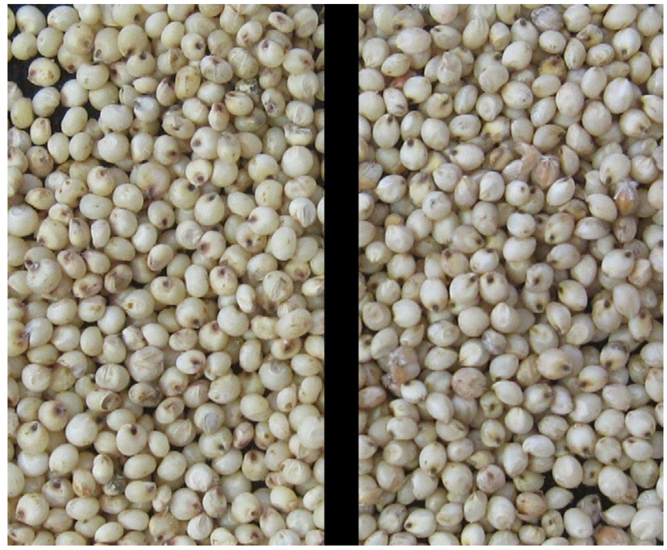

Figure 1. Grain from CI0947*bmr* (left) and Sureno (right) grown in San Andres, El Salvador, in 2011.

CI0947*bmr* is a dual-purpose (grain and forage) cultivar that can be grown exclusively as forage or silage cultivar or as a grain crop with the crop residue used as forage. In addition, the crop will ratoon, and multiple crops can be produced from a single planting (data not shown). Phenotypically, grain of CI0947 has a white pericarp and thin mesocarp and does not possess a pigmented testa layer (Figure 1). The basic plant and glume color is tan. It displays a

Table 1. Agronomic performance of sorghum cultivars CI0947*bmr* and Sureno taken from replicated field trials (including 14 other experimental *bmr* lines) evaluated in 10 environments throughout Central America in 2010 and 2011.

Environment		CI0947*bmr*	Sureno		CI0947*bmr*	Sureno	
		Days to anthesis			Plant height (cm)		
Guatemala	2010	68	68	ns	235	270	*
El Salvador	2010	72	71	ns	200	226	*
Honduras	2010	–	73		298	261	*
Nicaragua	2010	77	68	*	250	262	ns
Costa Rica	2010	71	68	ns	193	171	*
Panamá	2010	70	70	ns	236	203	ns
Guatemala	2011	83	84	ns	240	266	ns
El Salvador	2011	71	72	ns	211	233	ns
Honduras	2011	73	81	*	192	248	*
Nicaragua	2011	79	75	*	219	255	*
Combined		74	73	ns	227	240	ns
		Dry biomass yield (kg ha^{-1})			Grain yield (kg ha^{-1})		
Guatemala	2010	15,770	16,531	ns	–	–	
El Salvador	2010	12,141	13,715	ns	6033	7274	ns
Honduras	2010	11,026	13,319	*	2447	2833	ns
Nicaragua	2010	9,611	12,810	*	3878	4666	ns
Costa Rica	2010	8,605	7,765	ns	5190	4631	ns
Panamá	2010	12,009	11,884	ns	6896	5966	ns
Guatemala	2011	15,765	12,598	*	6993	7490	ns
El Salvador	2011	12,829	13,808	ns	5099	4169	ns
Honduras	2011	8,438	10,964	ns	2954	4198	ns
Nicaragua	2011	11,604	17,388	*	4521	6714	*
Combined		11,780	13,078	ns	4890	5327	ns

* Significant difference among the means of CI0947*bmr* and Sureno using contrast analysis at $P < 0.05$.

prominent brown midrib, which is characteristic of *bmr12* (Porter et al., 1978). CI0947*bmr* is photoperiod sensitive but flowers in approximately 75 to 80 d in short-day, dry-season Central American environments (Table 1). When grown in long-day, summer seasons, the maturity is delayed, with the exact date dependent on both planting date and the specific environment. For plant height, it is genetically a two dwarf ($dw_1Dw_2Dw_3dw_4$), with height averaging 2.1 m and ranging from 1.92 to 2.98 m depending on the environment (Table 1). A common problem detected in *bmr* sorghum genotypes is lodging (Bean et al., 2002), but no lodging was observed in any of these trials. The absence of lodging may be due to favorable conditions or to improvements in the lodging tolerance in *bmr* sorghum (Bean et al., 2013), but additional evaluation will be needed to determine if lodging will be an issue when CI0947*bmr* is commercially produced.

Availability

CI0947*bmr* was officially released by several National Agricultural Research Programs: in Guatemala as ICTA F947, in El Salvador as CENTA S-3*bmr*, and in Nicaragua as INTA CI0947. In Central America, seed of CI0947*bmr* is maintained and is available on request from CENTA in San Andres, San Salvador, El Salvador. In the United States, seed is maintained and available on request from the Sorghum Breeding Program in the Department of Soil and Crop Sciences, Texas A&M University, College Station, TX 77843-2474 Seed of this material has also been deposited in the National Plant Germplasm System and will be available through NPGS 20 yr from the date of publication.

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Table 2. Biomass composition of sorghum cultivars CI0947*bmr* and Sureno taken from replicated field trials (including 14 other experimental *bmr* lines) evaluated in 10 environments throughout Central America in 2010 and 2011.

Environment		CI0947bmr	Sureno		CI0947bmr	Sureno	
		Acid detergent fiber (ADF) (%)			Acid detergent lignin (ADL) (%)		
Guatemala	2010	–	40		–	7	
El Salvador	2010	32	38	*	3	5	*
Honduras	2010	32	30	*	2	4	*
Nicaragua	2010	35	37	*	4	6	*
Costa Rica	2010	25	26	ns	9	10	*
Panamá	2010	27	30	*	7	8	*
Guatemala	2011	40	41	ns	4	6	*
El Salvador	2011	33	33	ns	9	11	*
Honduras	2011	43	44	ns	10	13	*
Nicaragua	2011	26	23	*	7	8	*
Combined		33	34	ns	6	8	*
		Neutral detergent fiber (%)			Total digestible nutrients (%)		
Guatemala	2010	–	67	–	53		
El Salvador	2010	55	60	*	58	55	*
Honduras	2010	55	54	ns	58	60	*
Nicaragua	2010	63	61	*	56	56	*
Costa Rica	2010	42	44	*	64	63	*
Panamá	2010	45	45	ns	61	60	*
Guatemala	2011	67	68	ns	55	55	ns
El Salvador	2011	57	57	ns	58	57	*
Honduras	2011	70	70	ns	53	52	ns
Nicaragua	2011	61	61	ns	56	56	ns
Combined		57	58	ns	58	57	ns
		Crude protein (%)			In vitro dry matter digestibility (%)		
Guatemala	2010	–	2		62	52	ns
El Salvador	2010	4	3	*	63	54	ns
Honduras	2010	4	4	ns	60	64	ns
Nicaragua	2010	3	4	*	64	59	ns
Costa Rica	2010	6	6	ns	62	67	ns
Panamá	2010	3	4	*	64	–	
Guatemala	2011	8	7	ns	59	58	ns
El Salvador	2011	9	7	*	66	56	ns
Honduras	2011	9	7	*	57	62	ns
Nicaragua	2011	8	7	*	70	54	*
Combined		6	5	ns	63	58	*

* Significant difference among the means of CI0947*bmr* and Sureno using contrast analysis at $P < 0.05$.

Table 3. Grain composition of sorghum cultivars CI0947*bmr* and Sureno taken from replicated field trials (including 14 other experimental *bmr* lines) evaluated in 10 environments throughout Central America in 2010 and 2011.

Environment		CI0947*bmr*	Sureno		CI0947*bmr*	Sureno	
		Protein (%)			Starch (%)		
Guatemala	2010	10.7	–		66.1	–	
El Salvador	2010	9.2	8.3	*	67.5	68.5	*
Honduras	2010	10.7	11.2	ns	66.4	66.6	ns
Nicaragua	2010	9.0	9.5	ns	67.0	67.6	ns
Costa Rica	2010	7.9	9.4	*	69.0	68.3	ns
Guatemala	2011	8.9	9.1	ns	67.8	68.2	ns
El Salvador	2011	11.0	10.6	ns	66.3	67.6	*
Honduras	2011	11.0	12.6	*	66.5	65.1	ns
Nicaragua	2011	10.7	9.6	*	66.3	67.4	*
Combined		9.9	10.1		67.0	67.4	*
		Fiber (%)			Fat (%)		
Guatemala	2010	2.1	–	3.8	–		
El Salvador	2010	1.9	2.1	*	3.0	2.4	*
Honduras	2010	1.8	2.0	*	3.1	2.9	*
Nicaragua	2010	1.8	2.1	*	3.0	2.7	*
Costa Rica	2010	1.8	1.8	ns	1.9	2.0	ns
Guatemala	2011	2.0	2.2	*	3.5	3.2	*
El Salvador	2011	2.0	2.0	ns	3.6	3.1	*
Honduras	2011	2.0	1.9	ns	3.7	3.3	*
Nicaragua	2011	1.8	2.1	ns	3.4	3.1	*
Combined		1.9	2.0	*	3.2	2.8	*
		Ash (%)					
Guatemala	2010	1.3	–				
El Salvador	2010	1.2	1.2	ns			
Honduras	2010	1.3	1.3	ns			
Nicaragua	2010	1.3	1.3	ns			
Costa Rica	2010	1.2	1.3	ns			
Guatemala	2011	1.2	1.2	ns			
El Salvador	2011	1.2	1.2	ns			
Honduras	2011	1.2	1.2	ns			
Nicaragua	2011	1.3	1.3	ns			
Combined		1.2	1.3	ns			

* Significant difference among the means of CI0947*bmr* and Sureno using contrast analysis at $P < 0.05$.

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