30–33 cultivars. The data collected for each cultivar and for each of the three parameters in each season from 1995 to 2005 were indexed as a percent of the highest value observed among all the cultivars assayed in that season and then averaged to minimize the confounding effects of differences in disease pressure between years. For various reasons, including the lack of agronomic data for the 2010–11 season, the cultivars assayed in the subsequent trials (2007 to 2011) could not be classified according to the same criteria. On the other hand, because the new entries were grown along with cultivars already assayed for CSBMV resistance in other seasons, there was ample opportunity to adequately classify their response to CSBMV by the use of numerous direct comparisons and, thus, produce a synoptic table comprising all the 133 cultivars assayed (Table 5, p. 37). The CSBMV responses presented in the table are obviously most dependable for cultivars assayed in numerous trials (up to 10 or 11 in the case of Duilio, Iride, Creso, and Simeto), whereas those based on the results of one trial only are merely indicative. We note that although nearly half of the 133 cultivars listed carry a major gene for CSBMV resistance located on the short arm of chromosome 2B, none were immune to CSBMV infection and only 16 consistently showed high levels of resistance.

ITEMS FROM MEXICO

NATIONAL INSTITUTE FOR FORESTRY, AGRICULTURE, AND LIVESTOCK RESEARCH (INIFAP–CIRNO)
Campo Experimental Valle del Yaqui, Apdo. Postal 155, km 12 Norman E. Borlaug, entre 800 y 900, Valle del Yaqui, Cd. Obregón, Sonora, México CP 85000.

CEVY Oro C2008: Yield and quality performance in experimental and semicommercial plots and status of area grown with this durum wheat cultivar in southern Sonora, Mexico.

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Abstract. Commercial durum wheat cultivar CEVY Oro C2008, developed for the wheat-producing areas of northwest Mexico, is spring type and resistant to leaf rust, with an experimental average grain yield of 5.6 t/ha, test weight of 83.0 kg/hl, 13.5% protein, and 28.1 points of the Minolta b value. CEVY Oro C2008 averaged 7.1, 7.76, and 7.2 t/ha in 2008–09, 2009–10, and 2010–11, respectively, with a maximum yield potential of 8.7 t/ha, in commercial fields of cooperating wheat producers from southern Sonora, and an average of 29.08 points of the Minolta b value. After its release, this cultivar was cultivated in 3,233 ha in southern Sonora during 2009–10, 6,161 ha during 2010–11, 931 ha during 2011–12, and in 2012–13 it was cultivated only in 185 ha. Cultivar CIRNO C2008, which has a high yield potential, was cultivated in 3,256, 87,105, 154,915, and 196,295 ha during those four seasons. Despite research efforts to diversify the sources of resistance to leaf rust and to improve quality, wheat production and comercialization are still based on grain yield, despite the risks that monocultivar culture represents in a region where leaf rust is endemic with the appearance of new races of the causal agent.

Introduction. Worldwide production of durum wheat in 2009 was 686.6 x 10^6 tons (FAO 2011a). China was the main producer, with 115.1 t, followed by India with 80.6 t. Mexico produced 4.1 x 10^6 tons from which 1.1 x 10^6 were exported (FAO 2011b). Of the area grown with wheat in Mexico, 63.9% (457,541 ha) corresponded to the states of Sonora, North Baja California, and Sinaloa, during the fall–winter 2008–09 crop season, with an estimated value of US$646 x 10^6 (SIAP 2011) (Exchange rate 1:12, May 2013). During the 2010–11 crop season, 288,766 ha were grown with wheat in southern Sonora, 70% corresponded to durum wheat predominating cultivars CIRNO C2008 and Átil C2000, and bread wheat cultivar Tacupeto F2001 (OEIDRUS 2011). In northwest Mexico, spring wheat is grown during the fall–winter season under irrigation. Durum wheat is mostly cultivated in the state of Sonora; since the 2001–02 crop season, this type of wheat has occuppied more than 70% of the area grown with wheat (Camacho et al. 2004). The preference for durum wheat by farmers in northwest Mexico was greatly influenced by the implementation of federal quarantine No. 16 against Karnal bunt of wheat (SARH 1987), because durum wheat is more tolerant to this disease than bread wheat. Durum wheat also has greater yield potential, better value in the international market, and, at that time, the durum wheat cultivar grown Altar C84 was resistant to leaf rust. This disease is endemic in the region and develops rapidly on susceptible cultivars giving rise to new and more virulent races (Figueroa et al. 2010). The durum wheat cultivar mostly grown in the region up to crop season 2003–04 was Altar C84, despite the loss of its resistance to the new race BBG-BN (Singh et al. 2004), which affected production during the 2000–01 and 2001–02 crop seasons (Figueroa-López et al. 2002). Durum wheat cultivar Júpare C2001 (Camacho-Casas et al. 2004), resistant to the leaf rust races that affected durum wheat cultivars released until 2000, dominated the area grown with wheat in southern Sonora from 2003–04 to 2008–09, reaching 119,327 ha (42.3%) during that last season (Fig. 1). However, leaf rust overcame the resistance of this cultivar, therefore efforts are not only focused on diversifying the source of resistance to this disease, but also to increase grain pigment, an important characteristic of quality for the export market. Our objective is to present the current status of durum wheat cultivar CEVY Oro C2008, released for commercial use in northwest Mexico.

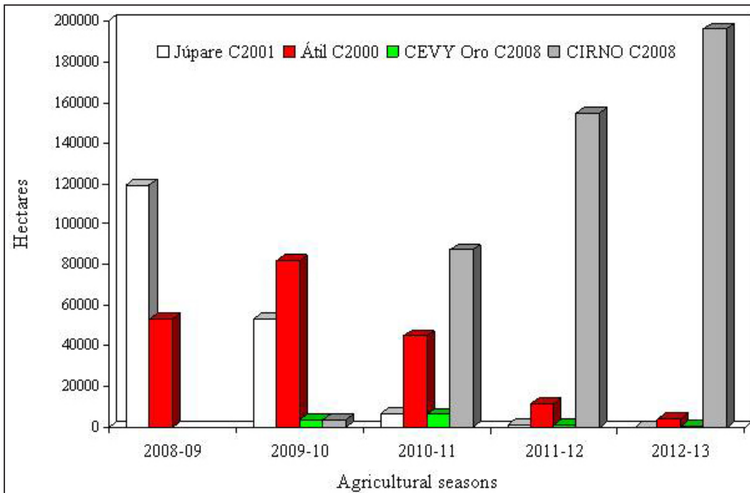

Fig. 1. Area (ha) sown with several durum wheat cultivars in southern Sonora, Mexico, during the 2008–09 to 2012–13 agricultural seasons.

Origin of CEVY Oro C008. The collaborative project between the Norman E. Borlaug Experimental Station, which belong to the Mexican National Institute For Forestry, Agriculture, and Livestock Research (INIFAP), and the International Maize and Wheat Improvement Center (CIMMYT) has the objectives of improving the cost/benefit and competitiveness of wheat by releasing cultivars with better yield, quality, resistance to disease, and efficient water use (Figueroa-López et al. 2011a). As a result of this project, the line 'SCRIP_1//DIPPER_2/ BUSHEN_3/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1' was released under the name CEVY Oro C2008 (Fuentes-Dávila et al. 2010), which is a durum wheat cultivar originated from hybridizations made in the Durum Wheat Breeding Program of CIMMYT. The cross and selection history is CDSS02Y00381S-0Y-0M-19Y-0M. CEVY Oro C2008 has the registration TRI-111-240209 in the National Catalogue of Plant Cultivars of the National Seed Inspection and Certification Service.

General characteristics of CEVY Oro C2008. Cultivar CEVY Oro C2008 is a spring wheat with a biological cycle that averages 121 days to physiological maturity under three complementary irrigations and depending on the sowing date (Fuentes-Dávila et al., 2010). Heading takes from 74 to 92 days with an average of 81. CEVY Oro C2008 is tall with a average height of 93 cm, a maximum of 105, and minimum of 85. Plant growth habit is erect and shows null or low frequency of recurved flag leaves. Grain shape is semi-elongated, 7.26 mm long, 3.0 mm wide, with an average weight of 52 mg. Grain coloration when treated with phenol is nil or very light. CEVY Oro C2008 is resistant to the leaf rust races prevailing in the wheat-producing areas of northwest Mexico, therefore, farmers will not have to depend on application of fungicides for control. Leaf rust in the most important disease in Mexico economically, historically causing 30–60% loss according to the cultivar and weather conditions (Villaseñor et al. 2003). CEVY Oro C2008 also is resistant to Karnal bunt.

Yield and quality, experimental evaluation. CEVY Oro C008 was evaluated at the Norman E. Borlaug Experimental Station (CENEB) in the Yaqui Valley, Sonora, during the fall–winter 2006–07, 2007–08, and 2008–09 crop seasons with three complementary irrigations; average experimental yield was 5.97, 4.79, and 5.96 t/ha, respectively. The maximum yield obtained was 6.53 t/ha with a 15 November sowing date with three complementary irrigations. Based on the statistical analysis, the best dates for sowing this cultivar are between 15 November and 1 December 1. No yield differences were noted between the first two sowing dates, but late ones do (15 December and 1 January).

Several physico-chemical parameters affect the industrial quality of durum wheat cultivars, however, protein content and quality and the pigment present in the endosperm of the grain affect noticeably the parameters considered for evaluation of semolina used for pasta making. Although protein content and quality are affected by crop management, mainly by nitrogen fertilization, cultivar and its yield potential are known to be associated with protein present in the grain. Evaluations carried from season 2006–07 to 2008–09 have shown that CEVY Oro C2008 is consistently superior to cultivar check Júpare C2001 in content of yellow pigment. CEVY Oro C2008 produces a grain with an average specific weight of 83 kg/hl and 13.5% protein at 12% moisture content. The intensity of yellow pigment in the endosperm of CEVY Oro C2008 grain has an average of 28.1 points in the Minolta b scale and is the reason for the designation 'Oro' (golden), which confers a high value in the international market.

Yield and quality, semi-commercial validation. Wheat, as with other crops, fluctuats in yield between years and between locations depending, among other factors, on water availability and nutrients. In validation plots with two cooperating farmers in the Yaqui Valley in blocks 609 and 2518, during the fall–winter 2008–09 crop season, the highest yield obtained from CEVY Oro C2008 was 7.5 t/ha, with an average of 7.1 t/ha. During the 2009–10 crop season, in blocks 1718 and 2520 and in the Mayo Valley experimental site, the highest yield potential obtained was 8.5 t/ha with an average of 7.76 t/ha. During 2010–11, in blocks 809, 1718, and 2518, and in Bacorehuis, Sinaloa, the highest yield obtained was 8.7 t/ha with an average of 7.06 t/ha.

From the farmer`s point of view, grain yield has been the main parameter for choosing a cultivar; however, in the case of durum wheat, pigment is a very important factor to consider for export. In validation plots with two cooperating farmers in the Yaqui Valley, in block 1718 and 2520, during the fall-winter 2009–10 crop season, the average of the b Minolta value was 29.4, while in 2010–11 it was 28.75 in blocks 1718 and 2518.

Table 1. Area (ha) grown with wheat during the 2009–10 and 2012–13 agricultural seasons in southern Sonora, Mexico (% indicates the percent of the total area growing wheat).

2009–10			2012–13		
Cultivar	**Area (ha)**	**%**	**Cultivar**	**Area (ha)**	**%**
Durum wheat					
Átil C2000	81,777	33.07	CIRNO C2008	196,295	77.90
Júpare C2001	53,164	21.50	Movas C2009	8,576	3.40
Samayoa C2004	23,318	9.43	Huatabampo Oro C2009	6,222	2.47
Sáwali Oro C2008	4,761	1.93	RSM Imperial C2008	4,538	1.80
CIRNO C2008	3,256	1.32	Átil C2000	4,080	1.62
CEVY Oro C2008	3,233	1.31	Patronato Oro C2008	3,183	1.26
Platinum	2,655	1.07	Sáwali Oro C2008	1,181	0.47
Patronato Oro C2008	2,325	0.94	RSM Chapultepec C2008	848	0.34
Aconchi C89	1,019	0.41	CEVY Oro C2008	185	0.07
RSM Imperial C2008	980	0.40			
Banámichi C2004	826	0.33			
RSM Chapultepec C2008	499	0.20			
Rafi C97	351	0.14			
Río Colorado	296	0.12			
Nácori C97	241	0.10			
Altar C84	105	0.04			
TOTAL	178,806		TOTAL	225,108	
Bread wheat					
Tacupeto F2001	40,552	16.40	Tacupeto F2001	8,824	3.50
Kronstad F2004	25,021	10.12	Roelfs F2007	5,223	2.07
Abelino F2004	736	0.30	Kronstad F2004	4,166	1.65
RSM-Norman F2008	659	0.27	RSM-Norman F2008	2,312	0.92
Rayón F89	636	0.26	Navojoa M2007	2,301	0.91
Tarachi F2000	384	0.16	Villa Juárez F2009	1,942	0.77
Roelfs F2007	248	0.10	Onavas F2009	1,724	0.68
Navojoa M2007	235	0.10	Abelino F2004	160	0.06
Monarca F2007	4	0.00	Ocoroni F86	149	0.06
			Tepahui F2009	92	0.04
			Japaraqui F2009	20	0.01
TOTAL	68,475		TOTAL	26,913	

Commercial cultivation of CEVY Oro C2008. After the release for commercial cultivation, durum wheat cultivar CEVY Oro C2008 occuppied 3,233 ha in southern Sonora (Table 1, p. 40) during the crop season 2009-10 (Fuentes-Dávila et al. 2011) (Fig. 1, p. 39) and 6,161 ha during 2010–11 (Valenzuela-Herrera et al. 2012). The most popular cultivars during 2008–09, Júpare C2001 and Átil C2000, were sown in 119,327 and 53,106 ha, respectively. The area planted to Júpare C2001 was reduced 53,164 ha in 2009–10 and Átil C2000 increased to 81,777 ha. The susceptibility of Júpare C2001 to leaf rust since 2008 and its reduction in preference by farmers, was more obvious during the 2010–11 season when only 6,638 ha were sown. Átil C2000, which has shown higher grain yield than Júpare, also had a reduced area to 44,826 ha. During the 2011–12 crop season, Átil was sown in 11,343 ha and Júpare in 913 ha, while in 2012–13, Átil was sown in 4,080 ha and Júpare was not grown in southern Sonora (Table 1, p. 40). The availability of the new durum wheat cultivars under the designation 'Oro' (golden), due to the high pigment content, and generated by the collaborative breeding project between INIFAP and CIMMYT, in response to the requests by the farmers of the region, seemed to have a rise in area sown with this type of cultivar in 2010–11; CEVY Oro C2008 occupied 6,161 ha, however, in 2011-12 it was sown in 931 ha and in 2012–13 in only 185 ha. On the other hand, durum wheat cultivar CIRNO C2008, publized as the improved Átil due to leaf rust resistance, has occupied 3,256 ha during 2009–10, 87,105 in 2010–11, 154,915 ha in 2011–12, and 196,295 in the 2012–13 crop seasons since its release. Despite research efforts in durum wheat to diversify the sources of resistance to leaf rust and to improve quality for export, efforts that have generated cultivars with both attributes since 2008, e.g., CEVY Oro C2008, Patronato Oro C2008, Sáwali Oro C2008, and, more recently, Huatabampo Oro C2009, the production and commercialization of durum wheat in this region of Mexico, continues to be based on grain yield. Due to the risks that monocultivar culture represents (Figueroa-López et al. 2011b), and based on scientific knowledge and the experiences with the durum wheat cultivars Altar C84 (Figueroa-López et al. 2002) and Júpare C2001 (Figueroa-López 2009) in northwest Mexico, we expect that the commercial longevity of durum wheat cultivar CIRNO C2008 will be more limited than expected. The appearance of new races of leaf rust in the next few crop seasons have a high possiblity to overcome its resistance, with consequent negative effects on economics and the environment, for the application of fungicides that will be neeed in the region and the lack of sufficient seed of other cultivars with resistance that could replace CIRNO C2008.

Conclusions. Durum wheat cultivar CEVY Oro C2008 released in 2008 for commercial cultivation, was sown in an area of 3,233 ha in southern Sonora during the crop season 2009–10, 6,161 ha during 2010–11, 931 ha during 2011–12, and only 185 ha during 2012–13. New or different schemes for durum wheat commercialization are needed, so that quality can be better remunerated and, therefore, genetic diversity for resistance to leaf rust is maintained in the region, which in turn will increase the commercial longevity of the cultivars generated.

References.

Camacho-Casas MA, Figueroa-López P, and Huerta-Espino J. 2004. Júpare C2001, nueva variedad de trigo duro para su cultivo en el noroeste de México. Folleto Técnico No. 47, INIFAP-CIRNO, Campo Experimental Valle del Yaqui. Cd. Obregón, Sonora, México. 16 p (In Spanish).

FAOSTAT. 2011a. World wheat production 2009. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor. Consulted 5 December, 2011.

FAOSTAT. 2011b. Imports, exports, commodity by country 2009. http://faostat.fao.org/site/342/ default.aspx. Consulted 5 December, 2011.

Figueroa-López P, Gaxiola-Verdugo LA, Suárez-Beltrán A, Alvarez-Zamorano R, and Camacho-Casas MA. 2002. Análisis comparativo de las epidemias de roya de la hoja de trigo cristalino en el Valle del Yaqui, Sonora, México, en los años 2001 y 2002. *In:* Memorias XXIX/V Congreso Nacional/Internacional de la Sociedad Mexicana de Fitopatología, 2–5 July, 2002, Monterrey, Nuevo León, México. Abstract F-73 (In Spanish).

Figueroa-López P. 2009. La roya de la hoja del trigo en el sur de Sonora: Crónica de una epidemia anunciada. *In:* Memoria: Día del Agricultor 2009. Publicación Especial No. 16, INIFAP, CIRNO, Campo Experimental Norman E. Borlaug, Cd. Obregón, Sonora, México. Pp. 16-17 (In Spanish).

Figueroa-López P, Félix-Fuentes JL, Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, and Mendoza-Lugo JA. 2010. CIRNO C2008, nueva variedad de trigo cristalino con alto rendimiento potencial para el estado de Sonora. Revista Mexicana de Ciencias Agrícolas 1(5):745-749 (In Spanish).

Figueroa-López P, Gaxiola-Verdugo LA, Suárez-Beltrán A, Alvarez-Zamorano R, and Camacho-Casas MA. 2002. Análisis comparativo de las epidemias de roya de la hoja de trigo cristalino en el Valle del Yaqui, Sonora, México, en los años 2001 y 2002. *In:* Memorias XXIX/V Congreso Nacional/Internacional de la Sociedad Mexicana de Fitopatología, 2–5 July, 2002, Monterrey, Nuevo León, México. Abstract F-73 (In Spanish).

Figueroa-López P, Fuentes-Dávila G, Cortés-Jiménez JM, Tamayo Esquer LM, Félix-Valencia P, Ortiz-Enríquez E, Armenta-Cárdenas I, Valenzuela-Herrera V, Chávez-Villalba G, and Félix-Fuentes JL 2011a. Guía para producir trigo en el sur de Sonora. Folleto para productores No. 39, INIFAP-CIRNO, Campo Experimental Norman E. Borlaug, Cd. Obregón, Sonora, México. 63 p (In Spanish).
Figueroa-López P, Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, and Mendoza-Lugo JA. 2011b. El mosaico genético de resistencia a roya de la hoja en trigo cristalino, un importante objetivo no logrado en el sur de Sonora. *In:* Memoria: Día del Agricultor 2011. Publicación Especial No. 18, INIFAP, CIRNO, Campo Experimental Norman E. Borlaug, Cd. Obregón, Sonora, México. Pp. 11-12 (In Spanish).
Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, Figueroa-López P, and Mendoza-Lugo JA. 2010. CEVY ORO C2008, variedad de trigo cristalino para el noroeste de México. INIFAP, Centro de Investigación Regional del Noroeste, Campo Experimental Valle del Yaqui. Folleto Técnico No. 70, Cd. Obregón, Sonora, México. 28 p. ISBN 978-607-425-307-8 (In Spanish).
Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, Figueroa-López P, and Mendoza-Lugo JA. 2011. HUATABAMPO ORO C2009, variedad de trigo cristalino para el noroeste de México. INIFAP, Centro de Investigación Regional del Noroeste, Campo Experimental Valle del Yaqui. Folleto Técnico No. 78, Cd. Obregón, Sonora, México. 29 p. ISBN 978-607-425-589-8 (In Spanish).
OEIDRUS (Oficina Estatal de Información para el Desarrollo Rural Sustentable del Estado de Sonora). 2011. Estadísticas Agrícolas. http://www.oeidrus-sonora.gob.mx/. Consultado en febrero del 2011 (In Spanish).
SARH. 1987. Cuarentena interior No. 16 contra el Carbón Parcial del trigo. Secretaría de Agricultura y Recursos Hidráulicos. Diario Oficial, (jueves) 12 March, 1987, México (In Spanish).
SIAP (Servicio de Información Agroalimentaria y Pesquera). 2011. Anuarios dinámicos. Available at http://www.siap.sagarpa. gob.mx/ar_comdeanuadin.html. Consulted July 2011.
Singh RP, Huerta-Espino J, Pfeiffer W, and Figueroa LP. 2004. Ocurrence and impact of a new leaf rust race on durum wheat in the Northwestern Mexico during 2001-2002. Plant Dis 88:703-708.
Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, Figueroa-López P, Fuentes-Dávila G, and Mendoza-Lugo JA. 2012. VILLA JUÁREZ F2009, variedad de trigo harinero para el noroeste de México. INIFAP, Centro de Investigación Regional del Noroeste, Campo Experimental Norman E. Borlaug. Folleto Técnico No. 85. Cd. Obregón, Sonora, México. 30 p. ISBN 978-607-425-753-3 (In Spanish).
Villaseñor EOM, Huerta EJ, Leyva MSG, Villaseñor ME, and Espitia RE. 2003. Análisis de virulencia de la roya de la hoja (*Puccinia triticina* Ericks.) del trigo (*Triticum aestivum* L.) en los valles altos de México. Revista Mexicana de Fitopatología 21:56-62 (In Spanish).

Characteristics and description of phenotypic components of Ónavas F2009 a new bread wheat cultivar for southern Sonora, Mexico.

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Abstract. Commercial cultivar Ónavas F2009 was developed at the Norman E. Borlaug Experimental Station through a collaborative project between INIFAP and CIMMYT, for the wheat-producing areas of the states of Sinaloa, Sonora, South Baja California, and Baja California in Mexico. The pedigree and selection history is 'KAMBARA1*2/BRAMBLING' (selection history: CGSS01B00069T-099Y-099M-099M-099Y-099M-20Y-0B). Ónavas F2009 has the registration TRI-121-100910 in the Catalog of Cultivars Feasible for Registration. This cultivar is spring type and resistant to leaf rust, with an experimental average grain yield of 6.012 t/ha. Ónavas F2009 has an average of 81 days to heading and 121 to physiological maturity, average height of 97 cm, plant growth habit is intermediate, and shows a high frequency of recurved flag leaves. Ear shape, in profile view, is parallel sided, density is lax, and the length excluding awns is very long. Ear glaucosity is medium and, at maturity, becomes white. The shoulder width of the lower glume is absent or very narrow, shoulder shape is sloping, the beak length is short and slightly curved. Grain shape is semi-elongated, and grain coloration, when treated with phenol, is light.

Introduction. Bread wheat production in Mexico was 3.9 x 10^6 tons in 2010, which was not enough to fulfill the national demand, so 3.3 x 10^6 tons had to be imported to suffice consumption needs (OEIDRUS 2011). In order to assure minimum strategic reserves with the objective of reducing the risk of depending on fluctuating international market prices, the regional industry reacted by implementing 'agriculture by contract' with wheat producers several years ago (Melis-Cota 2008).

Despite the problems caused by Karnal bunt at the beginning of the 1980s (SARH 1987), 220,409 ha were sown with bread wheat in 1990–91, which represented 89% of the area grown with wheat in the state of Sonora. However, since the 1994–95 season, durum wheat has reached more area than bread wheat in the state. The area grown with wheat in 2010–11 in Sonora was 292,247 ha (Table 2); 87% (254,531 ha) corresponded to the southern region (OEIDRUS 2011). The predominate durum wheat cultivars were CIRNO C2008 and Átil C2000 with more than 40% of the total area. Bread wheat cultivars occupied 30% of the area.

Leaf rust and Karnal bunt are the most important diseases in southern Sonora (Figueroa-López et al. 2011). However, since year 2000, incidence of stripe or yellow rust has increased in the region with the appearance of new races of the fungus. The cultivar Tacupeto F2001 was the most grown bread wheat cultivar in 2009–10 and 2010–11 in southern Sonora (Table 2). Despite its quality attributes for the milling industry, Tacupeto F2001 has shown susceptibility to stripe rust (up to 80% severity) and moderate susceptibility to leaf rust (up to 40% severity), levels that make chemical application necessary, increasing production costs. Therefore, the collaborative project between the Mexican National Institute For Forestry, Agriculture, and Livestock Research (INIFAP) and the International Maize and Wheat Improvement Center (CIMMYT) with support by the farmer´s union (PIEAES) of the Yaqui Valley, has the objective of improving the cost/benefit and competiveness of bread wheat by producing advanced lines with better quality, yield, resistance to disease, and better water use efficiency, that could be released as commercial cultivars (Figueroa-López et al. 2011).

Table 2. Area (ha) grown with wheat during the 2010–11 and 2009–10 agricultural seasons in southern Sonora, Mexico (% indicates the percent of the total area growing wheat).

2010–11			2009–10		
Cultivar	**Area (ha)**	**%**	**Cultivar**	**Area (ha)**	**%**
Durum wheat					
CIRNO C2008	88,235	30.5	Átil C2000	81,777	33.07
Átil C2000	50,236	17.3	Júpare C2001	53,164	21.50
Sáwali Oro C2008	14,353	4.9	Samayoa C2004	23,318	9.43
Patronato Oro C2008	11,753	4.0	Sáwali Oro C2008	4,761	1.93
Júpare C2001	10,069	3.4	CIRNO C2008	3,256	1.32
RSM Imperial C2008	7,149	2.4	CEVY Oro C2008	3,233	1.31
CEVY Oro C2008	6,197	2.1	Platinum	2,655	1.07
Río Colorado	5,111	1.7	Patronato Oro C2008	2,325	0.94
Samayoa C2004	4,905	1.6	Aconchi C89	1,019	0.41
Rafi C97	1,806	0.6	RSM Imperial C2008	980	0.40
RSM Chapultepec C2008	1,650	0.5	Banámichi C2004	826	0.33
Others	1,210	0.4	RSM Chapultepec C2008	499	0.20
Platinum	1,173	0.4	Rafi C97	351	0.14
Aconchi C89	752	0.2	Río Colorado	296	0.12
			Nácori C97	241	0.10
			Altar C84	105	0.04
TOTAL	204,599	70	TOTAL	178,806	
Bread wheat					
Tacupeto F2001	36,819	12.6	Tacupeto F2001	40,552	16.40
Kronstad F2004	18,681	6.4	Kronstad F2004	25,021	10.12
Roelfs F2007	10,358	3.6	Abelino F2004	736	0.30
Navojoa M2007	8,046	2.8	RSM-Norman F2008	659	0.27
RSM Norman F2008	4,499	1.5	Rayón F89	636	0.26
Cachanilla F2000	3,493	1.2	Tarachi F2000	384	0.16
Rayón F89	2,576	0.9	Roelfs F2007	248	0.10
Abelino F2004	1,355	0.5	Navojoa M2007	235	0.10
Palmerín F2004	964	0.3	Monarca F2007	4	0.00
Others	538	0.1			
Oasis F86	319	0.1			
TOTAL	87,648	30	TOTAL	68,475	

Pedigree, history selection and description of Ónavas F2009. After evaluating grain yield since the 2007–08 agricultural season at the Norman E. Borlaug Experimental Station (CENEB), we proposed to release the experimental bread wheat line 'KAMBARA1*2/BRAMBLING' as the cultivar Ónavas F2009 (Figueroa-López et al. 2012). Ónavas F2009 is a spring type bread wheat cultivar, which originated from hybridizations made in the Bread Wheat Breeding Program of CIMMYT. The cross number and history selection is CGSS01B00069T-099Y-099M-099M-099Y-099M-20Y-0B. Shuttle breeding was carried out between the experimental stations of El Batán, state of Mexico (B) (19°30'N and 2,249 msnm); San Antonio Atizapán, state of Mexico (M) (19°17'N and 2,640 msnm); and the Yaqui Valley (Y) (27°20'N and 40 msnm) in Sonora (Table 3).

Table 3. Selection history and localities where cultivar Onavas F2009 was evaluated (For season: F–W = fall–winter and S–S = spring–summer; for irrigation type: RR = regular rainfed and NI = normal irrigation; and planting dates were 15 and 30 November, 15 December, and 1 January).

Activity	Locality	Season	Irrigation
Triple genetic cross	El Batan, Mexico	S–S/2001	RR
F_1 generation	Cd. Obregon, Sonora	F–W/2002–03	NI
F_2 generation	Atizapan, Mexico	S–S/2003	RR
F_3 generation	Atizapan, Mexico	S–S/2004	RR
F_4 generation	Cd. Obregon, Sonora	F–W/2004–05	NI
F_5 generation	Atizapan, Mexico	S–S/2005	RR
F_6 generation	Cd. Obregon, Sonora	F–W/2005–06	NI
F_7 generation	El Batan, Mexico	S–S/2006	RR
Yield trials by CIMMYT		F–W/2007–08	NI
Yield trials by INIFAP AT different planting dates	Cd. Obregon, Sonora	F–W/2008–09	NI

The most important phenotypic characteristics of Ónavas F2009, according to the International Union for the Protection of New Varieties of Plants (UPOV, 1994), are given (Table 4). Cultivar Ónavas F2009 has an average of 81 days to heading with a range of 72 to 88. With a biological cycle with an average of 121 days for physiological maturity, the cycle may be shortened due to the lack of cold hours if planting is late (Wardlaw and Moncur 1995), and may average 107 days when sowing is done at the end of December. Ónavas F2009 has an average height of 97 cm (Fig. 2, p. 45), a maximum of 114 and minimum of 85. Plant growth habit is intermediate and shows a high frequency of recurved flag leaves.

Table 4. Characteristics and description of the phenotypic components of cultivar Onavas F2009.

Structure	Characteristic	Description
Coleoptile	Anthocyanin coloration	Absent or very weak
First leaf	Anthocyanin coloration	Absent or very weak
Plant	Growth habit	Intermediate
	Frequency of recurved flag leaves	Very high
	Length (stem, spike, and awns)	Long
	Seasonal type	Spring
Spike	Time of emergence	Medium
	Glaucosity	Medium
	Length (excluding awns)	Long
	Hairiness of margin of first rachis segment	Weak
	Color (at maturity)	White
	Shape in profile view	Parallel sided
	Density	Lax
Flag leaf	Glaucosity of blade	Strong
Straw	Pith in cross section (halfway between base of ear and stem node below)	Thin
Culm	Glaucosity of neck	Medium
Lower glume	Shape of shoulder	Sloping
	Shoulder width	Absent or very narrow
	Length of beak	Short
	Shape of beak	Slightly curved
	Hairiness on external surface	Weak
Awns	Presence	Present
Awns at the tip of ear	Length	Short
Grain	Coloration with phenol	Light

Spike shape in profile view is parallel sided, density is lax, and the length excluding awns is very long. Ear glaucosity is medium, becoming white at maturity. The shoulder width of the lower glume is absent or very narrow, (spikelet in mid-third of spike), shoulder shape is sloping, beak length is short, and slightly curved. Grain shape is semi-elongated (Fig. 3), and grain coloration when treated with phenol is light.

Fig 2. Bread wheat cultivar Ónavas F2009 has an average height of 97 cm. Plants present an intermediate growth habit and a very high frequency of recurved flag leaves.

Acknowledgements. The authors wish to thank the International Maize and Wheat Improvement Center (CIMMYT), for providing the advanced lines from which Ónavas F2009 originated.

Fig. 3. Grain shape of the bread wheat cultivar Ónavas F2009 is semi-elongated. Grain color after treatement with phenol is light.

References.

Figueroa-López P, Fuentes-Dávila G, Cortés-Jiménez JM, Tamayo Esquer LM, Félix-Valencia P, Ortiz-Enríquez E, Armenta-Cárdenas I, Valenzuela-Herrera V, Chávez-Villalba G, and Félix-Fuentes JL. 2011. Guía para producir trigo en el sur de Sonora. Folleto para productores No. 39, INIFAP-CIRNO, Campo Experimental Norman E. Borlaug. Cd. Obregón, Sonora, México. 63 p (In Spanish).

Figueroa-López P, Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, and Mendoza-Lugo JA. 2012. ÓNAVAS F2009, variedad de trigo harinero para el noroeste de México. Folleto Técnico No. 86, INIFAP, Centro de Investigación Regional del Noroeste, Campo Experimental Norman E. Borlaug, Cd. Obregón, Sonora, México. 26 p (In Spanish).

Melis-Cota H. 2008. Situación actual y perspectivas del trigo en el mercado nacional. Mundo Lácteo y Cárnico 24:28-31 (In Spanish).

OEIDRUS (Oficina Estatal de Información para el Desarrollo Rural Sustentable del Estado de Sonora). 2011. Estadísticas Agrícolas. http://www.oeidrus-sonora.gob.mx/. Consulted 26 September, 2011.

SARH. 1987. Cuarentena interior No. 16 contra el Carbón Parcial del trigo. Secretaría de Agricultura y Recursos Hidráulicos. Diario Oficial, 12 March, 1987, México.

UPOV. 1994. Guidelines for the conduct of tests for distinctness, homogeneity and stability of durum wheat varieties (*Triticum durum* Desf.). http://www.upov.int/index_ en.html. 22 September, 2009.

Wardlaw IF and Moncur L. 1995. The response of wheat to high temperature following anthesis: I. The rate and duration of kernel filling. Aus J Plant Physiol 22:391-397.

Effect of the level of wheat seed infection with Karnal bunt on germination and tiller production.

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Abstract. The germination and tiller production of random selected seed showing different levels of infection with Karnal bunt were evaluated during the 2008–09 crop season at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico. Sowing was on 8 and 17 December, 2008. Seed germination was 100%, 100%, and 95% for seed with 1, 2, and 3 levels of infection, respectively, sown on 8 December, while for sowing date 17 December, infection levels were 85%, 90%, and 85%. The range of the number of tillers produced by seed with infection levels 1, 2, and 3, sown on 8 and 17 December in the left and right rows of the bed was 7-37, 10-28, 7-31, 8-33, 5-33, and 7-42, and 16-39, 16-46, 8-33, 8-38, 19-43, 28-42, respectively. The average number of tillers produced was 17.7, 17.8, and 20.9 for seed with levels of infection 1, 2, and 3, respectively, sown on 8 December and 25.5, 20.8, and 27.2 for the 17 December sowing date. The average number of tillers produced was higher in seed with the highest level of infection for both sowing dates, and higher in seed sown on 17 December than on 8 December.

Introduction. Karnal bunt of wheat caused by Tilletia indica occurs on bread wheat (Mitra 1931), durum wheat, and triticale (Agarwal et al. 1977). The fungus affects partially the grains in a plant (Bedi et al. 1949). In general, infected grains are partially affected and in some occasions totally destroyed. Although the fungus may penetrate the embryo, it does not necessarily cause damage (Chona et al. 1961; Mitra 1935). Partially infected grains may give rise to healthy plants, although the percentage of germination decreases depending the level of infection (Bansal et al. 1984; Rai and Singh 1978; Singh 1980). Severely affected seed loses viability or shows abnormal germination (Rai and Singh 1978). Our objective was to determine the percentage of germination and tiller production under field conditions from wheat seed with different levels of infection caused by Karnal bunt.

Materials and methods. Germination and tiller production of random selected seed showing different levels of infection with Karnal bunt were evaluated during the 2008–09 crop season at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, Mexico. The seed was obtained from the various nurseries evaluated for their reaction to Karnal bunt inoculation during the 2007–08 crop season. Sowing was on 8 and 17 December, 2008, on beds with two rows using 10 seeds in a 1-m row. For the first sowing date, 20 seeds with a 1 level of infection (point of infection at the base of the seed) were used, 20 with a 2 level of infection (~30% of the seed affected with karnal bunt), and 20 with a 3 level of infection (~50% of the seed affected) (Fig. 4), for a total of six rows. The same number of seeds and similar levels of infection were used for the second sowing date. Counts on seed germination and number of tillers produced by each seed were made several times during the season. The agronomic management followed the technical recommendations by INIFAP (Figueroa-López et al. 2011).

Fig. 4. Karnal bunt seed infection levels. A, level 1 infection (point of infection at base of seed); B, infection level 2 (~20 of the seed infected); and C, infection level 3 (~50% of the seed infected).

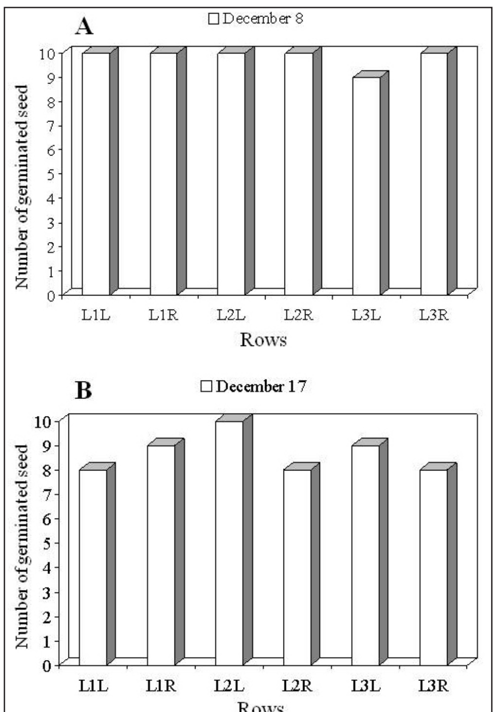

Fig 5. Germination of seed with different levels of Karnal bunt infection sown on 8 (A) and 17 (B) December, 2008 (for rows, L1L indicates an infection level of 1, left row in bed, L1R indicates a level 1 infection in the right row of the bed, etc.).

Results and discussion. Seed germination was 100%, 100%, and 95% for seed with 1, 2, and 3 levels of infection, respectively, sown on 8 December (Fig. 5A). For the 17 December sowing date, 85%, 90%, and 85% of the seed was infected at the 1, 2, and 3 levels, respectively (Fig. 5B). Rai and Singh (1978) reported a decrease in the percent seed germination with similar levels of infection as those used in our study, from 84% to 57% and to 49% in the cultivar Arjun from the harvest of 1975, and from 84% to 72% and to 58% from the harvest in 1976. Singh (1980) also reported a decrease from 74% to 72% and to 59% with cultivar CC-464, and Bansal et al. (1984) reported a decrease from 84% to 83% and to 79% with cultivar WL711. The percent seed germination observed in our study was much higher than those reported by these researchers, especially the germination of seed with an infection level 3; the average germination of seed sown on 8 December was 98.33%, whereas germination of seed sown on 17 December was 86.66%. The factor that could account for the difference in the results obtained in our study from the previously mentioned studies is that we did not use seed from the same cultivar with different levels of infection, but rather randomly selected seed from different nurseries and previous inoculation tests.

The range of the number of tillers produced by seed with infection levels 1, 2, and 3, sown on December 8 and 17 in the left and right rows of the bed was as follows: 7-37, 10-28, 7-31, 8-33, 5-33, and 7-42 (Fig. 6, p. 47), and 16-39, 16-46, 8-33, 8-38, 19-43, and 28-42 (Fig. 7, p. 47), respectively. The average number of tillers produced was 17.7, 17.8, and 20.9 for seed with levels of infection 1, 2, and 3, respectively, sown on 8 December and 25.5, 20.8, and 27.2 for the 17 December sowing date. Rai and Singh (1978) reported that infected seeds that retained their viability produced a higher proportion of abnormal seedlings compared to the healthy control, and viable seed producing abnormal seedlings in 1975 was 13.09% (level 1), 17.54% (level 2), and 22.44% (level 3) and in 1976 was 7.14% (level 1), 20.83% (level 2), and 24.13% (level 3). Singh (1980) reported that the loss in seedling length over the healthy control was 6.74% (level 1), 12.06% (level 2), and 26.21% (level 3). Bansal et al. (1984) reported that seed with trace infection or moderately low infection produced normal seedlings, but severely affected seed showed very poor vigor and the majority of the seed belonging to grade 5 (seed with practically the whole endosperm destroyed), did not germinate, and in the rest of the grades, seedlings were pale and weak. The results of our study did not correlate with those of Rai and Sing, Singh, and Bansal et al., but rather a random response was observed. However, we did not evaluate seedling development, and the seed used was not obtained from a single cultivar, but rather from randomly selected seed from various nurseries. Another piece of interesting data from our study is that the average number of tillers produced was higher in seed with the highest level of infection for both sowing dates, and higher in seed sown on 17 December than on 8 December.

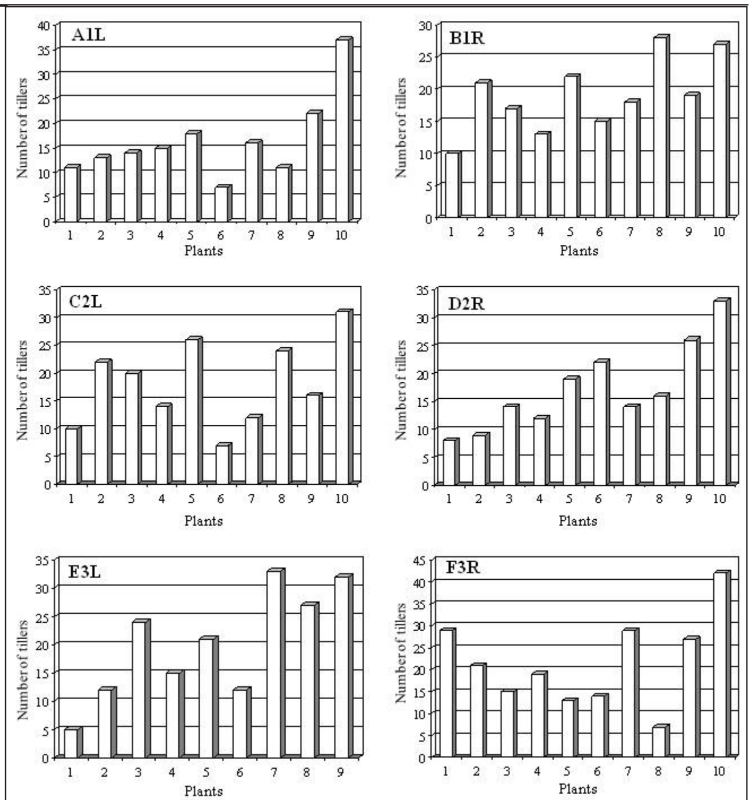

Fig. 6. Number of tillers produced in wheat plants originating from seed with Karnal bunt infection levels 1, 2, and 3 on the left (L) and right (R) of 1-m rows sown on 8 December, 2008.

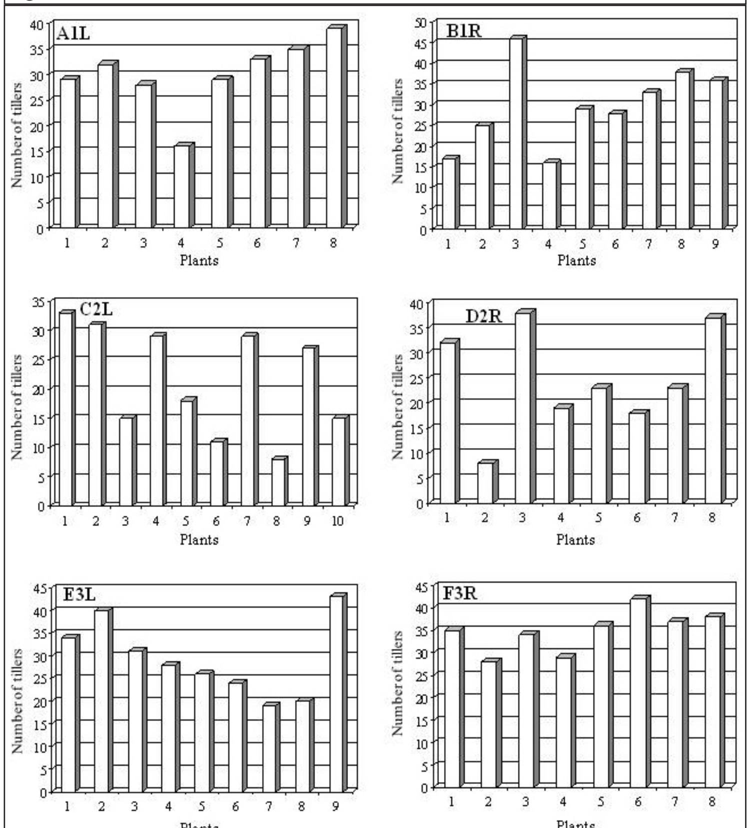

Fig. 7. Number of tillers produced in wheat plants originating from seed with Karnal bunt infection levels 1, 2, and 3 on the left (L) and right (R) of 1-m rows sown on 17 December, 2008.

Conclusions. Seeds, with points of Karnal bunt infection at the base of the seed and ~30% and ~50% of the seed affected, were able to germinate and produce tillers. The range of germination was 85–100%, and the range of the number of tillers produced was 5–46.

References.

Agarwal VK, Verma HS, and Khetarpal RK. 1977. Occurrence of partial bunt on triticale. Plant Protect Bull 25:210-211.

Bansal R, Singh DV, and Joshi LM. 1984. Effect of Karnal bunt pathogen [*Neovossia indica* (Mitra) Mundkur] on weight and viability of wheat seed. Ind J Agric Sci 54:663-666.

Bedi SKS, Sikka MR, and Mundkur BB. 1949. Transmission of wheat bunt due to *Neovossia indica* (Mitra) Mundkur. Ind Phytopathology 2:20-26.

Chona BL, Munjal RL, and Adlakha KL. 1961. A method for screening wheat plants for resistance to *Neovossia indica*. Ind Phytopathology 14:99-101.

Figueroa-López P, Fuentes-Dávila G, Cortés-Jiménez JM, Tamayo Esquer LM, Félix-Valencia P, Ortiz-Enríquez E, Armenta-Cárdenas I, Valenzuela-Herrera V, Chávez-Villalba G, and Félix-Fuentes JL. 2011. Guía para producir trigo en el sur de Sonora. Folleto para productores No. 39, INIFAP-CIRNO, Campo Experimental Norman E. Borlaug. Obregón, Sonora, México. 63 p.

Mitra M. 1931. A new bunt of wheat in India. Ann Appl Biol 18:178-179.
Mitra M. 1935. Stinking smut (bunt) of wheat with a special reference to *Tilletia indica* Mitra. Ind J Agric Sci 5:1-24.
Rai RC and Singh AA. 1978. A note on the viability of wheat seeds infected with Karnal bunt. Seed Res 6:188-190.
Singh DV. 1980. A note on the effect of Karnal bunt infection on the vigour of wheat seed. Seed Res 8:81-82.

Reaction of selected cultivars and lines of durum and bread wheat to black point.

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Abstract. Twenty advanced lines of durum wheat and commercial cultivars Samayoa C84, CEVY Oro C2008, CIRNO C2008, Patronato Oro C2008, Sáwali Oro C2008, Imperial C2008, and Chapultepec C2008, 21 advanced lines of bread wheat, and the commercial cultivars Tacupeto F2001, Kronstad F2004, Navojoa M2007, Roelfs F2007, and Norman F2008, were evaluated for their reaction to black point under natural conditions during the 2009–10 crop season at three sowing dates. The range of infected grain for the first sowing date for durum wheat lines and cultivars was 0 to 50.66%, 0 to 17.75% for the second date, and 0 to 5.51% for the third. Only the line 'SOMAT_4/INTER_8//VERDI/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ ALBA-D/5/AVO/HUI/7/PLATA_13/8/RAFI97/9/ MALMUK_1/ SERRATOR_1' did not present infected grain in any of the three dates. The range of infected grain for the first sowing date for bread wheat lines and cultivars was 0–30.87%, 0–23.06% for the second date, and 0–10.80% for the third. Only the line 'PFAU/MILAN//TROST/3/ PBW65/2*SERI.1B' did not present infected grain at any of the three dates.

Introduction. More than 100 species of fungi, including *Alternaria*, *Fusarium*, and *Helminthosporium* spp., can be isolated from newly harvested wheat grain. These fungi are most important in humid field environments, where they infect seed when relative humidity exceeds 90% and seed moisture content exceeds 20%. Rainfall during seed maturation and humid weather prevailing for a few days prior to harvest (Prescott et al. 1986; Watkins 2013) favor black point (BP). Expanding green kernels are most susceptible. Premature seed senescence also promotes BP, because many of the fungi are saprophytic (Wiese 1987). *Alternaria alternata* and *Bipolaris sorokiniana* are generally considered the primary causal agents of the disease (Mathur and Cunfer 1993). Infected ears may look normal, but there may be elliptical, brown to dark brown lesions on the inner side of the glumes. The disease is more pronounced as brown to dark brown or blackish, localized discolored areas, usually around the embryo end of seeds (Adlakha and Joshi 1974; Hanson and Christensen 1953; Rana and Gupta 1982; cited by Mathur and Cunfer 1993). The discoloration may also occur near the brush, in the crease, or any part of the seed and may be light or dark or with a distinct margin (Fig. 8). Severe infection causes discoloration and shrivelling of the whole seed (Adlakha and Joshi 1974). In southern Sonora, Mexico, black point is an endemic disease of durum and bread wheat, although incidence is variable from year to year. Wheat breeding programs select for disease resistance during seed evaluation after harvest, however, there is not a formal project on BP in Sonora. Our objective was to evaluate the reaction of selected durum and bread wheat advanced lines and commercial cultivars for their reaction to black point under natural conditions during the 2009–10 crop season.


Fig. 8. Symptoms of black point in wheat grain.

Materials and methods. Twenty advanced lines of durum wheat; the commercial durum wheat cultivars Samayoa C84, CEVY Oro C2008, CIRNO C2008, Patronato Oro C2008, Sáwali Oro C2008, Imperial C2008, and Chapultepec C2008; 21 advanced lines of bread wheat; and the commercial bread wheat cultivars Tacupeto F2001, Kronstad F2004, Navojoa M2007, Roelfs F2007, and Norman F2008 (Table 5, pp. 49-50), were evaluated for their reaction to black point under natural conditions, during the 2009–10 crop season at the Norman E. Borlaug Experimental Station in block 910 in a clay soil with pH 7.8, in the Yaqui Valley, Mexico. Sowing dates were 19, 25, and 30 November, 2009, using 8 g of seed for a 0.7-m long bed with two rows. Harvest was done manually, and the counting of healthy and infected seed was done by visual inspection. The agronomic management followed the technical recommendations by INIFAP (Figueroa-López et al. 2011).

Results. Durum wheat. The range of infected grain for the first sowing date for durum wheat lines and cultivars was 0–50.66%, with an average of 7.38; 0–17.75%, with an average of 0.99 for the second date; and 0–5.51%, with an

Table 5. Advanced lines and commercial durum and bread wheat cultivars evaluated for their reaction to black point in the field in three sowing dates, during the crop season 2009–10, in the Yaqui Valley, Sonora, Mexico.

	Pedigree and selection history
Durum wheats	
1.	Samayoa C2004
2.	CEVY Oro C2008
3.	CIRNO C2008
4.	Patronato Oro C2008
5.	Sawali Oro C2008
6.	1A.1D5+10-6/3*MOJO//RCOL/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1 CDSS02Y00408S-0Y-0M-4Y-0Y
7.	GUAYACANINIA/POMA_2//SNITAN/4/D86135/ACO89//PORRON_4/3/SNITAN CDSS02B00562S-0Y-0M-2Y-1M-04Y-0B
8.	CMH83.2578/4/D88059//WARD/YAV79/3/ACO89/5/2*SOOTY_9/RASCON_37/6/1A.1D5+10-6/3*MOJO/3/AJAIA_12/F3LOCAL(SEL. ETHIO. 135.85)//PLATA_13 CDSS02B00720S-0Y-0M-8Y-1M-04Y-0B
9.	SOMAT_4/INTER_8//VERDI/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/RAFI97/9/MAL-MUK_1/SERRATOR_1 CDSS04Y01242T-0TOPB-4Y-0M-06Y-3M-1Y-0B
10.	TGBB/CANDEF//LALA/GUIL/3/BONVAL/4/TILO_1/LOTUS_4/5/TILO_1/LOTUS_4 CDSS02B01344T-0TOPB-0Y-0M-2Y-2M-04Y-0B
11.	MOHAWK/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR84/3/HUI/ POC//BUB/RUFO/4/FNFOOT CDSS04SH00022S-22Y-2M-5Y-1M-1Y-0B
12.	SILK_3/DIPPER_6/3/ACO89/DUKEM_4//5*ACO89/4/PLATA_7/ILBOR_1//SOMAT_3 CDSS02B00290S-0Y-0M-8Y-4M-04Y-0B
13.	CBC 509 CHILE/6/ECO/CMH76A.722//BIT/3/ALTAR 84/4/AJAIA_2/5/KJOVE_1/7/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLA-TA_13/8/SOOTY_9/RASCON_37//WODUCK/CHAM_3 CDSS02B00596S-0Y-0M-5Y-1M-04Y-0B
14.	ARMENT//2*SOOTY_9/RASCON_37/4/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN CDSS02B00643S-0Y-0M-1Y-4M-04Y-0B
15.	GUAYACAN INIA/GUANAY/10/LD357E/2*TC60//JO69/3/FGO/4/GTA/5/SRN_1/6/TOTUS/7/ENTE/MEXI_2//HUI/4/YAV_1/3/LD357E/2*TC60//JO69/8/SOMBRA_20/9/JUPARE C 2001 CDSS04Y00275S-8Y-0M-06Y-4M-1Y-0B
16.	SOMAT_4/INTER_8/4/GODRIN/GUTROS//DUKEM/3/THKNEE_11/5/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN CDSS04Y00746T-0TOPB-4Y-0M-06Y-1M-1Y-0B
17.	PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/RAFI97/9/MALMUK_1/SERRATOR_1/10/AR-MENT//SRN_3/NIGRIS_4/3/CANELO_9.1/11/SHAG_21/DIPPER_2//PATA_2/6/ARAM_7//CREX/ALLA/5/ENTE/MEXI_2//HUI/4/YAV_1/3/LD357E/2*TC60//JO69 CDSS04Y00993T-0TOPB-16Y-0M-06Y-1M-1Y-0B
18	ALTAR 84/BINTEPE 85/3/STOT//ALTAR 84/ALD/4/POD_11/YAZI_1/5/VANRRIKSE_12/SNITAN/6/SOOTY_9/RASCON_37//WO-DUCK/CHAM_3 CDSS04Y01051T-0TOPB-21Y-0M-06Y-2M-1Y-0B
19.	CANELO_9.1/SNITAN/10/PLATA_10/6/MQUE/4/USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/THKNEE_11/9/CHEN/ALTAR 84/3/HUI/POC//BUB/RUFO/4/FNFOOT CDSS02B00348S-0Y-0M-4Y-1M-04Y-0B
20.	YAV79/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/5/MINIMUS/COMB DUCK_2//CHAM_3/3/GREEN_19 CDSS02B01063T-0TOPB-0Y-0M-1Y-4M-04Y-0B
21.	DUKEM_1//SORA/2*PLATA_12/3/SOMAT_4/INTER_8 CDSS04Y00520S-18Y-0M-06Y-4M-1Y-0B
22.	RANCO//CIT71/CII/3/COMDK/4/TCHO//SHWA/MALD/3/CREX/5/SNITAN/6/YAZI_1/AKAKI_4//SOMAT_3/3/AUK/GUIL//GREEN CDSS04B00151S-3Y-0M-2Y-0M-2Y-0B
23.	GODRIN/GUTROS//DUKEM/3/THKNEE_11/4/DUKEM_1//PATKA_7/YAZI_1/3/PATKA_7/YAZI_1/5/AJAIA_12/F3LOCAL(SEL. ETHIO.135.85)//PLATA_13/3/ADAMAR CDSS04B00367T-0TOPY-10Y-0M-4Y-0M-4Y-0B
24.	MOHAWK/6/LOTUS_5/F3LOCAL(SEL.ETHIO.135.85)/5/CHEN/ALTAR 84/3/HUI/POC//BUB/RUFO/4/FNFOOT CDSS05Y00087S-64Y-0M-1Y-0M-1Y-0B
25.	AJAIA_3/SILVER_16//AJAIA_13/YAZI/4/ARMENT//SRN_3/NIGRIS_4/3/CANELO_9.1/5/GODRIN/GUTROS//DUKEM/3/THKNEE_11 CDSS05Y00512T-0TOPB-21Y-0M-4Y-0M-1Y-0B
26.	Imperial C2008
27.	Chapultepec C2008

Table 5. Advanced lines and commercial durum and bread wheat cultivars evaluated for their reaction to black point in the field in three sowing dates, during the crop season 2009–10, in the Yaqui Valley, Sonora, Mexico.

	Pedigree and selection history
Bread wheats	
1.	Tacupeto F2001
2.	Kronstad F2004
3.	Navojoa M2007
4.	Roelfs F2007
5.	TOBA97/PASTOR CMSS97M05756S-040M-020Y-030M-015Y-3M-1Y-3M-0Y
6.	KAMB1*2/BRAMBLING CGSS01B00069T-099Y-099M-099M-099Y-099M-20Y-0B
7.	BETTY/3/CHEN/AE.SQ//2*OPATA CMSW00WM00150S-040M-040Y-030M-030ZLM-3ZTY-0M
8.	WBLL1*2/BRAMBLING CGSS01B00062T-099Y-099M-099M-099Y-099M-12Y-0B
9.	BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ CGSS01B00045T-099Y-099M-099M-099Y-099M-26Y-0B
10.	BABAX/LR42//BABAX/3/ER2000 CMSA01Y00176S-040P0Y-040M-030ZTM-040SY-24M-0Y-0SY
11.	PFAU/MILAN/3/BABAX/LR42//BABAX CMSS02M00056S-030M-28Y-0M-040Y-25ZTB-0Y-01B-0Y
12.	THELIN/2*WBLL1 CGSS02Y00079T-099B-099B-099Y-099M-6Y-0B
13.	PBW343//CAR422/ANA/3/ELVIRA CMSS02M00409S-030M-1Y-0M-040Y-10ZTB-0Y-02B-0Y
14.	BABAX/LR42//BABAX/3/ER2000 CMSA01Y00176S-040P0Y-040M-030ZTM-040SY-30M-0Y-0SY
15.	TC870344/GUI//TEMPORALERA M 87/AGR/3/2*WBLL1 CMSA01Y00725T-040M-040P0Y-040M-030ZTM-040SY-10M-0Y-0SY
16.	ROLF07/YANAC//TACUPETO F2001/BRAMBLING CGSS05B00121T-099TOPY-099M-099NJ-4WGY-0B
17.	WAXWING*2/KRONSTAD F2004 CGSS04Y00020T-099M-099Y-099ZTM-099Y-099M-3WGY-0B
18.	WHEAR/KRONSTAD F2004 CGSS04Y00106S-099Y-099M-099Y-099M-9WGY-0B
19.	KEA/TAN/4/TSH/3/KAL/BB//TQFN/5/PAVON/6/SW89.3064/7/SOKOLL CMSS04Y00153S-099Y-099ZTM-099Y-099M-5WGY-0B
20.	CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/WH576/7/WH 542/8/WAXWING CMSS04Y00364S-099Y-099ZTM-099Y-099M-2WGY-0B
21.	BECARD CGSS01B00063T-099Y-099M-099M-099Y-099M-33WGY-0B
22.	WHEAR/SOKOLL CMSS04Y00201S-099Y-099ZTM-099Y-099M-11WGY-0B
23.	PFAU/MILAN//TROST/3/PBW65/2*SERI.1B CMSS04M01426S-0TOPY-099ZTM-099Y-099M-3RGY-0B
24.	WHEAR/KRONSTAD F2004 CGSS04Y00106S-099Y-099M-099Y-099M-3WGY-0B
25.	CHEWINK CGSS03B00074T-099Y-099M-099Y-099M-6WGY-0B-3B
26.	Norman F2008

average of 0.48 for the third (Fig. 9A, p. 50). Only the line 'SOMAT_4/INTER_8//VERDI/10/PLATA_10 /6/MQUE/4/ USDA573//QFN/AA_7/3/ALBA-D/5/AVO/HUI/7/PLATA_13/8/RAFI97/9/ MALMUK_1/ SERRATOR_1' did not present infected grain at any of the three dates. Although all commercial cultivars in the overall average of infection, were in the 0.1–5.0% infection category (Fig. 10A, p. 51), at the first sowing date they had the highest potential for susceptibility, CIRNO C2008 had 13.93% infection, Samayoa C2004 12.13%, Patronato Oro C2008 6.03%, and Sáwali Oro C2008 5.85%. Lines with the highest levels of infection in the first sowing date were 'SOMAT_4/INTER_8/4/GODRIN/ GUTROS//DUKEM/3/THKNEE_11/5/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN' with 50.66% and 'SILK_3/ DIPPER_6/3/ACO89/DUKEM_4//5*ACO89/4/ PLATA_7/ ILBOR_1//SOMAT_3' with 16.9%. SOMAT_4 showed a 17.75% infection at the second sowing date.

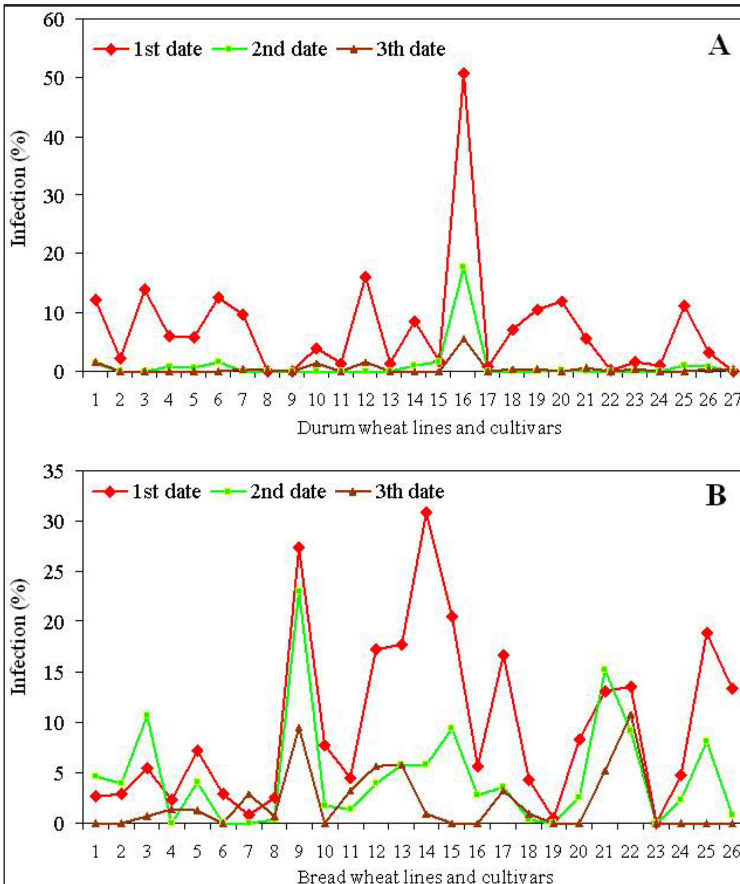

Fig. 9. Percent infection with black point in 20 advanced lines and seven commercial durum wheat cultivars (A) and in 21 advanced lines and five commercial bread wheat cultivars (B) in the Yaqui Valley, Sonora, Mexico, during the 2009–10 crop season.

Bread wheat. The range of infected grain for the first sowing date for the bread wheat lines and cultivars was 0–30.87%, with an average of 9.69%; 0–23.06% for the second date, with an average of 4.60%; and 0–10.80% at the third date, with an average of 2.01% (Fig. 9B). Only the line 'PFAU/MILAN//TROST/3/PBW65/2*SERI.1B' did not present infected grain at any of the three dates. Commercial cultivars Tacupeto F2001, Kronstad F2004, Roelfs F2007, Norman F2008, and 10 advanced lines had 0.1–5.0% infection, and Navojoa M2007 and five lines had 5.1–10.0% infection (Fig. 9B). The highest infection were observed at the first sowing date in lines 'BABAX/LR42//BABAX/3/ER2000' with 30.87%, 'BABAX/LR42//BABAX*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ' with 27.33%, and 'TC870344/GUI//TEMPORALERA M87/AGR/3/2*WBLL1' with 20.53%.

Conclusions. Black point is an endemic disease in southern Sonora, Mexico. The overall average infection in a selected group of advanced lines and commercial cultivars of durum wheat sown on three dates was 2.95%, with a range of 0–50.66%. Among the durum wheat commercial cultivars, CIRNO C2008 showed the highest infection with 13.93%. The overall average infection in the bread wheats was 5.43%, with a range of 0–30.87%. Among the bread wheat commercial cultivars, Norman F2008 had the highest infection at 13.29%.

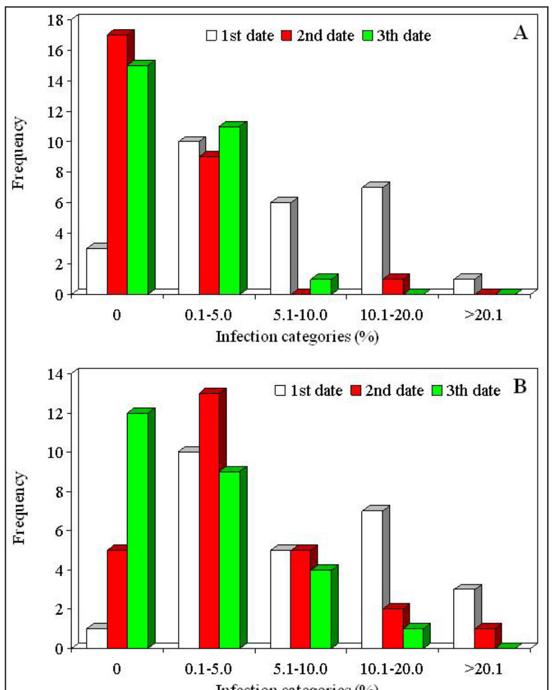

Fig. 10. Results of natural infection with black point in 20 advanced lines and seven commercial durum wheat cultivars (A) and in 21 advanced lines and five commercial bread wheat cultivars (B) in the Yaqui Valley, Sonora, Mexico, during the 2009–10 crop season.

References.

Figueroa-López P, Fuentes-Dávila G, Cortés-Jiménez JM, Tamayo Esquer LM, Félix-Valencia P, Ortiz-Enríquez E, Armenta-Cárdenas I, Valenzuela-Herrera V, Chávez-Villalba G, and Félix-Fuentes JL 2011. Guía para producir trigo en el sur de Sonora. Folleto para productores No. 39, INIFAP-CIRNO, Campo Experimental Norman E. Borlaug. Cd. Obregón, Sonora, México. 63 p (In Spanish).

Mathur SB and Cunfer BM. 1993. Seed-borne Diseases and Seed Health Testing of Wheat. Danish Government Institute of Seed Pathology for Developing Countries, Hellerup, Denmark. 168 p.

Prescott JM, Burnett PA, Saari EE, Ramsom J, Bowman J, de Milliano W, Singh RP, and Bekele G. 1986. Wheat Diseases and Pests: A guide for field identification. CIMMYT. Mexico, D.F. 135 p.

Watkins JE. 2013. Black point disease of wheat. University of Nebraska-Lincoln. http://baylor.agrilife.org/files/2011/06/blackpointnebguide_2.pdf. Consulted on 23 March, 2013.

Wiese MV. 1987. Compendium of Wheat Diseases. APS Press, St. Paul, MN, USA. 112 p.

Reaction of bread wheat lines and cultivars to Karnal bunt under artificial inoculation during the 2011–12 crop season in the Yaqui Valley, Mexico.

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Abstract. Twenty-one advanced bread wheat lines and four commercial cultivars were evaluated for resistance to Karnal bunt by artificial inoculation during the 2011–12 crop season at two dates in the Yaqui Valley, Mexico. The infection range was 0.66-24.35% for the first date and 0.57–30.04% for the second date. Only lines 'FRET2/TUKURU//FRET2/3/MUNIA/CHTO//AMSEL/4/FRET2/TUKURU//FRET2' and 'KACHU/3/C80.1/3*BATAVIA//2*WBLL1/4/KACHU' were in the 2.6–5.0% infection category. Tepahui F2009 and seven lines had 5.1–10.0% infection and Roelfs F2007, Ónavas F2009, Villa Juárez F2009, and 12 lines had 10.1–30.0%. Commercial cultivars with the highest percent infection were Roelfs F2007 (10.19%) and Villa Juárez F2009 (18.53%). Lines that showed the highest infection were 'FRET2/TUKURU//FRET2/3/TACUPETOF2001*2/ KIRITATI' with 27.41% and 'ROLF07/4/BOW/NKT//CBRD/3/CBRD/5/FRET2/ TUKURU//FRET2' with 30.03%.

Introduction. Karnal bunt of wheat was first identified in India (Mitra 1931), and later in Mexico (Duran 1972), Pakistan (Munjal 1975), Nepal (Singh et al. 1989), Brazil, (Da Luz et al. 1993), the United States of America (APHIS 1996), Iran (Torarbi et al. 1996), and the Republic of South Africa (Crous et al. 2001). *Triticum aestivum* is most susceptible plant species to Karnal bunt (Fig. 11). Under artificial inoculation, some lines may show more than 50% infected grain (Fuentes-Dávila et al. 1992; 1993). The causal agent of this disease is the fungus *Tilletia indica* (Mitra 1931) (syn. *Neovossia indica*). Although *T. indica* may affect durum wheat and triticale (Agarwal et al. 1977), the level of infected grain is generally low. Control of this pathogen is difficult, because the teliospores are resistant to physical and chemical factors (Krishna and Singh 1982; Zhang et al. 1984; Smilanick et al. 1988). Chemical control can be accomplished by applying fungicides during flowering (Fuentes-Dávila et al. 2005), however, this measure is not feasible when quarantines do not allow tolerance levels for seed production. Resistant wheat cultivars are the best means to control this disease. Our objective was to evaluate 21 advanced bread wheat lines and four commercial cultivars for resistance to Karnal bunt.


Fig. 11. Karnal bunt (*Tilletia indica*) symptoms on the grain of bread wheat.

Materials and methods. Twenty-one advanced bread wheat lines and four commercial cultivars (Roelfs F2007, Tepahui F2009, Ónavas F2009, and Villa Juárez F2009) (Table 6, p. 53) were evaluated for resistance to Karnal bunt during the fall–winter of the 2011–12 crop season in block 910 in a clay soil with a pH 7.8, in the Yaqui Valley, Sonora, Mexico. Sowing dates were 30 November and 9 December, 2011, using a 1-m bed with two rows. Inoculum was prepared by isolating teliospores from infected kernels, followed by centrifugation in a 0.5% sodium hypochlorite solution and plating on 2% water-agar Petri plates. After teliospore germination, fungal colonies were transferred and multiplied on potato-dextrose-agar. Inoculations were carried out by injecting 1 mL of an allantoid sporidial suspension (10,000/mL) during the boot stage (Fig. 12) in 10 heads from each line and cultivar. High relative humidity in the experimental area was provided by a fine spray of water with back-pack manual sprayers. Harvest was done manually, and the counting of healthy and infected grains was done visually to determine the percentage of infection. Evaluated lines originated from the collaborative project between the International Maize and Wheat Improvement Center (CIMMYT) and the National Institute for Forestry, Agriculture and Livestock Research in Mexico (INIFAP).


Fig. 12. Artificial inoculation of bread wheat with a sporidial suspension of *Tilletia indica* by boot injection in the field.

Results. The range of infection for the first planting date was 0.66–24.35%, with a mean of 8.96 (Fig. 13, p. 54). The range of infection for the second planting date was 0.57–30.04%, with a mean of 12.44. The frequency of lines in the different infection categories in the two dates is shown in Fig. 14 (p. 54). The mean of the three highest percentage of

Table 6. Advanced bread wheat lines and commercial cultivars artificially inoculated with karnal bunt (*Tilletia indica*) in the field in two sowing dates, during the 2011–12 crop season, in the Yaqui Valley, Sonora, Mexico.

	Pedigree and selection history
1.	Roelfs F2007
2.	Tepahui F2009
3.	Onavas F2009
4.	Villa Juárez F2009
5.	PBW343//CAR422/ANA/3/ELVIRA CMSS02M00409S-030M-1Y-0M-040Y-10ZTB-0Y-02B-0Y
6.	MONR/3/GAV/ROM//BAR TC-060024-10R-0OAX-0R-6C
7.	MILAN/KAUZ//PRINIA/3/BAV92/4/PASTOR*2/BAV92/5/TACUPETO F2001*2/KUKUNA CMSA05Y01021T-040M-040ZTP0Y-040ZTM-040SY-14ZTM-01Y-0B
8.	SOKOLL*2/TROST CMSA05Y01186T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-03Y-0B
9.	SOKOLL*2/3/BABAX/LR42//BABAX CMSA05Y01225T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-01Y-0B
10.	WBLL1*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES CMSS05B00060S-099Y-099M-099Y-099ZTM-14WGY-0B
11.	TACUPETO F2001/6/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PASTOR/7/ROLF07 CMSS06Y00716T-099TOPM-099Y-099ZTM-099Y-099M-3RGY-0B
12.	ROLF07/4/BOW/NKT//CBRD/3/CBRD/5/FRET2/TUKURU//FRET2 CMSS06Y00605T-099TOPM-099Y-099ZTM-099Y-099M-11WGY-0B
13.	WAXWING/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/KIRITATI//ATTILA*2/PASTOR CMSS07Y00288S-0B-099Y-099M-099Y-17M-0WGY
14.	WBLL1*2/KURUKU/4/PFAU/SERI.1B//AMAD/3/WAXWING CMSS07Y00338S-0B-099Y-099M-099Y-9M-0WGY
15.	STLN/MUNAL #1 CMSS07Y00452S-0B-099Y-099M-099Y-22M-0WGY
16.	PBW343*2/KUKUNA*2//FRTL/PIFED CMSS06Y00831T-099TOPM-099Y-099ZTM-099NJ-099NJ-5WGY-0B
17.	PBW343*2/KUKUNA*2//FRTL/PIFED CMSS06Y00831T-099TOPM-099Y-099ZTM-099NJ-099NJ-22WGY-0B
18.	WBLL1/FRET2//PASTOR*2/3/MURGA CMSS06Y00937T-099TOPM-099Y-099ZTM-099Y-099M-8WGY-0B
19.	FRET2/TUKURU//FRET2/3/MUNIA/CHTO//AMSEL/4/FRET2/TUKURU//FRET2 CMSS06Y00878T-099TOPM-099Y-099ZTM-099Y-099M-18WGY-0B
20.	KACHU/3/C80.1/3*BATAVIA//2*WBLL1/4/KACHU CMSS06Y01283T-099TOPM-099Y-099ZTM-099Y-099M-14WGY-0B
21.	BECARD/KACHU CMSS06B00169S-0Y-099ZTM-099Y-099M-13WGY-0B
22.	FRET2/TUKURU//FRET2/3/TACUPETO F2001*2/KIRITATI CMSS07B00081S-099M-099NJ-099NJ-12WGY-0B
23.	BECARD/QUAIU #1 CMSS07B00230S-099M-099NJ-099NJ-21WGY-0B
24.	ROLF07*2/5/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES CMSS06B00704T-099TOPY-099ZTM-099Y-099M-23WGY-0B
25.	BECARD/AKURI CMSS06B00411S-0Y-099ZTM-099Y-099M-1WGY-0B

infection of the susceptible check was 100%. Only the lines 'FRET2/TUKURU// FRET2/3/MUNIA/CHTO//AMSEL/4/FRET2/TUKURU//FRET2' and 'KACHU/3/C80.1/ 3*BATAVIA//2*WBLL1/4/KACHU' were in the 2.6–5.0% infection category; lines with less than 5% infection are considered resistant (Fuentes-Dávila and Rajaram 1994). Tepahui F2009 and seven lines had 5.1–10.0% infection, and Roelfs F2007, Ónavas F2009, and Villa Juárez F2009 and 12 lines had 10.1–30.0% infection. Commercial cultivars with the highest infection were Roelfs F2007 (10.19%) and Villa Juárez F2009 (18.53%). Lines that showed the highest infection were 'FRET2/TUKURU//FRET2/3/TACUPETOF2001*2/KIRITATI' (27.41%) and 'ROLF07/4/BOW/NKT//CBRD/3/CBRD/5/FRET2/TUKURU//FRET2' (30.03%).

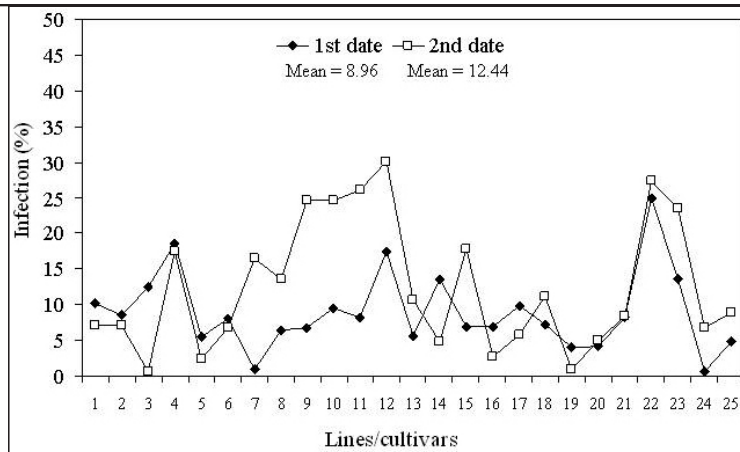

Fig. 13. Percent infection with Karnal bunt (*Tilletia indica*) of 21 elite advanced bread wheat lines and four commercial cultivars artifically inoculated in the field at two dates during the 2011–12 crop season in the Yaqui Valley, Sonora, Mexico.

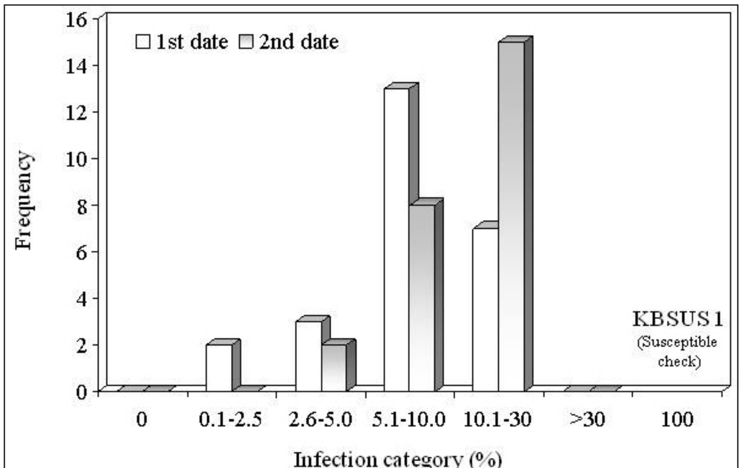

Fig. 14. Results of artificial field inoculation at two dates with Karnal bunt (*Tilletia indica*) of 21 elite advanced bread wheat lines and four commercial cultivars during the 2011–12 crop season in the Yaqui Valley, Sonora, Mexico. The infection level of KBSUS 1 is the mean of the three highest infection scores.

References.

Agarwal VK, Verma HS, and Khetarpal RK. 1977. Occurrence of partial bunt on triticale. Plant Protect Bull 25:210-211.

APHIS. 1996. Karnal bunt: situation report update (March 29). USDA-APHIS, Plant Protection and Quarantine (http://www.aphis.usda.gov/oa/bunt).

Crous PW, Van Jaarsveld AB, Castlebury LA, Carris LM, Frederick RD, and Pretorius ZA. 2001. Karnal bunt of wheat newly reported from the African continent. Plant Dis 85:561.

Da Luz WC, Mendes MAS, Ferreira MASV, and Urben AF. 1993. *Tilletia indica* on wheat in the south of the state of Rio Grande do Sul, Brazil and measures for eradication. Fitopatologia Brasileira 18:S329.

Duran R. 1972. Further aspects of teliospore germination in North American smut fungi II. Can J Bot 50:2569-2573.

Fuentes-Davila G and Rajaram S. 1994. Sources of resistance to *Tilletia indic*a in wheat. Crop Protect 13(1):20-24.

Fuentes-Davila G, Rajaram S, Pfeiffer WH, and Abdalla O. 1992. Results of artificial inoculation of the 4th Karnal Bunt Screening Nursery (KBSN). Ann Wheat Newslet 38:157-162.

Fuentes-Davila G, Rajaram S, Pfeiffer WH, Abdalla O, Van-Ginkel M, Mujeeb-Kazi A, y Rodríguez-Ramos R. 1993. Resultados de inoculaciones artificiales del 5o. vivero de selección para resistencia a *Tilletia indica* Mitra. Rev Mex Micro 9:57-65 (In Spanish).

Fuentes-Dávila G, Tapia-Ramos E, Toledo-Martínez JA, and Figueroa-López P. 2005. Evaluación de efectividad biológica de folicur 250 EW (Tebuconazol) para el control del carbón parcial (*Tilletia indica*) del trigo (*Triticum aestivum*), en el valle del Yaqui, Sonora, México, durante el ciclo de cultivo 2003-2004. *In:* Abstracts, XIII Congreso Latinoamericano de Fitopatología, III, Taller de la Asociación Argentina de Fitopatólogos, 19-22 April, 2005, Villa Carlos Paz, Córdoba, Argentina. Abstract HC-29, p. 271 (In Spanish).

Krishna A and Singh RA. 1982. Effect of physical factors and chemicals on the teliospore germination of *Neovossia indica*. Ind Phytopathology 35:448-455.

Mitra M. 1931. A new bunt of wheat in India. Ann Appl Biol 18:178-179.

Munjal RL. 1975. Status of Karnal bunt (*Neovossia indica*) of wheat in northern India during 1968-69 and 1969-1970. Ind J Mycol Plant Path 5:185-187.

Smilanick JL, Hoffmann JA, Secrest LR, and Wiese K. 1988. Evaluation of chemical and physical treatments to prevent germination of *Tilletia indica* teliospores. Plant Dis 72:46-51.

Torarbi M, Mardoukhi V, and Jalaiani N. 1996. First report on the occurrence of partial bunt on wheat in the southern parts of Iran. Seed and Plant 12:8-9.

Zhang Z, Lange L, and Mathur SB. 1984. Teliospore survival and plant quarantine significance of *Tilletia indica* (causal agent of Karnal bunt) particularly in relation to China. Eur Plant Protect Bull 14:119-128.

Study on dissemination of Tilletia indica propagules from artificially inoculated wheat spikes that might cause infection to neighboring noninoculated spikes.

Guillermo Fuentes-Dávila.

Abstract. Experiments were conducted at the Norman E. Borlaug Experimental Station, in Mexico during the 1987–88 to 1990–91 crop seasons, to determine if there is spread of fungal propagules from artificially inoculated spikes to neighboring noninoculated ones. Inoculated spikes were injected during the boot stage with 1 mL of a sporidial suspension with a concentration of 10,000/mL. In 1987–88, data was collected from the susceptible cultivars Genaro T81, Glennson M81, and WL711, which were inoculated on 33 different dates. Approximately 50 spikes were collected around each inoculated spike. In crop season 1988–89, WL711 was inoculated on four dates, five in 1989–90 in five, and seven in 1990–91. The number of spikes evaluated were 40 in 1988–89, 1989–90 50 in, and 50 in 1990-91. The number of inoculated spikes per date were five in 1988–89, six in 1989–90, and ten in 1990–91. At maturity, spikes around the inoculated spikes were harvested and threshed by hand to determine the number of healthy and infected grains. The percent of spikes infected with Karnal bunt during crop seasons 1987–88 was 0.19 (3,033 spikes evaluated), 0.12 in 1988–89 (800 spikes), 0.40 in 1989–90 (1,500 spikes), and 1.74 in 1990–91 (3,450 spikes). The total percent affected spikes, 74 out of 8,783, was 0.84. The percent infected wheat grains with Karnal bunt during 1987–88 was 0.029 (126,647 spikes evaluated), 0.003 in 1988–89 (33,405 spikes), 0.10 in 1989–90 (67,468 spikes), and 0.14 in 1990–91 (135,457 spikes). The total percent of infected grains, 300 out of 362,977, was 0.082. Results of the experiments showed that dissemination of fungal propagules from inoculated spikes is nil or extremely low.

Introduction. *Tilletia indica* Mitra (syn. *Neovossia indica* (Mitra) Mundkur) is the causal agent of Karnal bunt disease of wheat, which was first identified in India (Mitra 1931), and later in Mexico (Duran 1972), Pakistan (Munjal 1975), Nepal (Singh et al. 1989), Brazil, (Da Luz et al. 1993), the United States of America (APHIS 1996), Iran (Torarbi et al. 1996), and the Republic of South Africa (Crous et al. 2001). Teliospores of this organism are resistant to extreme cold, heat, chemical treatments (Smilanick et al. 1985), and can survive up to three (Bonde et al. 2004) to four years in field soil (Krishna and Singh 1982), making control difficult. Fairly good chemical control with fungicide applications during flowering can be accomplished (Salazar-Huerta et al. 1997), however, in northwest Mexico, due to quarantine regulations (SARH 1987), this measure is still not profitable for commercial use. Evaluation of various *Triticum* species for resistance to *T. indica* has been on-going since the 1940s (Anonymous 1943: Bedi et al. 1949; Gautam et al. 1977; Singh et al. 1986; Singh et al. 1988). Aujla et al. (1986) reported the release of wheat cultivars WL1562, PBW120, and PBW65 as resistant in India, and Camacho-Casas et al. (1993) reported resistanc in cultivar Arivechi M92 in Mexico. The use of resistant cultivars offers the best alternative for farmers where Karnal bunt is a problem. Therefore, since the early 1980s, the Wheat Program of the International Maize and Wheat Improvement Center and the Mexican National Institute for Forestry, Agriculture, and Livestock Research implemented a project on breeding for resistance to *T. indica*. Because disease incidence is erratic in northwest Mexico, evaluation of experimental germ plasm can not rely on natural occurrence of the disease, therefore, this project is based primarily on artificial inoculation of experimental wheat germ plasm, which has brought up the concern of some government personnel and farmers that the fungus might be disseminated or spread from inoculated wheat spikes and if this activity might increase the inoculum level in the soil. Dhaliwal et al. (1988) reported trapping sporidia from underneath inoculated spikes under laboratory and field conditions and that these were infective on artificially inoculated wheat. They also reported that more plants had bunted kernels near inoculated spikes in the field, and that counts of such plants decreased with the increasing distance from the inoculated spikes. Later, Dhaliwal (1989) indicated that there was limited secondary spread of Karnal bunt around the inoculated spikes in spite of abundant sporidial production by them, suggesting that environmental conditions favorable for inoculum production may not necessarily be the same as for inoculum dissemination and establishment of infection. He found only 22 out of 60 infected grains in two groups of 20 uninoculated spikes. Those two groups were under sprinkler irrigation. Also, the possibility that infection was caused by natural inoculum can not be discarded. Bains and Dhaliwal (1989), reported that wheat spikes inoculated with Karnal bunt, produced secondary sporidia when later incubated (intact/detached) under moist conditions. Our objective was to determine if there is spread of *T. indica* propagules from artificially inoculated spikes that could cause infection in the neighboring noninoculated spikes. This work has not been published previously.

Materials and methods. Experiments were conducted at the Norman E. Borlaug Experimental Station, previously known as CIANO, located in the Yaqui Valley, Sonora, Mexico (27°20'N, 105°55'W, elevation 39 masl), during crop seasons 1987–88 to 1990–91. For inoculum preparation, one-year-old teliospores were taken from naturally infected wheat grains from various locations in the Yaqui Valley to assure a genetically heterogenous composite of the fungus population. To isolate teliospores, infected grains were agitated for about 15 seconds in a test tube containing a water+tween solution using a vortex shaker, then sieved through a 60 um nylon microsieve to remove all debris. Teliospores were kept in the solution for 24 h to enhance germination. Thereafter, they were precipitated by centrifugation at 3,000 rpm, surface sterilized with sodium hypochlorite 0.5% a.i. for 2 min while centrifuging at 3,000 rpm, rinsed twice with distilled sterile water, and plated on water-agar (WA) 1.5%. Plates were incubated at room temperature (20–22°C) and teliospore germination was assessed starting five days after plating using a compound microscope at 10X. Pieces of agar with the fungus germinating were inverted onto the lids of potato-dextrose-agar (PDA) plates for ballistospore release and further multiplication. After 10 to 14 days, 2 to 3 mL of sterile distilled water were added to the plates and the colonies were scraped gently using a sterile spatula. Hyphae and sporidia were inoculated onto other plates with PDA using a sterile syringe, and the plates were incubated at 20°C in darkness for about nine days. After incubation, pieces of PDA with the different fungal propagules were transferred and placed upside down on the lids of sterile glass Petri plates, in order to induce production of allantoid secondary sporidia (Dhaliwal and Singh, 1989; Fuentes-Dávila et al., 1993). About three mL of sterile distilled water were added to the bottom of the plates. Then, the water-sporidia suspension was collected from the plates every 24 h; secondary allantoid sporidia were counted using a heamocytometer, and the concentration was adjusted to 10,000 per mL. Inoculation was performed by injection of 1 mL per spike in the boot (Zadoks et al. 1974), stages 48–49 and were identified with a colored plastic piece. Inoculations were carried out after 4 PM. To provide high relative humidity in order to assure a succesful infection, an overhead irrigation system was used after inoculation, and from 3–5 times/day for 15 min each time.

During the 1987–88 crop season, data was collected from inoculation of the susceptible cultivar Genaro T81, Glennson M81, and WL711, which had been artificially inoculated from 18 January to 3 March, giving a total of 33 different inoculation dates. Approximately 50 spikes were collected around each inoculated spike. For Genaro T81, 13 spikes were inoculated from 18 January to 10 February and 19 from 11–26 February; for Glennson M81, 17 spikes were inoculated from 19 January to 1 February; and for WL711, 12 spikes were inoculated from 11 Januray to 3 March. In the 1988–89 crop season, WL711 was inoculated on four dates (6, 11, 13, and 15 February), five in 1989–90 (24, 31 January, 8, 23 February, and 6 March) in 1989–90 in, and seven (18, 25 January, 1, 8, 15, 22 February, and 1 March) in 1990–91. The number of spikes evaluated were 40, 50, and 50 per inoculated spike per date in those three seasons. The number of inoculated spikes per date were 5 in crop season 1988-89, 6 in 1989-90, and 10 in 1990-91.

During 1987–88 to 1989–90, the experiment was carried out in material under an overhead irrigation system, and in 1990–91 without the system irrigation. The overhead irrigation was used to simulate rainfall and increase relative humidity, based on the fact that natural disease incidence is higher under those conditions (Aujla et al. 1977; Mundkur 1943; Bedi et al. 1949; Singh and Prasad 1978). However, because overhead irrigation might interfere with sporidial movement, the system was not used in 1991. At maturity, spikes around the inoculated ones were harvested and threshed by hand to determine the number of healthy and infected grains.

Results. The percent spikes infected with Karnal bunt (Fig. 15) was 0.19 in 1987–88 after evaluation of 3,033 spikes, 0.12 in 1988–89 (800 spikes evlautate), 0.40 in 1989–90 (1,500 spikes evaluated), and 1.74 in 1990–91 (3,450 spikes evaluated) (Table 7). The total infected spikes was 74 out of 8,783, or 0.84. The percent wheat grains infected with Karnal bunt to was 0.029 1987-88 (126,647 spikes evaluated), 0.003 in 1988–89 (33,405 spikes evaluated), 0.10 in 1989–90 (67,468 spikes evaluated), and 0.14 in 1990–91 (135,457 spikes evaluated) (Table 8, p. 57). The total percent of infected grains was 300 out of 362,977, or 0.082. The highest number of infected grains was obtained when no overhead irrigation was used, however, a greater number of spikes were evaluated, which increased the possibilities of finding


Fig. 15. Wheat spike showing infection by *Tilletia indica*.

Table 7. Number of infected spikes collected around spikes artificially inoculated with Karnal bunt (*Tilletia indica*) in the field during the 1987–88 to 1990–91 crop seasons at the Norman E. Borlaug Experimental Station, Yaqui Valley, Sonora, Mexico. The number of spikes evaluated in 1988 does not correspond to the expected, since some dates were repeated in three cultivars assessed.For inoculated spikes, the numerator indicates the numbe of inoculated spikes and the denominator the number of spikes collected around the inoculated spike.

	Inoculation		Spikes		
Season	Number	Spikes	Healthy	Infected	%
1987–88	33	1/50	3,033	6	0.19
1988–89	4	5/40	800	1	0.12
1989–90	5	6/50	1,500	6	0.40
1990–91	7	10/50	3,450	61	1.74

more. On the other hand, conducive environmental conditions for infection prevailed in the Yaqui Valley, which might have influenced a greater number of infected grains. Consequently, those grains might have been infected from inoculum coming from sources other than the artificially inoculated spikes. Despite the fact that the soil was not covered in the sorroundings of clusters of inoculated and noninoculated wheat plants, indications of sporidial spread or of any other fungal propagules is quite lacking, because the number of infected grains obtained was extremely low. If we assume that spread occurs in spikes closest to those that are inoculated, they would have the greatest chance of serving as points of inoculum arrival and, perhaps, would interfere with farther spread of propagules. The low frequency of spikes with a moderate number of infected grains can be considered as another indication of little or no spread of sporidia, considering also that the mean number of grains/spike (out of those evaluated) in cultivar WL711 is about 40. Results of the experiments show that dissemination of fungal propagules from inoculated spikes is nil or extremely low. In relation to the possibility of increasing inoculum levels in the soil by the activity of artificial inoculation in order to evaluate the reaction to *T. indica* of experimental germ plasm, because inoculated spikes are collected for evaluation, the possibilities of increasing inoculum levels in the soil are very low.

Table 8. Number of infected wheat grains obtained from spikes collected around spikes artificially inoculated with Karnal bunt (*Tilletia indica*) in the field during the 1987–88 to 1990–91 crop seasons at the Norman E. Borlaug Experimental Station, Yaqui Valley, Sonora, Mexico. The number of spikes evaluated in 1988 does not correspond to the expected, since some dates were repeated in three cultivars assessed.For inoculated spikes, the numerator indicates the numbe of inoculated spikes and the denominator the number of spikes collected around the inoculated spike.

	Inoculation		Grains		
Season	Number	Spikes	Healthy	Infected	%
1987–88	33	1/50	126,647	37	0.029
1988–89	4	5/40	33,405	1	0.003
1989–90	5	6/50	67,468	68	0.100
1990–91	7	10/50	135,457	194	0.143

Conclusions. Results of the experiments conducted during the 1987–88 to 1990–91 crop seasons showed that dissemination of fungal propagules from artificially inoculated spikes that could cause infection to neighboring noninoculated spikes is nil or extremely low.

Refererences.

Anonymous. 1943. Annual Report. Wheat-Sub-Station, Gurdaspur, India.pp. 1-15.

APHIS. 1996. Karnal bunt: situation report update (29 March). USDA-APHIS, Plant Protection and Quarantine (http://www.aphis.usda.gov/oa/bunt).

Aujla SS, Sharma I, Gill KS, and Grewal AS. 1986. Prevalence of Karnal bunt in Punjab as influenced by varietal susceptibility and meteorological factors. Plant Dis Res 1(1-2):51-54.

Aujla SS, Sharma YR, Chand K, and Sawney SS. 1977. Influenced of weather factors on the incidence and epidemiology of Karnal bunt disease of wheat in the Punjab. Ind J Ecol 4(1):71-74.

Bains SS and Dhaliwal HS. 1989. Release of secondary sporidia of *Neovossia indica* from inoculated wheat spikes. Plant and Soil 11:83-87.

Bedi SKS, Sikka MR, and Mundkur BB. 1949. Transmission of wheat bunt due to *Neovossia indica* (Mitra) Mundkur. Ind Phytopathology 2(1):20-26.

Bonde MR, Berner DK, Nester SE, Peterson GL, Olsen MW, Cunfer BM, and Sim T. 2004. Survival of *Tilletia indica* teliospores in different soils. Plant Dis 88:316-324.

Camacho-Casas MA, Félix-Valencia P, Huerta-Espino J, Salazar-Gómez JM, and Salazar-Huerta FJ. 1993. Baviácora M92 y Arivechi M92: nuevas variedades de trigo harinero. INIFAP, Centro de Investigación Regional del Noroeste, Campo Experimental Valle del Yaqui. Folleto Técnico No. 20, Cd. Obregón, Sonora, México. 14 p (In Spanish).

Crous PW, Van Jaarsveld AB, Castlebury LA, Carris LM, Frederick RD, and Pretorius ZA. 2001. Karnal bunt of wheat newly reported from the African continent. Plant Dis 85:561.

Da Luz WC, Mendes MAS, Ferreira MASV, and Urben AF. 1993. *Tilletia indica* on wheat in the south of the state of Rio Grande do Sul, Brazil and measures for eradication. Fitopatologia Brasileira 18:S329.

Dhaliwal HS. 1989. Multiplication of secondary sporidia of *Tilletia indica* on soil and wheat leaves and spikes and incidence of Karnal bunt. Can J Bot 67:2387-2390.

Dhaliwal HS, Randhawa AS, Sharma SK, Bains SS, Singh P, Kahlon PS, and Pal SS. 1988. Aparent spread of *N. indica* from infected spikes. Ann Wheat Newslet 34:58.

Dhaliwal HS and Singh DV. 1989. Production and inter-relationship of two types of secondary sporidia of *Neovossia indica*. Curr Sci 58(11):614-618.

Duran R. 1972. Further aspects of teliospore germination in North American smut fungi II. Can J Bot 50:2569-2573.
Fuentes-Dávila G, Rajaram S, Pfeiffer WH, Abdalla O, Van-Ginkel M, Mujeeb-Kazi A, and Rodriguez-Ramos R. 1993. Resultados de inoculaciones artificiales del 5o vivero de selección para resistencia a *Tilletia indica* Mitra. Revista Mexicana de Micología 9:57-65 (In Spanish).
Gautam PL, Pal S, Malik SK, and Saini DP. 1977. Note on reaction of promising wheat strains of Karnal bunt. Pantnagar J Res 2(2):228-229.
Krishna A and Singh RA. 1982. Investigations on the disease cycle of Karnal bunt of wheat. Ind J Mycol Plant Path 12(1):124 (Abstract).
Mitra M. 1931. A new bunt of wheat in India. Ann Appl Biol 18:178-179.
Mundkur BB. 1943. Studies in Indian cereal smuts. V. Mode of transmission of the Karnal bunt of wheat. Ind J Agric Sci 8(1):54-58.
Munjal RL. 1975. Status of Karnal bunt (*Neovossia indica*) of wheat in northern India during 1968-69 and 1969-1970. Ind J Mycol Plant Path 5:185-187.
Salazar-Huerta FJ, Figueroa-Lopez P, Smilanick JL, and Fuentes-Davila G. 1997. Evaluation of foliar fungicides for control of Karnal bunt of wheat during 1986-1989 in northwestern Mexico. Revista Mexicana de Fitopatología 15:73-80.
SARH. 1987. Cuarentena interior No. 16 contra el Carbón Parcial del trigo. Secretaría de Agricultura y Recursos Hidráulicos. Diario Oficial, (jueves) 12 de Marzo de 1987, México.
Singh A and Prasad R. 1978. Date of sowing and meteorological factors in relation to ocurrence of Karnal bunt of wheat in U.P. Tarai. Ind J Mycolog Plant Pat 8:2 (Abstract).
Singh A, Singh KP, and Tewari AN. 1988. Salient findings of Karnal bunt research at Pantnagar. Department of Plant Pathology, G.B. Pant University of Agriculture and Technology. Pantnagar-263 145.
Singh DV, Agarwal R, Shrestha JK, Thapa BR, and Dubin HJ. 1989. First report of *Tilletia indica* on wheat in Nepal. Plant Dis 73(3):273.
Singh DV, Joshi LM, and Srivastava KD. 1986. Varietal susceptibility and spread of Karnal bunt of wheat in India. Rachis, Barley Wheat Newslet 5(2):40-42.
Smilanick JL, Hoffmann JA, and Royer MH. 1985. Effect of temperature, pH, light and dessication on teliospore germination of *Tilletia indica*. Phytopathology 75(12):1428-1431.
Torarbi M, Mardoukhi V, and Jalaiani N. 1996. First report on the occurrence of partial bunt on wheat in the southern parts of Iran. Seed and Plant 12:8-9.
Zadoks JC, Chang TT, and Konzak CF. 1974. A decimal code for the growth stages of cereals. Weed Res 14:415-421.