Description of cultivar

Don Carlos M2015: new variety of bread wheat with wide adaptation for rainfed crops in Mexico

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Abstract

An alternative to face the biotic and abiotic problems in the wheat producing areas of rainforest in Mexico, is the use of improved varieties that minimize their negative effects. Result of the process of genetic improvement of the program of wheat of temporary of the INIFAP, puts at the disposal of the producers of Mexico the new variety of bread wheat bread Don Carlos M2015. The parents that gave rise to the variety were the BABAX∗2/PRL experimental line and the Tlaxcala F2000 variety; subsequently, the selection was made towards homozygosis through the mass method. As an advanced line, Don Carlos M2015 was evaluated in 79 locations in 11 states of Mexico in temporary conditions from 2012 to 2015, where it exceeded the overall yield of the 11 control varieties with which was compared 9% (Altiplano F2007) to 30% (Nana F2007), behavior that was similar under favorable, intermediate and critical production conditions. During this evaluation period, Don Carlos M2015 was moderately resistant to rusts and tolerant to the foliar diseases complex, surpassing in general all the control varieties. When evaluated with and without protection with fungicides, the blights and leaf spots affected the yield 18% and the yellow rust 16%, while the control varieties affected them up to 36% and 54%, respectively. Due to its combination of hard grain, strong medium mass and extensible, Don Carlos M2015 is suitable for baking in the semi-mechanized or manual industry and as an improver of tenacious and strong masses in the mechanized industry. Due to the above, Don Carlos M2015 is a new option for farmers in the areas of temporary wheat production in Mexico.

Keywords: bread wheat, disease tolerance, higher yield, new variety.

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In Mexico, 5.7 million tons of bread wheat (*Triticum aestivum* L.) are consumed annually and only 1.7 million tons are produced, so that approximately 4 million tons must be imported to supply the national demand. The United States of North America is the main wheat exporter to Mexico and Canada is the second one (CANIMOLT, 2016). An alternative to reduce imports is to increase the sown area, in irrigated areas it is difficult to increase it, because wheat competes with more profitable crops, under temporary there is good prospect to increase the area and production, since during the summer the wheat It is more profitable in lands where it is not convenient to plant corn (Villaseñor and Espitia, 2000) and because the wheat produced in the storms of the central region of Mexico is more competitive for freight than the harvested in the northwest or imported (Fuentes, 2008).

One option to improve profitability, increase national production and avoid imports, is the planting of new varieties with high yield potential in rainfed production areas close to grinding centers, so production in the states of Oaxaca, Puebla, Tlaxcala, Mexico, Hidalgo and Guanajuato are good options due to its proximity to the central zone of the country, the main grinding center of Mexico (CANIMOLT, 2016). It is important to indicate that there is a yield potential in these states of 2.1 to 4.8 t ha^{-1} depending on the locality and the variety used (Hortelano *et al*., 2016), so that the varieties of seasonal bread wheat should combine high yield potential, tolerance to foliar diseases and rusts, tolerance to drought and the quality demanded by the national industry.

In accordance with the above and as a result of the process of genetic improvement by the temporary wheat program of INIFAP-CEVAMEX, the institute makes the variety Don Carlos M2015 available to wheat producers in Mexico, which will allow facing the biotic problem and abiotic of the wheat zones of the country.

Obtaining the variety and characteristics

The variety of bread wheat (*Triticum aestivum* L.) Don Carlos M2015 is of spring habit and the experimental line was obtained in the breeding program of temporary wheat of the INIFAP-CEVAMEX, later that line was evaluated in the nurseries and trials national yields of wheat of temporary that implements year after year the indicated program. The line was obtained by hybridization, where a simple cross was made between the BABAX∗2/PRL experimental line and the Tlaxcala F2000 variety and later the homozygous selection was developed through the mass method.

The simple cross between its two parents occurred in the autumn-winter cycle (A-W) 2001-2002 in Chapingo, State of Mexico and was identified with the number TC020537, which was planted in its F_1 generation also in Chapingo, State of Mexico during the spring-summer cycle (S-P) 2002 under regular seasonal conditions and was harvested massively. The F_2 generation was planted in Roque, Guanajuato in 2002-2003 (A-W) cycle under conditions of limited irrigation (an irrigation of relief) and was harvested massively (0R). The F_3 generation was evaluated in Chapingo, State of Mexico during the 2003 P-V cycle under regular seasonal conditions and the population was massively harvested (0C).

The F_4 generation was planted in Roque, Guanajuato in 2003-2004 A-W cycle under normal irrigation conditions (three irrigation aid) and the population was harvested massively (0R). In its F_5 generation the population was planted in Chapingo, State of Mexico under favorable weather conditions in the 2004 P-V cycle where plant No. 16 (16C) was selected and harvested individually, this plant was planted in its F6 generation in Roque, Guanajuato in the 2004-05 A-W cycle under normal irrigation conditions, and where it was harvested massively (0R).

His genealogy and pedigree are the following:

BABAX∗2/PRL//TLAXCALA

TC-020537-0R-0C-0R-16C-0R

The indicated experimental line was evaluated during the 2005 S-P cycle in the preliminary yield test (PPR) in four localities of the states of Tlaxcala and Mexico, later during the 2006 S-P cycle it was evaluated in the national nursery of selection of temporary wheat (VSTHT). From the summer of 2007 to 2011 it was tested in the national trials of wheat yield of rainfed (ERTHT) in about 60 different trials and compared against the varieties Tlaxcala F2000, Náhuatl F2000, Juchi F2000 and Rebeca F2000, which exceeded in grain yield, from 2012 to 2015, it was decided to compare the experimental line against the 11 varieties planted in the different regions producing wheat in temperate Mexico (information presented in Table 4) and also stood out with respect to the varieties control by its greater grain yield in different conditions of rainfed production and by its greater resistance to diseases.

Reaction to diseases

In the Table 1 presents agronomic and phytopathological information of Don Carlos M2015 and the control varieties, where it is observed that this new variety reaches physiological maturity on average at 111 days, being located within the intermediate cycle genotypes; it is resistant to lodging and showed resistance to leaf rust, moderate resistance to moderate susceptibility to yellow rust and tolerance to foliar disease complex. Regarding its reaction to diseases, it was located as the genotype with greater resistance to the two rusts and tolerant to the foliar disease complex, which places it from the phytopathological point of view, as the most suitable variety for seasonal sowing.

Don Carlos M2015, has the specific race resistance genes to leaf rust Lr1, Lr10, Lr16, Lr17 and Lr23. These genes are effective in seedling status to the races CBJ/QB, CBJ/QL, CBJ/QQ (Huerta-Espino and Singh, 1994), LCJ/BN, BBG/BP, TCT/QB, TBD/TM, TCB/TD, MCJ/QM y MFB/SP (Singh, 1991). However, only Lr16 is effective in the seedling of the MBJ/SP and MCJ/SP breeds, which are the most common in Mexico since their identification in 1994 (Villaseñor *et al*., 2003). In adult plants, the resistance of Don Carlos M2015 is based on the action of the Lr34 genes, which confers resistance to leaf rust and other foliar diseases (Kratinger *et al*., 2009), and the Lr46 gene.

Table 1. Agronomic and phytopathological characteristics of Don Carlos M2015 and of control varieties in rainfed crops.

Variety	AP	A	RH	RA	F
Don Carlos M2015	90	R	0 to 10MR	10MR to 30MS	7/30 (T)
Altiplano F2007	92	T	0 to 15 MR	10MR to 30 MS	6/30 (T)
Nana F2007	91	T	15MR to 50 MS	30MS to 90S	7/30 (T)
Triunfo F2004	88	T	15MR to 30 MR	10MR to 70S	7/30 (T)
Náhuatl F2000	90	T	0 to 40MR	15MR to 60MS	7/80 (MS)
Tlaxcala F2000	87	T	10MR to 40MR	10MR to 40MS	7/40 (MS)
Juchi F2000	85	T	10MR to 30MR	20MS to 80S	7/40 (T)
Rebeca F2000	90	R	20MR to 50MS	10MR to 50MS	6/30 (MR)
Batán F96	84	T	40MS to 80S	20MR to 60MS	7/40 (T)
Romoga F96	87	S	10MR to 40MR	10MR to 40MS	7/60 (MS)

AP= plant height (cm); A= acame; R= resistant T= tolerant; reaction to leaf rust (RH) and yellow rust (RA) is the minimum and maximum reading observed for five years; S= susceptible; MR= moderately resistant; MS= moderately susceptible; reaction to foliar diseases (F) is the maximum reading observed in rainy environments where the complex of diseases caused by *Septoria tritici*, *S. nodorum*, *Phyrenophora tritici-repentis* and *Cochliobolus sativus*.

Don Carlos M2015, is susceptible in seedling to the race of yellow rust CMEX14.25 one of those that overcame the resistance of Nana F2007 during 2014. However, the low degrees of severity registered in the variety Don Carlos M2015 in field (minors of 30%) when artificial inoculations are made with the isolates CMEX14.25, MEX14.141 and MEX14.146 (identified during 2014 that overcame the resistance of Nana F2007 and combine virulence for the genes Yr2, Yr3, Yr6, Yr7, Yr8, Yr9, Yr17, Yr27 and Yr31 among others), indicate that the new variety bases its resistance to yellow rust on at least three slow-growing genes in adult plants, two of them Yr18 and Yr29, the first with pleiotropic effect at Lr34 and the second to Lr46 (William *et al*., 2003), both associated with the burning of the tip of the leaf.

Losses in grain yield due to the incidence of foliar diseases and yellow rust recorded in studies with the control and without the control of diseases in the variety Don Carlos M2015 and the varieties witnesses Altiplano F2007, Tlaxcala F2000 and Nana F2007 are presented in Tables 2 and 3, where it is observed that in this new variety there were losses of 18% and 16%, respectively, which were lower than those registered in the control varieties.

Table 2. Losses in grain yield caused by the foliar diseases complex in Don Carlos M2015 and control varieties evaluated in three temporal localities.

Variety	DF		DM		EF (%)		REND (kg ha^{-1})		Losses (%)
	SF	CF	SF	CF	SF	CF	SF	CF	(kg ha^{-1})
Don Carlos M2015	67	69	130	134	73	40	5785	7021	-18
Altiplano F2007	72	73	135	140	70	35	5597	6965	-20
Tlaxcala F2000	70	71	130	134	85	38	4938	6472	-24
Nana F2007	66	67	126	133	98	43	4313	6771	-36

DF= days to flowering; DM= days to maturity; REND= grain yield; EF= incidence of foliar disease complex.

Table 3. Losses in grain yield caused by the incidence of yellow rust in the variety Don Carlos M2015 and control varieties evaluated in four rainfed locations.

Variety	DF		DM		RAH		RAE		REND (kg ha^{-1})		Losses (%)
	SF	CF	SF	CF	SF	CF	SF	CF	SF	CF	(kg ha^{-1})
Don Carlos M2015	62	64	124	127	30	9	11	4	4374	5198	-16
Altiplano F2007	66	67	127	131	36	10	14	5	3846	4798	-20
Tlaxcala F2000	63	65	124	128	50	14	18	4	3627	4761	-24
Nana F2007	59	62	118	125	79	16	34	8	2320	4874	-54

DF= Days to flowering; DM= days to maturity; RA= incidence of yellow rust; H= sheet; E= spike; REND= grain yield.

Performance potential

In the Table 4 presents the comparison of grain yield of Don Carlos M2015 and the control varieties, where it is observed that it exceeded the overall yield of all the control varieties of 9.5% (Altiplano F2007) up to 30.6% (Nana F2007); it is worth noting the fact that only the Altiplano F2007 variety competed with the new variety.

Table 4. Comparison in the grain yield of Don Carlos M2015 and control varieties in different rainfed environments from 2012 to 2015.

Variety	G* (79 L)		AF (24 L)		AI (25 L)		AC (30 L)	
	(kg ha^{-1})	(%D)	(kg ha^{-1})	(%D)	(kg ha^{-1})	(%D)	(kg ha^{-1})	(%D)
Don Carlos M2015	2970	-	4263	-	3040	-	1912	-
Altiplano F2007	2687	-9.5	3848	-9.7	2802	-7.8	1682	-12
Rebeca F2000	2365	-20.4	3519	-17.4	2410	-20.7	1482	-22.5
Temporalera M87	2343	-21.1	3220	-24.5	2423	-20.3	1608	-15.9
Romoga F96	2325	-21.7	3159	-25.9	2487	-18.2	1527	-20.1
Tlaxcala F2000	2248	-24.3	3184	-25.3	2296	-24.5	1463	-23.5
Triunfo F2004	2215	-25.4	2963	-30.5	2299	-24.4	1538	-19.5
Náhuatl F2000	2184	-26.5	3169	-25.7	2196	-27.8	1401	-26.7
Batán F96	2150	-27.6	2887	-32.3	2280	-25	1462	-23.5
Gálvez M87	2139	-28	3032	-28.9	2165	-28.8	1431	-25.2
Juchi F2000	2117	-28.7	2870	-32.7	2217	-27.1	1440	-24.7
Nana F2007	2062	-30.6	2936	-31.1	2024	-33.4	1447	-24.3

G*= localities in general, State of Mexico (Chapingo, Santa Lucía, Axapusco, Coatepec, Tenango del Aire Juchitepec, Amecameca and Tlalmanalco), Tlaxcala (Soltepec, Nanacamilpa, Teacalco, Velasco, Terrenate, Huamantla, San Diego Ameca, Veloz and Fco. I. Madero), Hidalgo (Chimalpa), Puebla (Libres, Texcal and La Concepcion), Guanajuato (Roque), Oaxaca (Sinaxtla, Semoax, Yanhuitlan and Santiago Tillo), Chihuahua (Carbajales and Paramo), Aguascalientes (Pavilion and Sandovales), Durango (Fco. I. Madero and Valle de Guadiana) and Zacatecas (Calera). L= locality; %D= percentage of difference with respect to Don Carlos M2015; AF, AI and AC= favorable, intermediate and critical environments, respectively.

In conditions of favorable environments, Don Carlos M2015 also outperformed all the control varieties with differences that were 9.7% (Altiplano F2007) up to 30.5, 31.1, 32.3 and 32.7% with the varieties Triunfo F2004, Nana F2007, Batán F96 and Juchi F2000. In intermediate environments, the differences with the controls varied from 7.8% (Altiplano F2007) to 27.1, 27.8, 28.8, 33.4% with the varieties Juchi F2000, Náhuatl F2000, Gálvez M87 and Nana F2007, respectively. In conditions of critical environments Don Carlos M2015 presented a behavior similar to the other conditions, since it exceeded in yield all the control varieties, although in this condition, the differences were 12% (Altiplano F2007) up to 24.3, 24.7, 25.2, 26.7 % with the varieties Nana F2007, Juchi F2000, Gálvez M87 and Náhuatl F2000.

Industrial quality

Don Carlos M2015 is characterized by having hectoliter weights greater than 75 kg hL^{-1}, similar to the Altiplano F2007 and Náhuatl F2000 control varieties. Its grain is red and its hardness is classified as hard grain by its percentages lower than 47%. Due to its force values (W) of the mass between 200 and 300 x 10^{-4} J it is classified as medium gluten and because of its relationship between toughness and extensibility (PL< 1) less than unity is extensible mass which combined with its grain hard texture allows you to get good bread volume of 800 mL with values similar to the control variety Altiplano F2007. The flour of this variety is suitable for baking in semi-mechanized or manual industry and as an improver of tenacious and strong masses in the mechanized industry.

Conclusions

Don Carlos M2015 is a variety that adapts to all producing regions of rainfed wheat in Mexico, since it is widely adapted that can be planted in favorable or rainy environments (more than 500 mm), intermediate or rainy (between 300 to 500 mm) and critical or erratic (less than 300 mm) in the states of Oaxaca, Puebla, Tlaxcala, Hidalgo, Mexico, Guanajuato, Jalisco, Zacatecas, Durango and Chihuahua.

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Cited literature

CANIMOLT. 2016. Cámara Nacional de la Industria Molinera de Trigo. Reporte estadístico al 2015-2016. https://drive.google.com/file/d/0Bws40FQdCiaSTGxUQmgtR2JjbEU/view.

Fuente, P. J. L. 2008. ¿Quiénes somos? La industria molinera de trigo en México. Rev. CANIMOLT 1(1):4-10.

Hortelano, S. R. R.; Espitia, R. E.; Martínez, C. E.; Villaseñor M. H. E.; Huerta, E. J. y Mariscal, A. L. A. 2016. Productividad y calidad industrial de trigos harineros en relación a enfermedades. Agrociencia. 50(8):1027-1039.

Huerta-Espino, J. and Singh, R. P. 1994. First report of virulence for wheat leaf rust resistance gene Lr19 in Mexico. Plant Dis. 78(6):640-645.

Krattinger, S. G.; Lagudah, E. S.; Spielmeyer, W.; Singh, R. P.; Huerta-Espino, J.; McFadden, H.; Bossolini, E.; Selter, L. L. and Keller, B. 2009. A putative ABC transporter confers durable resistance to multiple fungal pathogens in wheat. Sci. 323(5919):1360-1363.

Singh, R. P. 1991. Pathogenicity variations of *Puccinia recondita* f.sp.*tritici* and *P. graminis* f.sp. *tritici* in wheat-growing areas of Mexico during 1988 and 1989. Plant Dis. 75(8):790-794.

Villaseñor, E. O. M.; Huerta, E. J.; Leyva, M. S. G.; Villaseñor, M. H. E. y Espitia, R. E. 2003. Análisis de virulencia de la roya de la hoja (*Puccinia triticina* Ericks.) del Trigo (*Triticum aestivum* L.) en Los Valles Altos de México. Rev. Mex. Fitopatol. 21(1):56-62.

Villaseñor, M. H. E y Espitia, R. E. 2000. Características de las áreas productoras de trigo de temporal. Problemática y condiciones de producción. In: Villaseñor, M. H. E y Espitia, R. E. (Eds.) El trigo de temporal en México. SAGAR, INIFAP, CIR-CENTRO y CEVAMEX. México. 85-98 pp.

William, M. R.; Singh, R. P.; Huerta, E. J.; Ortiz, I. J. and Hoisington, D. 2003. Molecular marker mapping of leaf rust resistance gene Lr46 ant its association with stripe rust resistance gene Yr29 in wheat. Phytopathol. 93(2):153-159.