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

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Introduction. Bread wheat production in Mexico was 3.9 x 10^6 tons in year 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, several years ago the regional industry reacted by implementing 'agriculture by contract' with wheat producers (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 wheat season 1994–95, 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 1); 87% (254,531 ha) corresponded to the southern region (OEIDRUS 2011). The predominating 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, caused by the fungus *Puccinia triticina*, and Karnal bunt, by *Tilletia indica*, are the most important diseases in southern Sonora (Figueroa-López et al. 2011). However, since 2000, the incidence of stripe or yellow rust (*P. striiformis*) has increased in the region with the appearance of new races of the fungus. Tacupeto F2001 was the most grown bread wheat cultivar in 2009–10 in southern Sonora (Table 2, p. 102) and in 2010–11 in the state. 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 and increase production costs. A 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

Table 1. Area (ha) grown with wheat during the 2010–11 agricultural season in Sonora, Mexico.

Cultivar	Area (ha)	Percent of total wheat area
Durum wheat		
CIRNO C2008	88,235	30.5
Átil C2000	50,236	17.3
Sáwali Oro C2008	14,353	4.9
Patronato Oro C2008	11,753	4.0
Júpare C2001	10,069	3.4
RSM Imperial C2008	7,149	2.4
CEVY Oro C2008	6,197	2.1
Río Colorado	5,111	1.7
Samayoa C2004	4,905	1.6
Rafi C97	1,806	0.6
RSM Chapultepec C2008	1,650	0.5
Others	1,210	0.4
Platinum	1,173	0.4
Aconchi C89	752	0.2
TOTAL		70.0
Bread wheat		
Tacupeto F2001	36,819	12.6
Kronstad F2004	18,681	6.4
Roelfs F2007	10,358	3.6
Navojoa M2007	8,046	2.8
RSM Norman F2008	4,499	1.5
Cachanilla F2000	3,493	1.2
Rayón F89	2,576	0.9
Abelino F2004	1,355	0.5
Palmerín F2004	964	0.3
Others	538	0.1
Oasis F86	319	0.1
TOTAL	87,648	30.0

cost/benefit and competiveness of bread wheat by producing advanced lines with better quality, yield, resistance to diseases, 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 agricultural season 2009–10 in Sonora, Mexico.

Cultivar	Area (ha)	Percent of total wheat area
Durum wheat		
Átil C2000	81,777	33.07
Júpare C2001	53,164	21.50
Samayoa C2004	23,318	9.43
Sáwali Oro C2008	4,761	1.93
CIRNO C2008	3,256	1.32
CEVY Oro C2008	3,233	1.31
Platinum	2,655	1.07
Patronato Oro C2008	2,325	0.94
Aconchi C89	1,019	0.41
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		
Bread wheat		
Tacupeto F2001	40,552	16.40
Kronstad F2004	25,021	10.12
Abelino F2004	736	0.30
RSM-Norman F2008	659	0.27
Rayón F89	636	0.26
Tarachi F2000	384	0.16
Roelfs F2007	248	0.10
Navojoa M2007	235	0.10
Monarca F2007	4	0.00
TOTAL	68,475	

Pedigree, history selection, and description of Villa Juárez F2009. After evaluations of grain yield carried out since the 2008–09 agricultural season at the Norman E. Borlaug Experimental Station (CENEB), we proposed to release the experimental bread wheat line 'WBLL1*2/BRAMBLING' as cultivar Villa Juárez F2009 (Valenzuela-Herrera et al. 2012). Villa Juárez 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 CGSS01B00062T-099Y-099M-099M-099Y-099M-12Y-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, p. 103).

The most important phenotypic characteristics of Villa Juárez F2009, according to the International Union for the Protection of New Varieties of Plants (UPOV 1994), are given in Table 4 (p. 103). This cultivar has an average of 72 days to heading with a range of 67 to 74, a biological cycle with an average of 114 days to physiological maturity; however, the cycle may be shortened due to the lack of cold hours if planting is late (Wardlaw and Moncur 1995), and may average 106 days when sowing is done at the end of December. Villa Juárez F2009 has an average height of 91 cm (Fig. 1), a maximum of 100, and minimum of 80. Plant growth habit is semi-prostrate 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 strong and at maturity it becomes white. The width of the lower glume is absent or very narrow (spikelet in mid-third of ear), shoulder shape is sloping, and the beak length is short and slightly curved. Grain shape is semi-elongated (Fig. 2, p. 103), and grain coloration when treated with phenol is lacking or very light.


Fig. 1. Bread wheat cultivar Villa Juárez F2009 has an average height of 91 cm. Plants are semi-prostrate and present a high frequency of rcurved flag leaves.

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

Fig. 2. Grain of the bread wheat cultivar Villa Jueares F2009 is semi-elongated. Grain color after treatemtn with phenol is lacking or very light.

Table 3. History selection and localities where cultivar Villa Juárez F2009 was evaluated. Planting dates for the INIFAP yield trials were 15 and 30, November, 15 December, and 1 January. For season, F–W = fall–winter and S–S = spring–summer; for irrigation conditions RR = regular rainfed, NI = normal irrigation, and RI = reduced irrigation.

Activity	Locality	Season	Irrigation conditions
Simple genetic cross	El Batan, Mexico	S–S/2001	RR
F_1 Generation	Cd. Obregon, Sonora	F–W/2001–02	NI
F_2 Generation	Atizapan, Mexico	S–S/2002	RR
F_3 Generation	Atizapan	S–S/2003	RR
F_4 Generation	Cd. Obregon	F–W/2003–04	NI
F_5 Generation	Atizapan	S–S/2004	RR
F_6 Generation	Cd. Obregon	F–W/2004–05	NI
F_7 Generation	El Batan	S–S/2005	RR
Yield trials by CIMMYT	Cd. Obregon	F–W/2005–06	NI
		F–W/2006–07	NI
Yield trials by INIFAP	Cd. Obregon	F–W/2007–08	NI and RI
		F–W/2008–09	NI and RI

Table 4. Characteristics and description of phenotypic components of cultivar Villa Juárez F2009.

Structure	Characteristic	Description
Coleoptile	Anthocyanin coloration	Absent or very weak
First leaf	Anthocyanin coloration	Absent or very weak
Plant	Growth habit	Semi-prostrate
	Frequency of plants with recurved flag leaves	High
Ear	Time of emergence	Early
Flag leaf	Glaucosity of blade	Strong
Ear	Glaucosity	Strong
Straw	Pith in cross section (halfway between base of ear and stem node below)	Thin
Culm	Glaucosity of neck	Medium
Plant	Length (stem, ear, and awns)	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	Medium
Ear	Length (excluding awns)	Very long
	Hairiness of margin of first rachis segment	Absent or very weak
	Color (at maturity)	White
	Shape in profile view	Parallel sided
	Density	Lax
Grain	Shape	Semi-elongated
	Coloration with phenol	None or very light
Plant	Seasonal type	Spring

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Reaction of elite bread wheat lines and cultivars to Karnal bunt under artificial inoculation, during the crop season 2009–10 in the Yaqui Valley, Mexico.

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Introduction. *Triticum aestivum* is the most susceptible plant species to Karnal bunt. Under artificial inoculation, some lines may show more than 50% infeted grain (Fuentes-Dávila et al. 1992, 1993). Although the fungus *Tilletia indica* (Mitra 1931) (syn. *Neovossia indica*) may affect durum wheat and triticale (Agarwal et al. 1977), the levels of infected grain are generally low. Control of this pathogen is difficult because 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),

Table 5. Elite bread wheat lines and commercial cultivars artificially inoculated with Karnal bunt (*Tilletia indica*) in the field at three planting dates, during the fall–winter 2009–10 crop season, in the Yaqui Valley, Sonora, Mexico.

Entry	Pedigree and selection history
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. tauschii*//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//TemporaleraA M87/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/WH542/8/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

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 elite, advanced, bread wheat lines and five commercial cultivars for resistance to Karnal bunt.

Materials and methods. Twenty-one elite, advanced, bread wheat lines and five commercial cultivars, Tacupeto F2001, Kronstad F2004, Navojoa M2007, Roelfs F2007, and Norman F2008 (Table 5, p. 104) were evaluated for resistance to Karnal bunt during the fall–winter 2009–10 crop season in block 910 in a clay soil with pH 7.8, in the Yaqui Valley, Sonora, Mexico. Planting dates were 19, 25, and 30, November 2009, 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 (Fig. 3). After teliospore germination, fungal colonies were transferred and multiplied on potato-dextrose-agar. Inoculations were by injecting 1 mL of an allantoid sporidial suspension (10,000/mL) during the boot stage (Fig. 4) in ten 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).

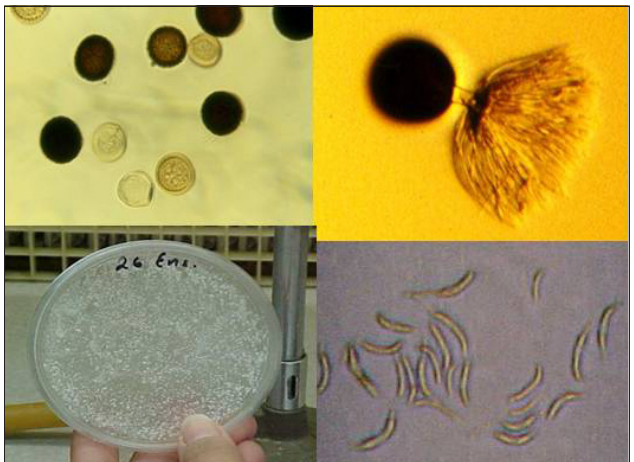

Fig 3. *Tilletia indica* inoculum preparation.

Fig. 4. Artificial inoculation by boot injection.

Results and discussion. The range of infection for the first planting date (19 November) was 0.00 to 30.68%, with a mean of 10.01; one line did not have any infected grains (Fig. 5). The range of infection for the second planting date (25 November) was 0.00 to 32.20%, with a mean of 9.10. Two lines did not have any infected grains For the third planting date (30 November), the range of infection was 0.00–45.26 with a mean of 17.09. The frequency of lines in the different infection categories at the three dates is shown (Fig. 6, p. 106). The suceptible check KBSUS 1 had 100% infection.

Overall, three lines fell within the 2.6–5.0 infection category, nine in the 5.1–10.0 category, and 14 in the 10.1–30.0 infection category (Fig. 7, p. 106). Lines with less than 5% infection are considered resistant (Fuentes-Dávila and Rajaram

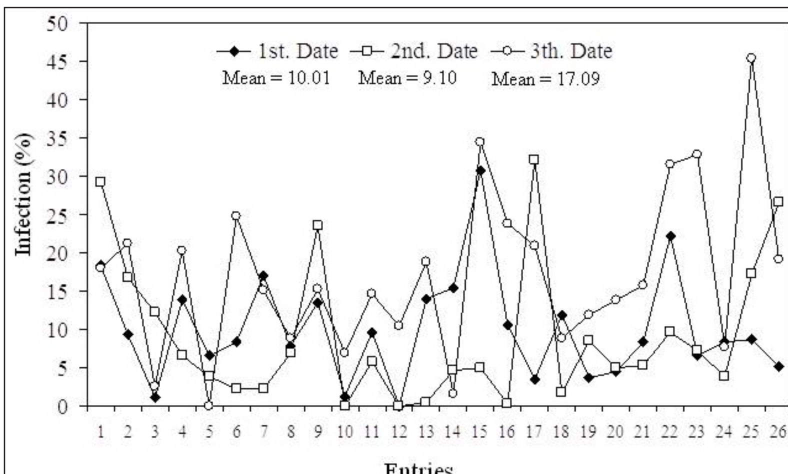

Fig. 5. Percent of infection with Karnal bunt (*Tilletia indica*) of 21 elite, advanced, bread wheat lines and five cultivars artificially inoculated in the field during the 2009–10 crop season at three dates in the Yaqui Valley, Sonora, México.

1994). Fifty-three percent of the entries were moderately susceptible to susceptible, including the cultivar Tacupeto F2001 and lines 'TC870344/GUI//Temporalera M 87/AGR/3/2*WBLL1', 'Whear/Sokoll', and 'Chewink'. Cultivar Navojoa M2007 and eight lines were within the 5.1–10.0% infection category; this cultivar had a mean of 5.25%. Cultivars Roelfs F2007, Kronstad F2004, Norman F2008, Tacupeto F2001, and ten lines were within the 10.1–30.0% infection category; the mean percentage of infection of these cultivars was 13.54, 15.73, 16.92, and 21.86, respectively. Cultivars with the highest levels of infection were Tacupeto F2001 with 29.22% and Norman F2008 with 26.53%. Lines with the highest percent infection were 'Chewink' (45.26%) and 'TC870344/GUI//TemporaleraM87/AGR/3/2*WBLL1' (34.41%), whereas lines with the lowest percent infection were 'Babax/LR42//Babax/3/ER2000' (2.76%), 'Toba97/Pastor' (3.47), and 'Thelin/2*WBLL1' (3.50%). Tacupeto F2001 has been and is the leading bread wheat cultivar in Sonora; the area grown with this cultivar in 2009–10 in the southern part of the state was 40,552 ha and in 2010–11 was 36,819 ha in the entire state (OEIDRUS 2011). Tacupeto F2001 complies with the quality requirements of the milling industry, however, susceptibility to stripe rust and moderate susceptibility to leaf rust and to Karnal bunt make necessary the application of fungicides; therefore, it is important to look for other cultivars that have been released by INIFAP, as well as experimental lines such as 'Babax/LR42//Babax/3/ER2000', 'Toba97/Pastor', and 'Thelin/2*WBLL1', which are considered resistant and good prospects for commercial release.

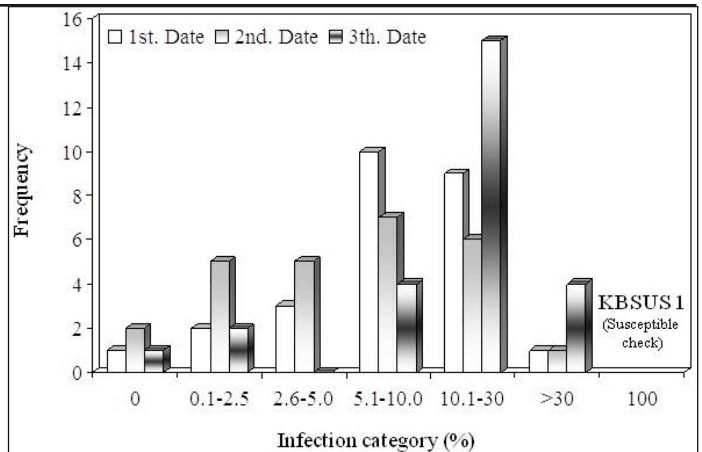

Fig. 6. Results of artificial field inoculatin of 21 elite, advanced, bread wheat lines and five cultivars with Karnal bunt (*Tilletia indica*) on three dates during the 2009–10 crop season in the Yaqui Valley, Sonora, México. The level of infection of KBSUS 1 is the mean of the three highest infection scores.

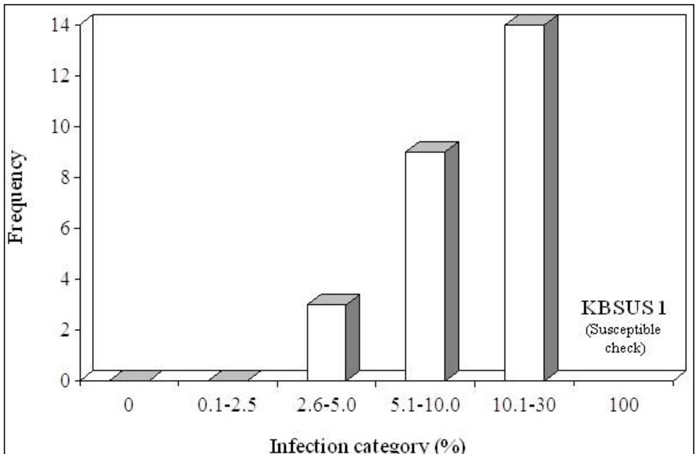

Fig. 7. Overall rating of 21 elite, advanced, bread wheat lines and five cultivars artificially inoculated with Karnal bunt (*Tilletia indica*) on three dates during the 2009–10 crop season in the field in the Yaqui Valley, Sonora, México. The level of infection of KBSUS 1 is the mean of the three highest infection scores.

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CO_2 flux in soils cultivated with wheat with and without tillage and with tillage in beds burning residues in the Yaqui Valley, Sonora, Mexico.

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Summary. CO_2 flux was quantified during a 10-year period in soils cultivated with wheat under no till or direct sowing and under tillage in beds burning residues. The evaluation was carried out at the Norman E. Borlaug Experimental Station located in block 910 in the Yaqui Valley, Sonora, in a clay soil. A dynamic, closed-chamber system was used. A greater CO_2 flux was observed in soils under no till or direct sowing with a difference of 0.030 g/m^2/h over tillage in beds burning crop residues. Direct sowing or no till treatments reduced the temperature, but increased significantly, the soil moisture content at a depth of 0–10 cm.

Introduction. Currently, there is an increasing interest in agricultural practices that reduce carbon losses in soils (Regina and Alakukku 2010). The intensive soil tillage has been a constant in management of agricultural soils. The main reasons for soil tillage have been the control of weeds, pests and diseases, sowing preparation, the increase of water storage, and the improvement of natural fertilization of plants. The adoption of conservation tillage practices has not only allowed greater control of the erosion, but also the reduction in losses of organic matter as a consequence of the intensive tillage of soils (Fuentes et al., 2010). Carbon sequestration can be one the most profitable agricultural activities in order to reduce the process of global warming and contribute to environmental security (Reicosky and Archer, 2005). The objective of the study was to quantify the CO2 flux in soils cultivated with wheat under no till or direct sowing, and under tillage in beds burning crop residues in the Yaqui Valley, Mexico.

Materials and methods. The evaluation was carried out at the Norman E. Borlaug Experimental Station, which belongs to the Mexican National Institute for Forestry, Agriculture, and Livestock Research located in block 910 in the Yaqui Valley, Sonora (27º22´3.01" N and 109º55´40.22" W) in a clay soil. CO_2 flux was quantified during 2011 in soils subjected during 10 years to conservation tillage under the scheme of no till or direct sowing, and tillage in beds burning residues; both with a summer fallow and wheat during the fall–winter season. The wheat crop was established over straw from the previous crop season for the no till and direct sowing treatments. Weeds that emerged after rain during the summer season were controlled with herbicides. Fertilization was broadcast. For the tillage in beds treatment, residues were burned after harvest, and the beds from the previous season were reutilized. The CO_2 flux was determined for each agricultural management during the period January–October 2011, with a total of 11 readings with six replications for each tillage method. The dates for the period of evaluation were 29 January, 5 February, 17 February, 11 March, 25 March, 15 April, 20 April, 29 April, 30 June, 1 July, 4 August, 4 October, and 5 October. The period of evaluation, from 29 January to 20 April, coincided almost entirely with the vegetative development of the wheat crop. To quantify CO_2 flux in the soil, a dynamic, closed-chamber system was used (Pumpanen et al. 2004), which consisted of an infrared gas analyzer (IRGA, LI-820, Licor, Lincoln NE, USA) connected to a console CR23X (Cambell Sci, Logan UT, USA) and to a pneumatic pump in order to circulate air through the system and a flux regulator. The air that circulates through the system is filtered in order to prevent impurities into the system; a thermopar monitors the temperature within the chamber and a pressure release valve in the top of the chamber (0.2 cm internal diameter and 1.8 cm height), and peripheral sensors of soil moisture (HH2 Moisture Meter, Delta-T Devices, Cambridge, England) and soil temperature (Fig. 8). The chamber has a cylindrical shape with an internal diameter of 10 cm and a height of 12.8 cm, which cover a volume of 1.44 x 10^{-3} m^3. The flux speed was adjusted

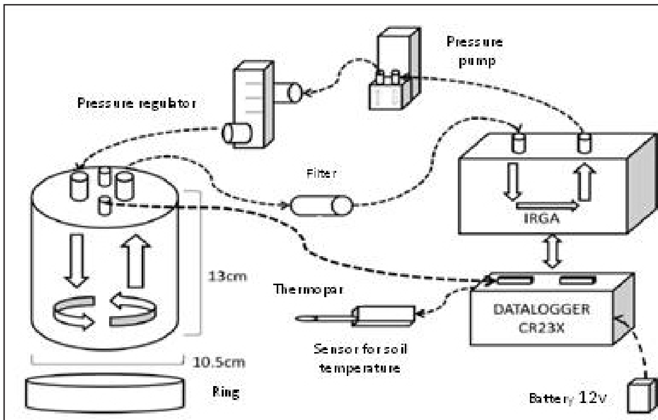

Fig. 8. Conceptual diagram of the soil respiration chamber (Cueva-Rodriquez 2011).

to a constant speed of 500 ml/min. The system measures the increment of CO_2 inside the chamber during 150 seconds. To calculate the flux, the sampling point and the slope of the relation time vs CO_2 concentration are used (Cueva-Rodríguez 2011). A completely randomized block design was used with six replications and 11 evaluation dates. Data were analyzed in Statgraphics Plus 5.1. Mean comparison was done with Tukey´s test (0.01).

Results and discussion. Greater CO_2 flux was observed in soils where wheat was subjected to no till or direct sowing, with an increase of 0.030 g/m^2/h over tillage in beds burning crop residues (Fig. 9); however, this difference was not statistically significant (Table 6). The highest CO_2 flux under no till was attributed to the straw layer, which reduced the temperature and increased the moisture content in the soil. A high negative correlation (r = –0.95) was observed between temperature and CO_2 flux. The regression coefficient indicated that CO_2 flux decreased 0.007 g/m^2/h for each centigrade increase in soil temperature and, as an average, the no till treatment decreased the temperature by 1.3ºC at 0–10 cm depth and increased the moisture content by 2.6%. In relation to the soil moisture content, the highest percentage of flux was between 23.64 and 25.27%; a higher or lower moisture content than the interval indicated caused a reduction in the value of the CO_2 flux. Therefore, a greater CO_2 flux was observed with direct sowing due to the temporal variability of the moisture content (Fig. 10), and a lower CO_2 flux for tillage in beds burning crop residues by the effect of a higher temperature observed during the months of the evaluation (Fig. 11, p. 109). The greatest CO_2 from soil under the two tillage systems was observed during the vegetative development of the wheat crop, when complementary irrigations were applied. We assumed that during this time, root respiration is more active. CO_2 flux decreased significantly after the month of March and primarily after the wheat harvest. From a study carried out in the central part of the valley in México about the effect of different types of tillage on carbon distribution and emissions during a crop season in plots with residues of maize and wheat, Fuentes et al. (2011) reported that wheat residues emit more CO_2 than maize residues because the decomposition rate of wheat residues is faster.

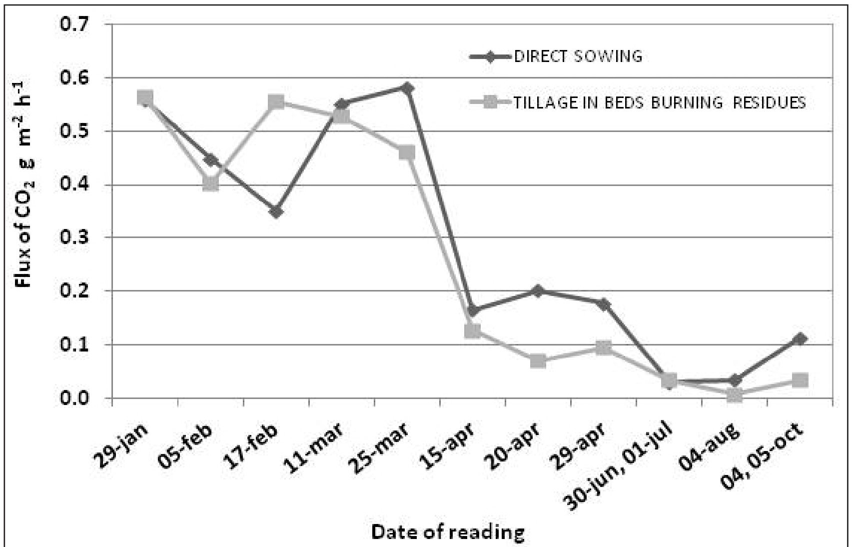

Fig. 9. Temporal variation of CO_2 flux in soils with two tillage systems

Table 6. Effect of two tillage systems upon CO_2 flux, temperature, and soil moisture, during a period January–October, 2011.

Treatment	CO_2 flux (g/m^2/h)	Moisture (%)	Soil temperature (°C)
Direct sowing	0.292	16.9 a	30.9 a
Tillage in beds with burn residue	0.262	14.3 b	32.2 b
		Tukey 0.01=1.4081	Tukey 0.01=1.08695

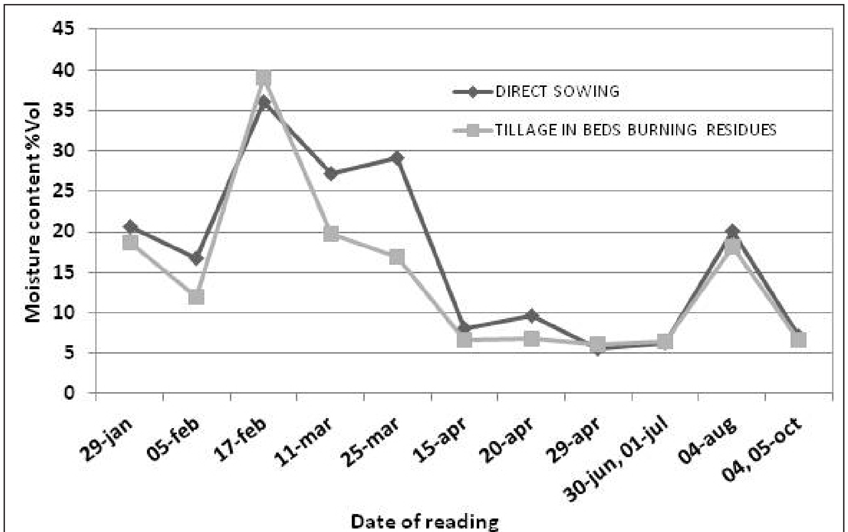

Fig. 10. Temporal variability of the soil moisture content under two tillage systems

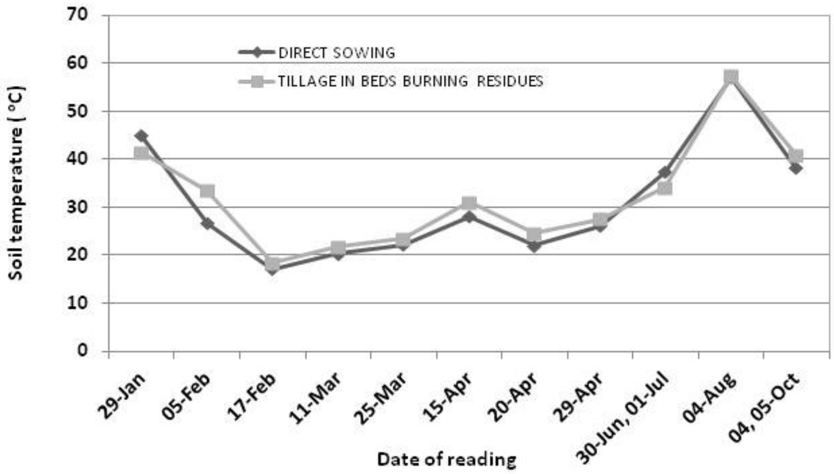

Fig. 11. Temporal variability of the soil moisture content under two tillage systems

Conclusions. No significant differences were observed in CO_2 flux between tillage treatments. Direct sowing or no till increases the soil moisture content, and this variable is correlated with CO_2 flux in the soil. Direct sowing or no till reduces the soil temperature, and this variable is negatively correlated with the CO_2 flux in the soil. It is necessary to consider other biotic and abiotic factors that influence the quantification of CO_2 flux, such as the microbial population and the content of organic and inorganic carbon in the soil, in order to understand in detail the functioning of agricultural soils as carbon reservoir, and the impact that tillage systems and crop production might have on the atmosphere and the global warming.

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Effect on seedling emergence of placing seed of bread wheat cultivar Rayón F89 in direct contact with three different fertilizers separately during sowing.

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Summary. The effect on seedling emergence of placing seed of the bread wheat cultivar Rayón F89 in direct contact with three different fertilizers separately during sowing was studied through a factorial experiment with two seed densities (40 and 80 kg/ha) and fertilizer rates of 0, 40, and 80 kg/ha of urea, ammonium sulphate, and mono-ammonium phosphate. Significant differences were found for seedling emergence/m^2 among the fertilizers evaluated, between seed densities, and fertilizer rates. No negative effect on seedling emergence was observed when wheat seed was placed in contact with mono-ammonium phosphate, whereas urea and ammonium sulphate caused a significant reduction in seedling emergence that was not compensated for by using a greater seed density.

Introduction. Any natural or industrialized material that contains at least 5% of one or more of the primary nutrients (N, P_2O_5, and K_2O) can be called a fertilizer. The presentation of mineral fertilizers is highly variable. Based on the process of fabrication, particles of mineral fertilizers can be of very different size and shape, granules, pellets, powder of coarse grain/compacted, or fine. Most fertilizers are provided in a solid form (FAO 2002). The efficiency of a fertilizer varies according to the nutrient and fertilizer source, and it depends on rates, method, timing, cultivar, management of the crop, and environmental conditions. Therefore, proper selection, timing, and way of application of a fertilizer will help to achieve greater agronomic efficiency and profitability by using this input (SAGARPA 2012). In order to increase the absorption efficiency by the plant roots, the most recommended method for application of a fertilizer is to place it in a band at the bottom of the furrow beside the seed. Although most fertilizers are soluble salts of various kinds, they vary greatly in their damage to seed germination and emergence of crops, which essentially depends upon the saline index. In wheat in the Yaqui Valley, México, an average of 250 kg/ha of nitrogen is applied. Fertilization costs in wheat represent 25–30% of the total production costs for the crop, depending on the rate and the nitrogen source used. Of the total rate, 75% is applied during presowing and the rest right before the first and second complementary irrigations. The efficiency of recovery of granulated fertilizers by the crop has been calculated to be 38%, which means that 62% of the fertilizer and resources that this represents are not being used by the wheat plant (Cortés 2008). At the commercial level, efficiencies of 20–48% have been observed (Cortés et al. 2011); however, there are no references about the use of fertilizers applied in direct contact with the seed in northwest Mexico. Our objective was to determine the effect of placing the seed in direct contact with three different fertilizers separately during sowing on seedling emergence of the bread wheat cultivar Rayón F89.

Materials and methods. The evaluation was carried out at the Norman E. Borlaug Experimental Station during the fall-winter 2000–01 agricultural season in a compacted clay soil with 101 kg/ha of $N–NO_3$ available in the topsoil layer, and 71 kg in the subsoil. The effect of three fertilizers on the emergence of bread wheat cultivar Rayón F89 was studied through a factorial experiment with two sowing densities (40 and 80 kg/ha of seed), and fertilizer rates of 0, 40, and 80 kg/ha of urea, ammonium sulphate, and mono-ammonium phosphate. Before sowing, land preparation was as follows: disking (2), planking, and bed formation. Sowing was done on moist soil on 15 December in beds with 80 cm separation and one row. The fertilizer was applied in a band at the bottom of the row on the bed, and the seed was placed over the fertilizer. A single, complementary irrigation was applied to the crop. An application of insecticide was necessary for aphid control, and weeds were eliminated manually. A randomized block experimental design with split plots and two replications was used. The experimental unit consisted of four 8-m rows; two linear meters from the central rows were used for seedling counts. The variables evaluated were seedling emergence and the percent of seedling emergence for each treatment. Data were analyzed with Statgraphics Plus 5.1. Mean comparison was done with Tukey´s test (0.01 and 0.05).

Results and discussion. Significant differences were found for seedling emergence/m^2, between the fertilizers evaluated, between seed densities, and fertilizer rates (Table 7), as well as in the interaction 'source x rate of fertilizer' and seed density and fertilizer rate. The average number of emerged seedlings/m^2 was 56, 77, and 112 for urea, ammonium sulphate, and mono-ammonium phosphate, respectively. The average number of emerged seedlings with seed densities of 40 and 80 kg/ha was 55 and 108, respectively, whereas with fertilizer rates of 0, 40, and 80 kg/ha, it was 119, 76, and 51, respectively. The interaction 'source x rate' showed an average number of emerged seedlings of 116, 39, and 15 for urea;

Table 7. Effect of placing the seed in direct contact with three different fertilizers separately during sowing, on seedling emergence of bread wheat cultivar Rayón F89 during the fall–winter of the 2000–01 agricultural season. Source of fertilizer, Tukey (0.01) = 54.24; rate of fertilizer, Tukey (0.05) = 41.03.

	Seedling emergence/m^2								
	40 kg/ha of seed rate of fertilizer (kg/ha)				80 kg/ha of seed rate of fertilizer (kg/ha)				
Fertilizer	0	40	80	Mean	0	40	80	Mean	Mean
Urea	75	24	15	38	156	53	16	75	56 a
Ammonium sulphate	90	43	24	52	146	120	39	101	77 a
Mono-ammonium phosphate	80	71	75	75	167	143	136	148	112 ab
Fertilizer rate mean	82 a	46 ab	38 b	55	156 a	105 b	64 b	108	

118, 81, and 31 for ammonium sulphate; and 124, 107, and 105 for mono-ammonium phosphate. The interaction 'seed density x rate of fertilizer' showed an average number of emerged seedlings of 82, 46, and 38 for 40 kg/ha of seed and 0, 40 and 80 kg/ha of fertilizer, and 156, 105, and 64 for 80 kg of seed with the corresponding fertilizer rates. Significant differences were observed for the percent of seedling emergence between the source of fertilizer, rate, and the interaction 'source x fertilizer rate'. The percent of seedling emergence was 46% for urea, 61% for ammonium sulphate, and 90% for mono-ammonium phosphate (Table 8, p. 111). Relative seedling emergence for seed densities of 40 and 80 kg/ha was 65.58 and 65.75%, respectively. Seedling emergence associated with the a fertilizer rate of 0 was 94.7%, 60.1% at 40 kg, and 42.2% at 80 kg. The interaction 'source x rate of fertilizer' showed that each rate of urea and ammonium sulphate reduced significantly the percentage of seedling emergence, but that was not the case for mono-ammonium phosphate. The observed values were 93.1, 30.8, and 13.7% for 0, 40, and 80 kg of urea; 94.1, 62.7, and 26.2% for ammonium sulphate; and 97.0, 86.7, and 86.7% for mono-ammonium phosphate.

Table 8. Effect of placing the seed in direct contact with three different fertilizers separately during sowing on the percentage of seedling emergence of bread wheat cultivar Rayón F89 during the fall–winter 2000–01 agricultural season. Fertilizer, Tukey (0.01) = 22.46; rate of fertilizer, Tukey (0.01) = 14.2; and 'source x rate of fertilizer', Tukey (0.01) = 24.61.

	Seedling emergence (%)/m²			
Fertilizer (kg/ha)	**Urea**	**Ammonium sulphate**	**Mono-ammonium phosphate**	**Mean**
0	93.14 a	94.05 a	96.95 a	94.71 a
40	30.79 b	62.65 b	86.74 a	60.06 b
80	13.72 b	26.22 c	86.73 a	42.22 c
Mean	45.88 b	60.97 b	90.14 a	

Conclusions. It is feasible to physically place wheat seed with mono-ammonium phosphate in direct contact during sowing, because there was no significant reduction in the percentage of seedling emergence with the rates evaluated. We do not recommended the use urea or ammonium sulphate in contact with the wheat seed, because of significant reduction in seedling emergence. Increasing the seed rate partially compensates the reduction in the percentage of wheat seedling emergence, when seed and fertilizer are placed in direct contact in the soil.

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Effect of residual nitrogen applied to wheat, on maize grain yield as a summer crop in the rotation, in the Yaqui, Valley Sonora, México.

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Introduction. In the Yaqui Valley, Sonora, México, fertilization costs in wheat and maize represent from 25 to 30% of the total production costs for the crop, depending on the rate and the nitrogen source used. Wheat is fertilized with an average of 250 kg/ha, 75% of the rate is applied during presowing and the rest right before the first and second complementary irrigations. Wheat efficiency to recover nitrogen is 38%, whereas 25% is lost by lixiviation and volatilization, and 37% is retained in the soil as residual nitrogen (Cortés and Uvalle 1998). The residual nitrogen from 250 units applied to wheat represent 92.5 units/hectare. Rates of 0, 75, 150, 225, and 300 nitrogen units applied to wheat, were associated to yields of 3.817, 3.973, 4.573, 4.744, and 5.176 ton/ha of maize, as a follow up crop when it was not fertilized (Cortés and Uvalle 1996). For wheat fertilization, the maximum economic yield and quality required by the market are taking into consideration, primarily the protein content. Therefore, it is important to apply an additional quantity of nitrogen (N), although not necessary for yield, it is very important for quality. For farmers who practice wheat–maize rotation (fall–winter–summer), the best viable solution consists in assuring the quality standards required by the industry (a minimum of 12.5% protein content), which implies increasing the rate of N in wheat in order to comply with an appropriate supply of N in the soil during formation and grain filling, with the understanding that a great quantity of residual N will be available in the soil at harvest, which will be used by maize, and will allow a significant reduction in production costs of this second crop, primarily on the concept of fertilization. However, the increasing use of chemical fertilizers is of great concern with respect to the effect on the environment. Nitrates lixiviated from the top soil layer are considered the main source of contamination, which are produced primarily by N-based fertilizers that were not taken up by the crop, and after harvest they remain as residual N in the soil. The amount of residual N increases based on the rate applied, method and time of application (Cortés et al. 1994; Isfan et al. 1995; Cortés and Uvalle 1998). Our objective was to determine the impact of residual N of wheat, on the maize response to N fertilization.

Materials and methods. The study was conducted at the Norman E. Borlaug Experimental Station, which belongs to the Mexican National Institute for Forestry, Agriculture and Livestock Research (INIFAP), during the fall–winter 1996–97 crop season. The station is located at 27°22' north latitude and 109°55' west longitude. Two experiments were established in order to determine the impact of residual N of wheat, on the maize response to N fertilization. Experiment 1: three N rates (150, 225, and 300 kg/ha) in the form of urea were applied to wheat, and four N rates (0, 75, 150, and 225 kg/ha) in the form of urea and ammonium sulphate were applied to summer maize. Experiment 2: three N rates (0, 150, and 300 kg/ha) in the form of urea were applied to wheat, and the four N rates used in experiment 1 in the form of urea were applied to maize. A split-split plot design was used with three replications; large plots corresponded to N sources, medium plots to N rates in wheat, and small plots to N rates in maize. For both experiments, the soil was prepared with minimum tillage based on the use of the same bed on which wheat was cultivated. Sowing was on 16 December with durum wheat cultivar Nacori C97 at the rate of 50 kg/ha on beds 80 cm apart with two rows. N was applied in band between the wheat rows and before the first complementary irrigation. Three complementary irrigations were applied, insecticide was used for aphid control, and weeds were eliminated mechanically and manually. Maize hybrid H-431 was sown on 20 June at a density of six seeds/m or 75,000 seeds/ha, which produced an average of 64,062 plants/ha at the end of the crop season. The total N rate was applied in band 25 days after sowing maize. The plot size was 38.4 m^2 and 6.4 m^2 was used for yield evaluation. Four complementary irrigations were applied and two insectide applications for pest control. Weed control was done mechanically and manually. The variable evaluated was grain yield of maize.

Results. ***Experiment 1.*** An increment of 938 kg/ha was observed in maize yield when N rates of 150 and 300 units applied to wheat, which is equivalent to a residual effect of 6.25 kg of maize per each kg of N applied to wheat. No significant differences were observed between urea and ammonium sulphate; maize yields were 4.555 and 4.614 ton/ha, respectively. When maize was not fertilized, the yield associated with the N rate of 150 kg/ha was 2.640 ton/ha, 3.389 tons/ha at an N rate of 225 kg, and 4.399 ton/ha at 300 kg N (Table 9). The application of N to maize caused a significant grain yield increase, however, only the difference between the treatments fertilized and the check was detected. The yields obtained with the N rates were 3.476 tons/ha at 0 kg, 4.641 at 75 kg, 4.967 at 150 kg, and 5.254 at 225 kg. The interaction between the maize response to N fertilization in function of the N applied to wheat as a previous crop indicated that when wheat is fertilized with 150 N units the average response of maize to fertilizer application is 15.98 kg of grain/kg N; the response to N is reduced to 10.58 kg of grain when wheat is fertilized with 225 kg/ha N, and when 300 kg/ha N are applied to wheat, the average response of maize to N application es 6.80 kg of grain/kg N applied.

Table 9. Nitrogen fertilization in wheat and its effect on nitrogen response in summer maize as a follow up crop in the Yaqui Valley, Sonora, México, during the fall–winter 1996–97 and summer 1997 agricultural seasons. Maize grain yield is the average of results obtained from applications of urea and ammonium sulphate, since there were no differences in maize response between these fertilizers.

Nitrogen rate in wheat (kg/ha)	Nitrogen rate in maize (kg/ha)	Maize grain yield (ton/ha)
150	0	2.640
150	75	4.642
150	150	4.310
150	225	4.922
Mean		4.128
225	0	3.389
225	75	4.158
225	150	5.242
225	225	5.450
Mean		4.560
300	0	4.399
300	75	5.124
300	150	5.349
300	225	5.389
Mean		5.066

Experiment 2. An increment of 2.437 ton/ha was observed in maize yield when N rates of 0 and 300 units applied to wheat were compared, which is equivalent to a residual effect of 8.12 kg of maize/each kg N applied to wheat. When maize was not fertilized, the yields associated with the N rates of 0, 150, and 300 kg of N applied to wheat were 2.020, 2.594, and 4.457 ton/ha, respectively. Significant differences between N rates in maize were observed; the yields obtained with the N rates of 0, 75, 150, and 225 kg/ha were 3.024c, 4.207b, 5.083ab, and 5.384a ton/ha, respectively (Tukey 0.01, 1.116 ton/ha). When wheat was not fertilized, the average response of maize to fertilizer application was 19.10 kg of grain/kg N. The response to N was reduced to 13.29 kg of grain when wheat was fertilized with 150 kg/ha, whereas for at 300 kg/ha N in wheat, the average response of maize to N application was 7.61 kg of grain/kg N applied (Table 10, p. 113). In terms

of the cost/benefit of wheat and summer maize, it is economically feasible to increase the N rates in wheat, which is not possible in maize, and reduce significantly the N rate in maize. This is based on the low response found to N fertilization at high levels of fertilization in wheat. When wheat was not fertilized, the economic threshold for N use by maize was a rate of 225 kg/ha, 150 kg/ha when wheat was fertilized with 150 kg of N, and the highest economic threshold was obtained with 75 kg/ha when wheat was fertilized with 300 kg of N.

Table 10. Nitrogen fertilization in wheat and its effect on nitrogen response in summer maize as a follow up crop in the Yaqui Valley, Sonora, México, during the fall–winter 1996–97 and summer 1997 agricultural seasons. Urea was used as the nitrogen source.

Nitrogen rate in wheat (kg/ha)	Nitrogen rate in maize (kg/ha)	Maize grain yield (ton/ha)
0	0	2.020
0	75	3.831
0	150	4.679
0	225	5.491
Mean		4.005
150	0	2.594
150	75	3.475
150	150	5.173
150	225	5.051
Mean		4.073
300	0	4.457
300	75	5.316
300	150	5.396
300	225	5.609
Mean		5.194

Conclusions.

1. There were no differences between fertilization with urea and ammonium sulphate under conditions of the Yaqui Valley, Sonora.
2. A significant residual effect of nitrogen applied to wheat was detected on maize yield and on the nitrogen rate needed for this crop.
3. Fertilization with 300 units of nitrogen in wheat, provides a physiological wheat yield with a protein content similar or superior to 12.5% and, also, maize as a follow up crop in the rotation can be cultivated with only 75 nitrogen units

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Nitrogen fertilization and its effect on quality and yield of durum wheat cultivar Nacori C97.

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Summary. We evaluated the interaction between nitrogen (N) fertilization, protein content, and yield of the durum wheat cultivar Nacori C97 at the Norman E. Borlaug Experimental Station during the 1998–99 agricultural season. The variables evaluated were percent grain protein at 12% humidity and grain yield. The sources of N, urea and ammonium sulphate, were used at the rates of 150, 225, and 300 kg/ha. A randomized block design with split plots and three replications was used; the large plots corresponded to the N source and the small plots to the rate. No significant differences were found between N sources for the two variables evaluated. The application of urea and ammonium sulphate produced yields and protein contents of 4.368 and 4.395 ton/ha and 12.57 and 13.28%, respectively. Rates of N increased grain yield with a significance of 0.055; yields with 150, 225, and 300 kg/ha were 4.074, 4.490, and 4.581 ton/ha, respectively; however, there were no statistical differences. The rate of N 225 kg/ha optimizes wheat yield and quality considering 12.5% of protein, however, in order to obtain greater grain yield, it should be considered to increase the rate to 300 units of this element.

Introduction. Protein concentration is one of the main parameters for wheat grain quality, and the availability of nitrogen (N) in the soil is the simple factor that increases its value (Ottman and Doerge 1994). N is an essential component of aminoacids, which constitute the primary structure of the protein molecule (Kent 1983). The effect of N availability on wheat yield and quality has been a topic of numerous investigations. An increment in the accumulation of N may be obtained by the application of greater rates or for the same rate of N, which can be achieved by increasing the efficiency recovery of the fertilizer applied (Sowers et al. 1994; Ortiz et al. 1997). Cortés et al. (1994a) and Ortiz et al. (1997) have indicated that rates, source, timing, and application method have an important role on the efficient management of these inputs. In general, the highest rates are less efficient than the lowest ones (Uvalle et al. 1997; Sayre and Moreno 1997; Ortiz et al. 1997). Application in band is better than broadcast (Cortés et al. 1994a; Keeney 1982), fractionated fertilization is better than total application (Ruiz 1985; Mahler et al. 1994; Cortés et al. 1994a, 1994b), and no significant differences have been found between N sources if managed properly (Cortés et al. 1994a; Ortiz et al. 1997). For optimum use of N-based fertilizers, the fractionated fertilization should consider the demand curve of the crop, the N available in the soil, and the quality requirements for the product. For quality purposes, Kent (1983) indicates that the N aborbed after heading promotes an increment on the protein level of the grain, whereas the N taken up during the early growth phases has a primary impact on production. Therefore, our objective was to evaluate the interaction between N fertilization, protein content, and yield of durum wheat cultivar Nacori C97.

Materials and methods. The study was conducted at the Norman E. Borlaug Experimental Station, which belongs to the Mexican National Institute for Forestry, Agriculture and Livestock Research (INIFAP), during the 1998–99 agricultural season. The station is located at 27°22' N latitude and 109°55' W longitude. A factorial experiment was established to evaluated two sources of N (urea and ammonium sulphate), and three N rates (150, 225, and 300 kg/ha) in wheat. A randomized block design with split plots and three replications was used; the large plots corresponded to the N source and the small ones to the rate of N. The experimental plot consisted of six 8-m rows, and the experimental unit consisted of the two central 4-m rows. Soil preparation consisted of minimum tillage reusing the bed from the previous crop. Sowing was on 16 December 16 in beds 80 cm apart with two rows with durum wheat cultivar Nacori C97 at a density of 50 kg/ha. Three complementary irrigations were provided to the crop during the beginning of jointing, heading, and beginning of grain formation. Weeds were controlled mechanically and manually. N rates were applied in band between the bed rows before the first complementary irrigation. Based on soil analysis and its availability, phosphorus was not applied. The variables evaluated were percent grain protein at 12% humidity and grain yield. Data were analyzed with MSTAT (Russell D. Freed, MSTAT Director Crop and Soil Sciences Deparment Michigan State University). Tukey`s test (0.05) was used for mean comparison.

Results. No significant differences for N source or for the interaction 'N sources x rate' were observed (Table 11). The mean grain yield was practically the same whether urea or ammonium sulphate were applied, the difference between these sources was only 27 kg/ha. The differences in yield between the sources and rates were 5 kg at 150 units, 19 kg at 225 units, and 105 kg at 300 units. There were no statistical differences between N rates, although the maximum difference in grain yield was 507 kg between the 300 and 150 N unit rates, followed by a difference of 416 kg between the 225 and 150 N unit rates, and 91 kg between the 225 and 300 N unit rates (Table 12). Protein content was slightly higher when Nacori C97 was fertilized with ammonium sulphate, however, the difference was not statistically significant (Table 13). On average, each N rate applied promoted a statistically

Table 11. Grain yield of the durum wheat cultivar Nacori C97 obtained with two nitrogen sources and the interaction of 'source x nitrogen rate', during the 1998–99 agricultural season, in the Yaqui Valley, Sonora, México.

Nitrogen source	Nitrogen rate (kg/ha)	Grain yield (ton/ha)
Urea	150	4.076
	225	4.500
	300	4.528
Mean		4.368
Ammonium sulphate	150	4.071
	225	4.481
	300	4.633
Mean		4.395

Table 12. Grain yield of the durum wheat cultivar Nacori C97 obtained with three nitrogen rates during the 1998–99 agricultural season in the Yaqui Valley, Sonora, México.

Nitrogen rate (kg/ha)	Grain yield (ton/ha)
150	4.074
225	4.490
300	4.581

Table 13. Percent grain protein of the durum wheat cultivar Nacori C97 obtained with three nitrogen rates during the 1998–99 agricultural season in the Yaqui Valley, Sonora, México.

Nitrogen source	Protein content (%)
Urea	12.57
Ammonium sulphate	13.28

Table 14. Percent grain protein of the durum wheat cultivar Nacori C97 obtained with three nitrogen rates during the 1998–99 agricultural season in the Yaqui Valley, Sonora, México (Tukey 0.05 = 0.652).

Nitrogen rate (kg/ha)	Protein content (%)
150	11.90 a
225	13.06 b
300	13.80 c

significant increase in grain protein content. A N rate of 225 units was sufficient to obtain the quality standard of 12.5% of protein (Table 14, p. 114). As an average, 75 N units applied before the first complementary irrigation caused an increment of 0.95% in the grain protein (Table 15).

Table 15. Percent wheat grain protein obtained from the interaction 'source x rate of nitrogen' in the durum wheat cultivar Nacori C97, during the 1998–99 agricultural season in the Yaqui Valley, Sonora, México.

Nitrogen source	Nitrogen rate (kg/ha)	Protein (%)
Urea	150	11.19
	225	12.79
	300	13.72
Ammonium sulphate	150	12.61
	225	13.33
	300	13.88

Conclusions.

1. No differences were found in grain yield of durum wheat cultivar Nacori C97 between the application of urea and ammonium sulphate.
2. A rate of 225 nitrogen units optimizes yield and quality of durum wheat cultivar Nacori C97.
3. The application of 300 nitrogen units increased quality, but not the grain yield of durum wheat cultivar Nacori C97.

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Effect of foliar nitrogen on yield and protein content of the durum wheat cultivars Nacori C97 in 1998–99 and Rafi C97 in 1999–2000, in the Yaqui Valley, Sonora, México.

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Summary. These studies were conducted at the Norman E. Borlaug Experimental Station in Sonora, México, during the 1998–99 and 1999–2000 agricultural seasons. In 1998–99, urea, a 32% urea solution, 45% ammonium nitrate, and 7.5% Flussigg nitrogen (10% nitrogen solution) were applied to the foliage of thedurum wheat cultivar Nacori C97 during jointing initiation, boot, and grain filling, and were compared with an untreated check. The soil was not fertilized. In 1999–2000, foliar applications of urea (16%), urea Lobi, Nitrocel, and Blitzer at the rate of 2.0 kg/ha were applied dur-

ing the milk-dough stage and compared with an untreated check. Soil fertilization rate was 200–52–00 of NPK. Average grain yield increase in 1998–99 was 1.305 ton/ha with foliar nitrogen (N) applications. Average yield of treatments with foliar N was 2.491 ton/ha and 1.428 ton/ha for the check. The highest yield was obtained with Flussigg, because it did not cause foliar damage as the other sources of N. The protein value increased 0.77% with one or two applications and 1.51% with the third. The highest protein value was 12.7% with three applications of ammonium nitrate. The highest grain yield (7.213 ton/ha) in 1999–2000 was obtained with urea (16%), statistically superior to the check with a difference of 1.095 ton/ha. There were no significant statistical differences between treatments for protein content. Grain yield was 7.213 ton/ha for 16% urea (11.22% protein), 6.199 ton/ha for Lobi (11.27% protein), 6.834 ton/ha for Nitrocel (11.35% protein), 6.510 ton/ha for Blitzer (11.37% protein), and 6.118 ton/ha for the check (11.32% protein).

Introduction. The average annual area established with wheat in the state of Sonora during the period 2000–09 was 252,586 ha, with a maximum of 320,476 ha and a minimum of 104,268 ha. During the same period, the average grain yield was 5.80 ton/ha for a production of 1,464,408 ton with a value of approximately \$253 x 10^6 USD. For the 2010–11 agricultural season, the area established with wheat in Sonora was 287,574 ha, 172,422 ha corresponded to the District of Rural Development (DRD) 148-Cajeme (Yaqui Valley) and 80,134 ha for the DRD-149-Navojoa, for a total of 252,556 ha in southern Sonora. The average price/ton fluctuated from \$100 USD in 2002 to \$340 USD in 2008 (OEIDRUS 2010). In Sonora, durum wheat production is oriented predominantely for the international market, whereas production of bread wheat is for the national market. Farmers must select cultivars that comply with the market requirements but, at the same time, with regional strategies for control of leaf rust and Karnal bunt. In the case of durum wheat, it is important that wheat cultivars also comply with quality standards established by the buyers, such as 90% of vitreous grains and 12% grain protein content (Cortés et al. 2011). Protein concentration is one of the main quality parameters for the wheat grain, and the nitrogen (N) available in the soil is the simple factor that has more influence on increasing its content (Ottman and Doerge 1994). Kent (1983) reported that the N absorbed after heading promotes an increment on the protein level of the grain, but the N absorbed in the early growth stages has an impact mainly on production. Plants take up nutrients primarily by the roots, however, leaves also have the capacity for absorbing water and nutrients. In theory, a plant can be nourished completely through leaves, but in practice, foliar fertilization is used as a complementary way to supply N, magnesium, and micro-elements. Foliar nutrition is important because frequently in soils with a sufficient nutrient content, nutrients are not available to the plant, such as iron and phosphorus under alcaline soil conditions. In this case, foliar application has a greater efficiency than applied to the soil. For an optimum application of this method of fertilization, it is important to consider the relative humidity, light, temperature, leaf age, contact zone and wet surface, and the chemical characteristics of the solution. Urea solutions may be applied to a maximum concentration of 15%, however, the critical growth periods in which foliar fertilization should not be applied must be taken into consideration. In the case of cereals, these periods occur between sowing and the appearance of the third leaf, as well as right after heading (Fink 1988). Gros and Domínguez (1992) reported that 100 kg/ha of urea can be applied in 300 L of water to wheat and other cereals, with minimum risks of leaf damage or consequences, which can be attributed to the waxy cuticle. The objective of this study was to determine the effect of foliar application of N on yield and protein content of the durum wheat cultivar Nacori C97.

Materials and methods. The study was conducted at the Norman E. Borlaug Experimental Station, which belongs to the Mexican National Institute for Forestry, Agriculture and Livestock Research (INIFAP), during the 1998–99 and 1999–2000 agricultural seasons. The station is located at 27°22'N latitude and 109°55'W longitude, in a compacted clay soil. In 1998–99, urea, a 32% urea solution, 45% ammonium nitrate, and 7.5% Flussigg nitrogen (10% nitrogen solution) were applied to the foliage of the durum wheat cultivar Nacori C97 during jointing initiation, boot, and grain filling, and were compared with an untreated check. The soil was not fertilized and the beds from the previous crop was reutilized. Sowing was on 16 December after summer maize in beds with two rows, at the rate of 50 kg/ha. Two complementary irrigations were applied; one application of an insecticide for pest control, and weeds were eliminated mechanically and manually. A randomized block design with split plots and two replications was used, the large plots corresponded to sources of foliar N and the small ones to the number of applications. The experimental unit consisted of six beds 6-m long and 80 cm apart, and the evaluation was carried out on two beds 4-m long. In 1999–2000, urea (16%), urea Lobi, Nitrocel, and Blitzer were applied at the rate of 2.0 kg/ha during heading, and were compared with an untreated check. Wheat was established under a conservation tillage system with drip irrigation; the previous summer crop was maize. Durum wheat cultivar Rafi C97 was sown at the rate of 100 kg/ha on 17 December in beds 80 cm apart with two rows. The irrigation lamina was 4.3 cm and fertilization 200–100–00 of NPK. Weeds were eliminated manually and there was no need for insect control. A randomized block design with four replications was used. The experimental unit consisted of two beds, 20-m long, 80 cm apart, and the evaluation was carried out on two beds, 4-m long. N solutions were applied in 381 L of water. Data were analyzed with MSTAT (Russell D. Freed, MSTAT Director Crop and Soil Sciences Deparment Michigan State University). Tukey's test (0.01, 0.05) was used for mean comparison.

Results and discussion. No significant differences between the number of applications for grain yield and protein content were observed in 1998–99. However, significant differences were found between the N sources evaluated (Table 16). Basically, the difference was observed between whether or not to apply the source of N, because 1, 2, or 3 applications were statistically similar, but different from the untreated check. The average grain yield increment when N was applied in relation to the check was 1,063 ton/ha. The average grain yield of the treatments was 2.491 ton/ha, whereas the check showed a yield of 1.428 ton/ha. The highest yield recorded was obtained with Flussig g; this possibly is due to the low level of leaf damage that was observed on plants treated with the other sources of N. The protein value increased 0.77% with one or two applications and 1.51% with the third. The highest value (12.7%) was obtained with three applications of ammonium nitrate (Table 17). In 1999–2000, significant differences were detected between treatments for grain yield. The highest yield (7.213 ton/ha) was obtained with urea (16%), statistically superior to the check with a difference of 1.095 ton/ha. Grain yields of 6.834, 6.510, and 6.199 ton/ha were obtained with Nitrocel, Blitzer, and urea Lobi, respectively, and were statistically similar to urea (16%). There were no significant statistical differences between treatments for protein content (Table 18). From the experimentation during both crop seasons, we determined that the response of the wheat to foliar N applications depends upon the base soil fertilization; under low availability of N in the soil, such as in 1998–99, all the N sources evaluated increased grain yield and protein content, which was not observed when 200 N units were applied to the soil.

Table 16. Grain yield of the durum wheat cultivar Nacori C97 after foliar application of four different sources of nitrogen, during the 1998–99 agricultural season, in the Yaqui Valley, Sonora, México (Tukey 0.01= 0.703).

	Grain yield (ton/ha)				
	Number of applications				
Fertilizer	0	1	2	3	Mean
Urea	1.211	2.368	2.413	2.476	2.117
Ammonium nitrate	1.755	2.432	2.332	2.128	2.162
Urea + ammonium nitrate	1.561	2.650	2.128	2.104	2.111
Flussig g	1.185	2.704	2.959	3.190	2.510
Mean	1.428 a	2.539 b	2.458 b	2.475 b	

Table 17. Grain protien content of the durum wheat cultivar Nacori C97 after foliar application of four different sources of nitrogen, during the 1998–99 agricultural season, in the Yaqui Valley, Sonora, México (Tukey 0.01= 0.703).

	Grain protein (%)				
	Number of applications				
Fertilizer	0	1	2	3	Mean
Urea	10.20	10.15	11.75	11.20	10.83
Ammonium nitrate	10.60	11.85	10.95	12.70	11.53
Urea + ammonium nitrate	10.45	10.55	10.15	12.25	10.85
Flussig g	9.50	11.30	11.00	10.65	10.61
Mean	10.19 a	10.96 a	10.96 a	11.70 b	

Table 18. Grain yield and protein content of the durum wheat cultivar Rafi C97 after foliar application of four different sources of nitrogen during the 1999–2000 agricultural season, in the Yaqui Valley, Sonora, México (Tukey 0.05 = 1.039).

Foliar nitrogen	Grain yield (ton/ha)	Protein (%)
Untreated check	6.118 b	11.32
Urea (16%)	7.213 a	11.22
Urea Lobi 2.0 kg/ha	6.199 ab	11.27
Nitrocel 2.0 kg/ha	6.834 ab	11.35
Blitzer 2.0 kg/ha	6.510 ab	11.37

Conclusions. Foliar application of nitrogen increases grain yield and the protein content when the soil is not fertilized; however, nitrogen application to the soil or a highly availability of this element reduces the possibility for a significant response to the foliar application of this element.

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Interaction between accumulation of cold hours and sowing date for wheat in the Yaqui Valley, Sonora, México.

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Summary. To study the interaction between accumulation of cold hours and sowing date for wheat in the Yaqui Valley, Sonora, México, data from the weather station network (14 stations) reported in www.pieaes.org.mx were used. Data covered the wheat crop seasons from 2005–06 to 2009–10, on different wheat sowing dates: 15 November and 1, 15, and 30 December. We considered that each season lasted 120 days. Cold hour (CH) production was 88.9% from December to March; 10% during November, April, and May; and 1% during June to October. The accumulation of CH according to sowing date was 1 December > 15 December > 15 November > 30 December. The greatest CH accumulation occurred during the second half of December. Based on the positive correlation (r = 0.50) between production of cold hours and wheat yield, 1 December 1 can be considered as the optimum sowing date in the Yaqui Valley, Sonora.

Introduction. Temperature is the main factor that controls the response of plants to the environment, especially those that require the accumulation of a total of cold hours (CH) in order to change from a vegetative stage to a reproductive stage (Flood and Halloran 1984). A CH is defined as the quantity of hours within a time range, when the temperature is lower than a specific amount of degrees (Gil 1997), or the period of vernalization that occurs between 0 and 12°C (FAO 2001; Miralles 2004). The requirement of CH by crops is not constant and varys according to the vegetative stage, the species, and cultivar. Crops must complete their reproductive development within the available growth stage in order to achieve the maximum yield, so that stresses might be avoided during vulnerable stages (Loomis and Connor 2002). In the case of wheat, temperature is the most important factor that induces plant growth from emergence to flowering and maturity (Rawson and Macpherson 2001; Miralles 2004). The ideal temperature for growth and development of this crop ranges from 10 to 24°C; wheat stops growth at 0°C (Rawson and Macpherson 2001). The Yaqui Valley comprises 252,000 ha for irrigated agriculture and, for the last 30 years, wheat has been the most cultivated crop covering 90% of the area and, therefore, the most investigated. New scientific and technological information explains the behaviour of this crop under different weather conditions and soils, which allows farmers the proper management of wheat in this region (INIFAP 2009). The objective of this work was to study the interaction between accumulation of CH and sowing date for wheat in the Yaqui Valley, Sonora, México.

Materials and methods. The data used for this study was obtained from the weather station network, which is published at www.pieaes.org.mx. Accumulated CH from the 14 weather stations in the Yaqui Valley during the wheat crop seasons 2005–06 to 2009–10 were recorded and analyzed, considering the sowing dates of 15 November and 1, 15, and 30 December. Although the optimum sowing date for this cereal has a range from 15 November to 15 December (INIFAP 2009), there are farmers that delay the sowing date for various reasons, such as water and seed availability, therefore, the date 30 December was taken into consideration for this study. Each agricultural season was estimated to consist of 120 days. The number of CH was calculated according to sowing date, month, and crop season. The wheat yield reported by OEIDRUS (2010) for the state of Sonora was used to make a correlation with the value of CH. A database was created in Excel with the geoposition in UTM units of weather stations, and the average value of CH during the seasons of evaluation. The database was exported to the program Idrisi Kilimanjaro (Eastman 2003), and a spatial distribution map of CH in the Yaqui Valley was created.

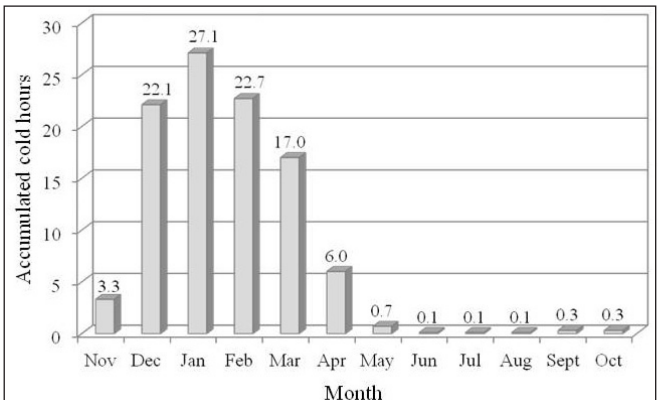

Fig. 12. Average accumulation of cold hours/month in the Yaqui Valley, Sonora, México, during the 2005–06 to 2009–10 crop seasons.

Results and discussion. The majority (89%) of accumulated CH during the year is produced during the months of December, January, February, and March. November, April, and May added another 10%, and the rest (1%) is produced during the months of June to October (Fig. 12, p. 118). It is possible to find CH during the summer months in some years. Félix et al. (2009) reported CH in June and July in 2008. The weather stations of the Yaqui Valley show recordings of the climatic variables every 10 minutes. The generation of CH regularly take place between the first hours (0–8 h) and the last (22–24 h) during the day, which correlates with the temperature (Fig. 13). Hours with the highest temperature difference was 06:50 and 15:00 with 16.3°C on 25 January, 2010. Of the seasons evaluated, 2007–08 had the greatest accumulation of CH (868), followed by 2005–06 (763), 2006–07 (742), 2009–10 (689), and 2008–09 (572) (Fig. 14).

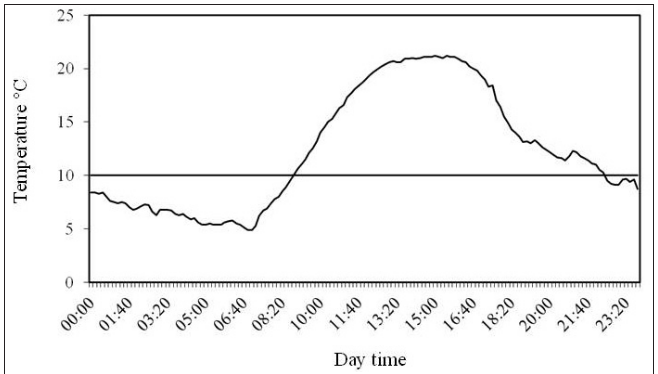

Fig. 13. Temperature reported in one day (25 January, 2010) with recording every 10 minutes in block 609, Yaqui Valley, Sonora, México.

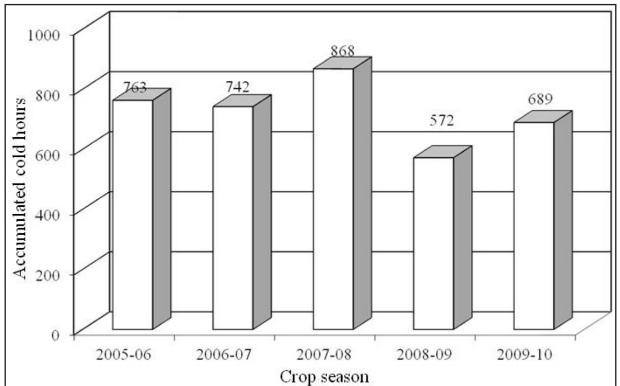

Fig. 14. Accumulated cold hours in the wheat crop seasons 2005–06 to 2009–10 in the Yaqui Valley, Sonora, México.

The accumulation of CH is related and has an effect on the wheat development depending on the sowing date. For the Yaqui Valley, INIFAP (2009) recommends an optimum sowing date 15 November to 15 December. This recommendation was based primarily on climatic conditions, water availability, and the probabilities of rust epidemics. The best sowing date is when a crop produces the highest yields within the local limitations. Once this date is determined, any delay will cause reductions in yield (Rawson and Macpherson 2001). The greatest accumulation of CH (658) in the Yaqui Valley was obtained with the sowing date of 1 December, followed by 15 December with 643 CH, 15 November with 600 CH, and 30 December with 573 CH (Fig. 15). The accumulation of CH every two weeks during 15 November to 15 April is shown (Table 19). For practical purposes, it should be considered that a proper tillering will take place with 150 CH (Félix et al. 2009). Average wheat yield in the Yaqui Valley in 2005–06 was 6.16 ton/ha, 6.25 in 2006-07, 6.07 in 2007-08, 5.68 in 2008-09, and 6.40 ton/ha in 2009-10 (OEIDRUS 2010). There was a positive correlation (r = 0.50) between CH and wheat yield (Fig. 16, p. 120). The spatial distribution of accumulated CH in the Yaqui Valley is shown (Fig. 17, p. 120). The areas with more accumulation of CH were the north-central, south, and southeastern parts of the valley. This figure can be a useful tool for farmers in order to plan crop management, and based on the location of their fields, select cultivars based on physiological maturity and the sowing date.

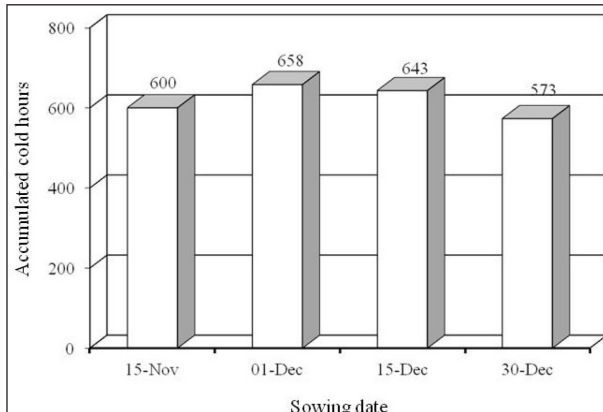

Fig. 15. Accumulated cold hours during a wheat season according to planting date and considering a season of 120 days (average of five crop seasons 2005–06 to 2009–10).

Table 19. Average accumulation of cold hours every two weeks during wheat crop seasons 2005–06 to 2009–10 in the Yaqui Valley, Sonora, México (SD = standard deviation).

	Accumulation of cold hours			
Period	**Maximum**	**Minimum**	**Mean**	**SD**
15–30 November	52	0	7	13.2
1–15 December	153	7	55	32.7
16–31 December	165	47	138	30.8
1–15 January	148	60	109	22.1
16–31 January	173	32	102	40.0
1–15 February	132	46	93	21.9
16–29 February	113	23	63	20.4
1–15 March	150	18	79	34.1
16–31 March	109	18	60	19.2
1–15 April	76	5	27	15.3

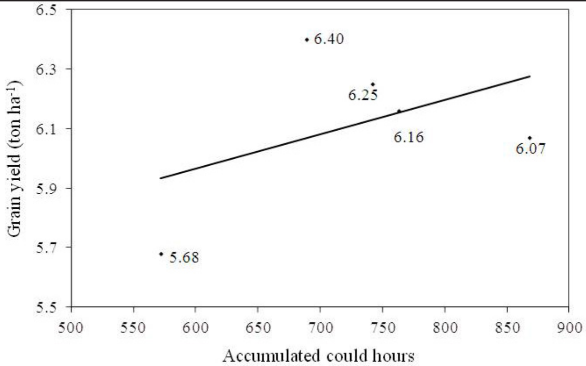

Fig. 16. Cold hours and wheat grain yield in the Yaqui Valley, Sonora, México, during the 2005–06 to 2009–10 crop seasons.

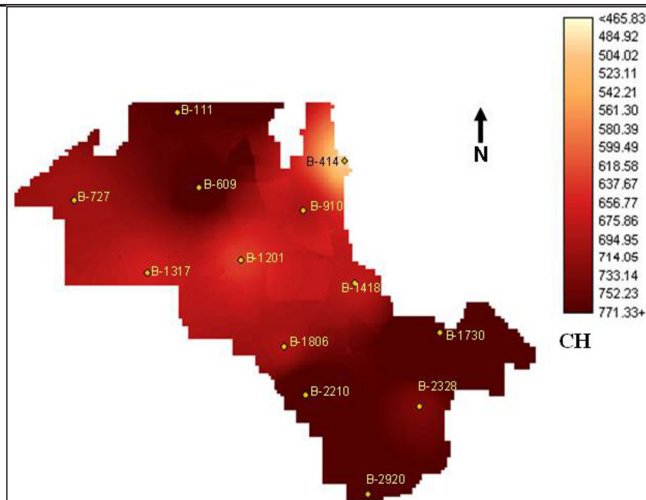

Fig. 17. Spatial distribution of total cold hours accumulated in the Yaqui Valley, Sonora, México, during the period from 15 November to 15 May (B = block).

Conclusions.

1. Accumulation of cold hours according to sowing date was 1 December > 15 December > 15 November > 30 December.
2. Based on the positive correlation (r = 0.50) between production of cold hours and wheat yield, 1 December can be considered as the optimum wheat sowing date in the Yaqui Valley.

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Effect of biofertilization on yield and quality of wheat in the Yaqui Valley, Sonora, México.

Alma Angélica Ortiz-Ávalos, Juan Manuel Cortés-Jiménez, Teresa de Jesús Ruiz-Vega, and Guillermo Fuentes-Dávila.

Summary. We evaluated the effect of biofertilizers on grain yield and quality of wheat. The study was carried out during the fall–winter 2010–11 wheat season in the Yaqui Valley, Sonora, México. Trials were established in a farmer's field where inoculations of wheat seed with *Azospirillum brasilense* (A), *Glomus intraradices* (G), and the combination

(A+G) were evaluated under the fermer's management scheme by the farmer and an untreated check. Wheat grain yield ranged from 6.46 to 10.81 ton/ha and a grain protein content from 9.78 to 12.92%. There was no response to the application of the fertilizers in relation to grain yield and quality, therefore, it is necessary to continue this type of study with native strains and analyze the soil content where trials will be established in order to assure proper conditions for the experiment.

Introduction. Wheat is the most important crop during the fall–winter in the Yaqui Valley, Sonora, and for the last 30 years it has covered more than 90% of the agricultural area. New scientific and technological information explains the behavior of this crop under different weather conditions and soils, which allows farmers proper management in this region (INIFAP 2009). However, the importance of this crop in the sustainability of agricultural systems has not been well studied, so there is interest in testing new inputs (biofertilizers) available in the market that offer similar or better grain yields at low cost and maintain a balance with nature. The first studies with biofertilizers were done in the central plateau of Mexico, which covers parts of the states of Guanajuato, Queretaro, Mexico, the Federal District, Tlaxcala, Puebla, and Morelos, with crops such as maize, wheat, barley, oats, sorghum, beans, and orange. Results indicated that biofertilizers provide 29% of the nitrogen that cereals require and almost 70% of the N requirement by grain legumes and allow the reduction of mineral fertilizers from 20 to 40%; they are cheap and easy to handle and apply (INIFAP-SAGARPA 2011). However, in the state of Morelos, maize grain yield was reduced when the microorganisms were used to inoculate the seed. In the state of Puebla, wheat yield increased 5% when seed was inoculated with *Glomus* (Gl) in relation to the fertilized check with 80-40-30 of NPK; however, yield was reduced when inoculation was carried out with *Azospirillum* (Az), and with a mixture of Gl+Az. In Amoloya, Hidalgo, in barley treatments inoculated with biofertilizers produced less yield than the fertilized check (46-23 of NP) (Irízar et al., 2003). Okon and Labandera (1994) reported that benefits from inoculation with *Azospirillum* depend on multiple factors, many of which can not be controlled under field conditions, such as temperature, rainfall, O_2 difusion, soil pH, poor soils, and the presence of competitive microorganisms, among others. Caballero et al. (1992) suggest that many more strains must be studied for each cereal, and Irízar el al. (2003) recommend to use strains from the region since a strain may not be effective in all locations and crops. We evaluated the effect of biofertilizers on grain yield and quality of wheat.

Materials and methods. The evaluation of biofertilizers was conducted during the fall–winter 2010–11 crop season in the Yaqui Valley, Sonora, México. Trials were stablished in nine modules with coöperating farmers, where the effects of the wheat seed inoculation with *Azospirillum brasilense* (A) and *Glomus intraradices* (G) from two different companies were evaluated, as well as the combination A+Z, under the management scheme of farmers (the average nitrogen units were 280, and 52 units of P2O5/ha), leaving an untreated check. Inoculation was carried out using 1 kg of biofertilizer for each 30 kg of seed. The durum wheat cultivar Patronato Oro C2008 was cultivated in module 1 and CIRNO C2008 in modules 2–7 and 9, and the bread wheat cultivar Kronstad F2004 in module 8. At harvest, grain yield and grain protein content at 12% humidity were recorded.

Results and discussion. Inoculation with *Azospirillum* and the combination *Azospirillum* + *Glomus* produced 8.76 ton/ha, 90 kg/ha less than the check, whereas *Glomus* 1 and *Glomus* 2 were 100 and 240 kg/ha, respectively, behind the check (Fig. 18). The yield range of the inoculation with *Azospirillum* was 6.46–10.81 ton/ha, 6.68–10.41 for *Glomus* 1, 6.84–10.28 for *Glomus* 2, 6.89–10.71 for the combination A+G, and 7.21–10.56 for the check (Table 19, p. 122). The yield range of bread wheat cultivar Kronstad F2004 in module 8 was 6.46–7.47 ton/ha with the lowest average of all modules with 6.89; module 3 showed the range 9.67–10.81 with an average of 10.33 and module 5 a range of 9.98-10.71 with an average of 10.30 ton/ha. Fallik et al. (1985) cited by Mendoza et al. (2004) indicate that the ability of *Azospirillum* to compete is significantly reduced in soils poor in organic matter, which is the case of the Yaqui Valley (Cortés et al. 2009), that could be the reason for the limited response of wheat to the inoculation with *Azospirillum*. Mendoza et al. (2004) also cites Caballero (personal communication) who reported an adequate symbiotic establishment when inoculations are carried out with native strains of

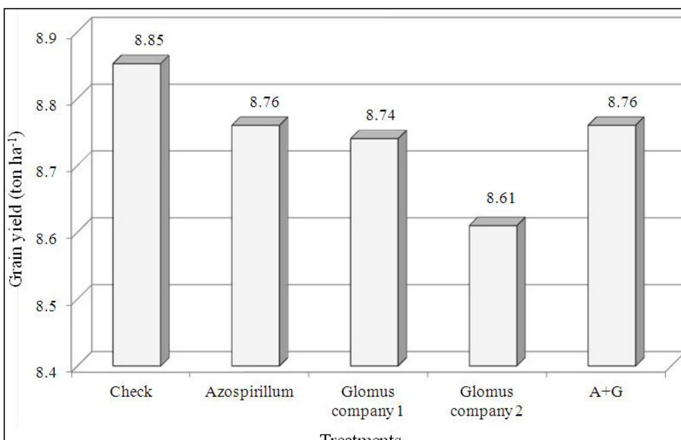

Fig. 18. Average grain yield of wheat in validation modules evaluated in the Yaqui Valley, Sonora, México, during the fall–winter 2010–11 crop season.

Azospirillum isolated from the same maize genotypes. Caballero et al. (1992) recommend as necessary to study the strains for cereals that can be used. Regarding grain protein, the highest percentage was obtained with *Glomus* (10.93), followed by the combination A+G, the check, and *Azospirillum* (Fig. 19). Protein content in module 2 was not possible to determine. The range of protein percent from inoculation with *Azospirillum* was 9.94–12.92, 9.78–12.87 for *Glomus* 1, 9.94–12.88 for *Glomus* 2, 9.78–12.87 for the combination A+G, and 9.98–12.81 for the check (Table 20). The range of protein percentage of bread wheat cultivar Kronstad F2004 in module 8 was 12.81–12.92 with the highest average (12.87). In general, there was no response of wheat in grain yield and percent of protein to the inoculation with biofertilizers. Mendoza et al. (2004) indicate that at least two factors are involved for the proper functioning of these fertilizers, the initial number of bacteria in the soil and the adaptation of bacteria to environmental conditions that prevail in arid regions. The introduction of a competitive strain of *Azospirillum* in completely different environment does not assure that such a strain will have the same behaviour as in its original niche.

Conclusions. There was no response to the application of biofertilizers (*Azospirillum brasilense* and *Glomus intraradices*) for wheat grain yield and quality. More experimental research should be carried out with the use of fertilizers in this crop, in relation to native strains, soil content, and the interaction chemical fertilization x organic fertilization.

Table 19. Effect of the inoculation with *Azospirillum brasilense*, *Glomus intraradices*, and their combination *Azospirillum+Glomus*, on percent grain yield of wheat in validation modules in the Yaqui Valley, Sonora, México, during the fall–winter 2010–11 crop season.

Module	Grain yield (ton/ha)				
	Check	*Azospirillum brasilense*	*G. intraradices* Company 1	*G. intraradices* Company 2	*Azospirillum + Glomus*
1	7.64	7.45	7.61	7.70	7.68
2	7.21	7.31	7.20	6.84	7.26
3	10.56	10.81	10.34	10.28	9.67
4	8.65	9.44	8.46	8.23	8.41
5	10.26	10.14	10.41	9.98	10.71
6	9.88	9.62	9.74	10.02	9.58
7	8.69	8.34	8.78	8.23	9.20
8 (module with bread wheat)	7.47	6.46	6.68	6.93	6.89
9	9.31	9.31	9.43	9.24	9.43

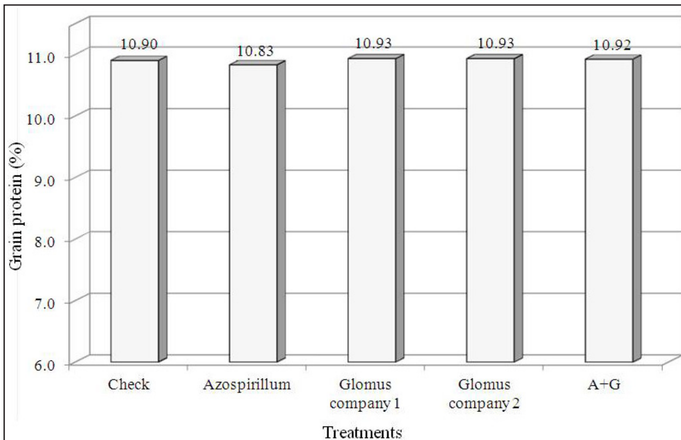

Fig. 19. Average protein percent of wheat in validation modules evaluated in the Yaqui Valley, Sonora, México, during the fall–winter 2010–11 crop season.

Table 20. Effect of the inoculation with *Azospirillum brasilense*, *Glomus intraradices*, and their combination *Azospirillum+Glomus*, on percent grain protein of wheat in validation modules in the Yaqui Valley, Sonora, México, during the fall–winter 2010–11 crop season.

Module	Grain yield (ton/ha)				
	Check	*Azospirillum brasilense*	*G. intraradices* Company 1	*G. intraradices* Company 2	*Azospirillum + Glomus*
1	9.98	10.07	9.94	9.94	9.99
2	10.53	10.35	10.71	10.51	10.77
3	10.13	10.22	9.78	10.01	9.82
4	10.03	10.22	10.56	10.41	10.66
5	10.10	9.94	9.80	9.87	9.78
6	11.98	11.96	12.08	12.08	11.88
7	12.81	12.92	12.87	12.88	12.87
8 (module with bread wheat)	11.64	10.97	11.67	11.68	11.63
9	9.31	9.31	9.43	9.24	9.43

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Two promising, elite, durum wheat lines for the Yaqui Valley, Sonora, México.

Pedro Figueroa-López, Gabriela Chávez-Villalba, Guillermo Fuentes-Dávila, José Luis Félix-Fuentes, Miguel Alfonso Camacho-Casas, Alberto Borbón-Gracia, and César Martín Armenta-Castro.

Introduction. Durum wheat cultivation in southern Sonora has been an excellent and convenient solution for the wheat producer in Sonora after the complex problems derived from epidemic levels of Karnal bunt present during the 1980s and the low competiveness of the bread wheat produced in the region, as shown by the manifest after the signing of the North American Free Trade Agreement (NAFTA) in the middle of the 1990s. On one hand, agronomic management of durum wheat is practically the same as that for bread wheat, so that the experience acquired by generations has not been wasted. On the other hand, durum wheat has shown greater yield potential than bread wheat and more tolerance to Karnal bunt, a disease that occurs endemically in the area. However, constraints for the crop have not disappeared completely, because leaf rust, a disease unknown in durum wheat in the region before the crop season 2000–01, currently represents a greater risk of yield loss. Grain quality, related to its pigmentation, also has become a trait to improve after the release of the cultivar Júpare C2001, which was resistant to the leaf rust but low in this characteristic.

Recently, several new durum wheat cultivars with different sources of resistance to leaf rust have been released in order to create a genetic mosaic that will diminish the risk of loss by epidemics. These cultivars also have been selected for their quality and grain yield, however, the Wheat Program of INIFAP in northwest Mexico faces a dissociation between quality and yield criteria, because the cultivar CIRNO C2008 was sown on more than 70% of the area cultivated with wheat in southern Sonora (152,838 out of 217,578 ha) due to its greatest yield potential, although it is one of the current cultivars with the lowest levels of grain pigmentation.

Other high-quality cultivars released during 2008, such as CEVY Oro C2008, Patronato Oro, and Sáwali Oro C2008, and Huatabampo Oro C2009 in 2009, have not attracted the attention of farmers, because they have a lower grain yield potential than CIRNO C2008. The collaborative project between INIFAP and CIMMYT on wheat breeding, aims at the release of new cultivars with better attributes, which will improve the phytosanitary status of the region and make a more profitable crop for the farmers domestically and internationally.

The identification of outstanding durum wheat experimental lines is one important component of the collaborative breeding project, where every year a set of 25 elite lines/cultivars are assembled and sown on several dates and managed under two irrigation regimes, using a randomized block design with three replications. Data recorded are grain yield, specific weight, 1,000-kernel weight, grain pigmentation, percentage of protein, days-to-flowering, days-to-maturity, height, percent lodging, percent black point, yellow berry, and Karnal bunt.

Progress report. The main characteristics of two outstanding durum wheat lines during the 2009–10 and 2010–11 agricultural seasons compared to the high-yielding cultivar CIRNO C2008 and the high-quality cultivar Sáwali Oro C2008 are given (Table 21). Line No. 1 (Fig. 20) 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 showed an average grain yield of 6,945 ton/ha. Line No. 2 (Fig. 21) ARMENT//2*SOOTY _9/RASCON_37/4/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN had 6,734 ton/ha, CIRNO C2008 was 6,648 ton/ha, and Sáwali Oro C2008 was 6,347 ton/ha. Both lines showed high levels of pigmentation, greater than that of CIRNO C2008, and line No. 2 was even greater than that of Sáwali Oro C2008. Both lines showed a lot of similarity to the

Fig. 20. Elite durum wheat line 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.

Fig. 21. Elite durum wheat line ARMENT//2*SOOTY _9/RASCON_37/4/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN.

Table 21. Average grain yield, agronomic and quality characteristics, and reaction to diseases of two elite durum wheat lines, compared to the high-yielding cultivar CIRNO C2008 and the high-quality cultivar Sáwali Oro C2008, in four sowing dates during the 2009–10 and 2010–11 agricultural seasons, in the Yaqui Valley, Sonora, México.

Cultivar/line	Grain yield (ton/ha)	Specific weight	1,000-kernel weight (g)	Pigmentation	Protein (%)	Days-to-flowering	Days-to-maturity	Height (cm)	Lodging	Black point (%)	Karnal bunt (%)	Yellow berry (%)
CIRNO C2008	6,648	82	60.6	22.1	13.5	82	125	81	0	4.6	2.3	0.2
Sáwali Oro C2008	6,347	82	46.1	28.6	13.2	83	125	88	1	2.4	1.1	0.6
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	6,945	82	51.8	28.2	12.7	82	124	83	0	1.8	4.5	0.6
ARMENT//2*SOOTY_9/RASCON_37/4/CNDO/PRIMADUR//HAI-OU_17/3/SNITAN	6,734	83	50.8	30.1	12.6	81	123	93	0	2.9	0.6	0.6
Mean	6,668	82	52.3	27.3	13.0	82	124	86	0	2.9	2.1	0.5

cultivar checks in days-to-flowering and maturity, as well as in specific weight. Thousand-kernel weight was similar for both lines (51.8 and 50.8 g), greater than that of Sáwali Oro C2008 (46.1) but lower than that of CIRNO C2008 (60.6). Although acceptable, the protein percent was lower in both lines than in the cultivar checks. Grain protein percent, as well as yellow berry, can be managed by an adequate rate of nitrogen as well as a proper timing. Line No. 2 is considerably taller than line No. 1 and the cultivars, however, it did not show any lodging. The percent black point was lower than that of the cultivar checks. Line No. 1 showed the highest level of Karnal bunt infection, however, it is still considered a resistant reaction (Fuentes-Dávila and Rajaram 1994). Both lines carry the gene *Lr14a* as does Sáwali Oro C2008, which has remained resistant to leaf rust for several years. Their release would be justified and the yield gap between high-yielding and high-quality cultivars would be reduced considerably. A more balanced set of commercial wheat cultivars with different genetic basis for resistance to leaf rust in the Yaqui Valley, Sonora, México, will be available as the preference for CIRNO C2008 is expected to decrease.

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Tepahui F2009, new bread wheat cultivar with high grain protein content and resistant to leaf rust for northwest Mexico.

Gabriela Chávez-Villalba, Miguel Alfonso Camacho-Casas, Pedro Figueroa-López, Guillermo Fuentes-Dávila, Víctor Valenzuela-Herrera, José Luis Félix-Fuentes, and José Alberto Mendoza-Lugo.

Summary. As a strategy to broaden the spectrum of resistant cultivars to leaf rust and increase its durability, the Mexican National Institute of Forestry, Agriculture, and Livestock Research released a new bread wheat (*Triticum aestivum* L.) cultivar with the name **Tepahui F2009**. Evaluations of experimental elite wheat lines were carried out under irrigation during the 2007–08 to 2009–10 fall–winter wheat seasons. Tepahui F2009 is resistant to the common leaf rust races in Mexico and it showed similar grain yield to the check Tacupeto F2001 with an average of 6.4 ton/ha. Average test weight of this cultivar was 81.9 kg/hL and grain protein content 13.12%. Tepahui F2009 presented a gluten strength of 362 W x 10-4 J. The balance of tenacity and elasticity (P/G) was 4.1. Tepahui F2009 is considered an excellent option for farmers in northwest Mexico, which will partly meet the domestic market demand.

Introduction. Wheat cultivars in Mexico are classified into five groups based on its species, hardness, gluten type, and potential use by the food industry (Peña et al. 2007). Bread-making wheat from group 1 is the most demanded by the national industry (CANIMOLT 2008); however, in the state of Sonora, which is the main wheat-producer in the nation with 47%, the preference for durum wheat (*Triticum durum*) from group 5 has prevailed since the 1994–95 crop season. During the 2010–11 crop season, the area grown with bread wheat in southern Sonora was 87,648 ha, which represents 30% of the area grown with wheat (OEIDRUS 2011). The production of this type of wheat in this region is more competitive with imported bread wheat, which is reflected in less imports by the national milling industry. However, the most grown bread wheat cultivar by farmers and the most demanded by the industry Tacupeto F2001 has lost its resistance to races of leaf rust present in this region, and the low yield potential of high protein cultivar Kronstad F2004, have led to a new generation of bread wheat cultivars. The collaborative project between INIFAP and CIMMYT on wheat breeding, aims at the release of new cultivars with better attributes that will improve the phytosanitary status of the region and make a more profitable crop for the farmers domestically and internationally. The identification of outstanding bread and durum wheat experimental lines is one important component of this collaborative breeding project. This article deals with a bread wheat line released as commercial cultivar for northwest Mexico.

Materials and methods. The evaluations of elite experimental wheat lines were carried out at the Norman E. Borlaug Experimental Station which belongs to the Mexican National Institute for Forestry, Agriculture, and Livestock Research located in block 910 in the Yaqui Valley, Sonora (27º22´3.01” N and 109º55´40.22” W, at 38 masl), during the 2007–08 to 2009–10 wheat seasons. Sowing dates were 15 November, 1 and 15 December, and 1 January. In 2007–08, lines/cultivars were subjected to two and three complementary irrigations, and in 2008–09 and 2009–10 to three and four. A randomized block design with three replications was used for these evaluations. Plots consisted of a bed 5-m long with two rows and a density of 100 kg/ha. Strong gluten-type regional check bread wheat cultivars included Tacupeto F2001 and Kronstad F2004. Agronomic management followed INIFAP's technical recommendations (Figueroa-López et al. 2011). Data recorded were: grain yield, test weight, 1,000-kernel weight, grain protein (determined with a NIR-Perten 9100 analyzer), flour extraction (with an experimental grinder Brabender), gluten strength (with an alveograph Chopin), optimum mixing time (with the Swanson mixer), and experimental bread making trials.

Results and discussion. Bread wheat experimental line 'Bettu/3/CHEN/*Ae. tauschii*//2*Opata' (later released as commercial cultivar Tepahui F2009) was identified as resistant to the new races of leaf rust (*Puccinia triticina*) present in southern Sonora during the 2007–08 wheat season and has maintained the resistance reaction during the last four seasons. This is one of the most important traits for the release of experimental lines as commercial cultivars in this region. The cross and selection history of this line is CMSW00WM00150S-040M-040Y-030M-030ZTM-3ZTY-0M-0SY-0CEVY-OCEVY. Grain yield is another important characteristic that a farmer will consider in order to adopt a new cultivar; as a result of the experimental trials during three crop seasons, Tepahui F2009 showed similar yield to the check Tacupeto F2001 with an average of 6.4 ton/ha, 3.1% higher than that of the other check Kronstad F2004 (Table 22). The range of the average yield during the three crop seasons was from 5.8 to 7.2 ton/ha. The highest yield was obtained when cultivars were sown from 15 November to 1 December (Table 23). The maximum yield difference between sowing dates (15 November–1 December and 1 January) for Tepahui F2009 was 700 kg, 1.2 ton between 1 December and 1 January for Tacupeto F2001, and 1.2 ton between 1 and 15 December for Kronstad F2004. Average test weight of Tepahui F2009 was 81.9 kg/hL, slightly superior to those of Tacupeto F2001 and Kronstad F2004 (80.5) (Table 24). These values are greater than those specified by the Mexican Norm NMX-FF-036-1996, which regulates wheat commercialization within the country (DGN, 1996), and establishes a minimum of 74 kg/hL for the quality grade Mexico 1. Test weight is partly positively related to flour yield (Finney et al. 1987), so Tepahui F2009 will likely produce high quantities of this subproduct.

Table 22. Experimental grain yield (ton/ha) of the bread wheat cultivar Tepahui F2009 and the checks Tacupeto F2001 and Kronstad F2004. The results are the average of three wheat seasons (2007–08 to 2009–10) of evaluation at the Norman E. Borlaug Experimental Station, Sonora, México.

	Cultivar		
Season	Tepahui F2009	Tacupeto F2001	Kronstad F2004
2007–08	5.8	5.7	6.0
2008–09	6.0	6.0	5.6
2009–10	7.2	7.5	6.9
Mean	6.4	6.4	6.2

Table 23. Experimental grain yield (ton/ha) by sowing date of the bread wheat cultivar Tepahui F2009 and the checks Tacupeto F2001 and Kronstad F2004. Average of three wheat seasons (2007–08 to 2009–10) of evaluation at the Norman E. Borlaug Experimental Station, Sonora, México.

	Cultivar		
Sowing date	Tepahui F2009	Tacupeto F2001	Kronstad F2004
15 November	6.7	6.1	6.2
1 December	6.7	7.2	6.8
15 December	6.1	6.1	5.6
1 January	6.0	6.0	6.0
Mean	6.4	6.4	6.2

Table 24. Test weight (kg/hL) of the bread wheat cultivar Tepahui F2009 and the checks Tacupeto F2001 and Kronstad F2004. Average of three wheat seasons (2007–09 to 2009–10) of evaluation at the Norman E. Borlaug Experimental Station, Sonora, México.

	Cultivar		
Season	Tepahui F2009	Tacupeto F2001	Kronstad F2004
2007–08	81.5	79.4	80.5
2008–09	82.7	81.8	81.0
2009–10	81.5	80.2	80.0
Mean	81.9	80.5	80.5

Table 25. Percent grain protein (at 12.5% humidity) of the bread wheat cultivar Tepahui F2009 and the checks Tacupeto F2001 and Kronstad F2004. Average of three wheat seasons (2007–09 to 2009–10) of evaluation at the Norman E. Borlaug Experimental Station, Sonora, México.

	Cultivar		
Season	Tepahui F2009	Tacupeto F2001	Kronstad F2004
2007–08	13.1	12.7	14.1
2008–09	13.5	13.0	14.1
2009–10	12.8	12.4	13.4
Mean	13.1	12.7	13.9

The average grain protein content of Tepahui F2009 was 13.1%, whereas the check cultivar Tacupeto F2001 showed 12.7 and Kronstad F2004 13.9% (Table 25). Tepahui F2009 presents a gluten strength of 362 W x 10-4 J, a characteristic of strong gluten wheats, and is greater than that of Tacupeto F2001 (315 W x 10-4 J), but lower than that of Kronstad F2004 (494 W x 10-4 J) (Table 26, p. 127). These three cultivars are appropriate for mechanized bread-making. The value of Tepahui F2009 with respect to the balance of tenacity and elasticity (P/G) was 4.1 (Table 27, p. 127). Tepahui F2009 represents a new option for farmers in northwest Mexico, but particularly for those in southern Sonora. This cultivar has shown tolerance levels acceptable to Karnal bunt and resistance to the races of leaf rust present in the region, it has a high protein content, and strong gluten. Its origin partially comes from *Aegilops tauschii*, a wild wheat used as a parent that is resistant to drought and it is a source of new genes for resistance to diseases (Cox et al. 1992). Therefore, Tepahui F2009 was released with the objective to have a cultivar with better baking quality than Tacupeto F2001 the most grown bread wheat cultivar, and it also has better grain yield than Kronstad F2004. According to the law of seed production and commercialization, after complying with the requirement of the International Union for the Protection of New Varieties of Plants (UPOV 1994), Tepahui F2009 was described and protected in the Catalogue of cultivars feasible for registration with the number TRI-119-270510.

Table 26. Gluten strength of the bread wheat cultivar Tepahui F2009 and the checks Tacupeto F2001 and Kronstad F2004. Average of three wheat seasons (2007–09 to 2009–10) of evaluation at the Norman E. Borlaug Experimental Station, Sonora, México (*Kronstad F2004 was not evaluated in 2007–08).

	Cultivar		
Season	**Tepahui F2009**	**Tacupeto F2001**	**Kronstad F2004***
2007–08	342	270	—
2008–09	328	253	545
2009–10	417	421	443
Mean	362	315	49

Table 27. Balance of tenacity and elasticity (P/G) of the bread wheat cultivar Tepahui F2009 and the checks Tacupeto F2001 and Kronstad F2004. Average of three wheat seasons (2007–09 to 2009–10) of evaluation at the Norman E. Borlaug Experimental Station, Sonora, México (*Kronstad F2004 was not evaluated in 2007–08).

	Cultivar		
Season	**Tepahui F2009**	**Tacupeto F2001**	**Kronstad F2004***
2007–08	3.8	4.5	—
2008–09	4.5	3.0	3.9
2009–10	3.9	3.9	3.7
Mean	4.1	3.8	3.8

Conclusions.

1. The release of cultivar Tepahui F2009 for northwest Mexico will contribute to reduce the risk of leaf rust epidemics in the region.
2. Tepahui F2009 will extend the durability of cultivars with resistance to leaf rust.
3. Tepahui F2009 will provide the necessary time for the breeding program to increase the genetic diversity of the two types of wheat grown in the region.
4. Tepahui F2009 will make bread wheat to be more competitive in the regional market.

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Identification of rust resistance genes in experimental bread wheat lines and cultivars.

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Introduction. With the implementation of molecular marker-assisted selection in wheat breeding to incorporate new sources of resistance to pathogens, it has been posible to protect this crop against diseases. The accumulation of different sources of resistance to a disease in the same genotype is a process known as pyramiding, which constitutes a promising estrategy for achieving durable resistance through time. This idea is difficult to implement in traditional breeding, because once a resistance gene is incorporated into a line, it becomes difficult to monitor other resistance genes for the same pathogen as all plants show the same resistant phenotype, unless the selection process is assisted by molecular markers for each of the genes target of pyramiding (Johnson 1984). Our objective was to evaluate experimental bread wheat lines and cultivars in order to determine the presence of genes *Lr34*, *Sr2*, *Sr24*, *Sr25*, and *Sr26*.

Materials and methods. From the experimental trial established every wheat season at the Norman E. Borlaug Experimental Station, which belongs to the Mexican National Institute for Forestry, Agriculture, and Livestock Research (INIFAP) located in block 910 in the Yaqui Valley, Sonora (27º22´3.01" N and 109º55´40.22" W, at 38 masl), during the 2010–11, fall–winter, agricultural season, 20 experimental, elite lines from the International Maize and Wheat Improvement Center (CIMMYT) Bread Wheat Program were evaluated for the presence of genes *Lr34*, *Sr2*, *Sr24*, *Sr25*, and *Sr26*, as well as four cultivars released by INIFAP and a bread wheat commercial cultivar from a private company (Table 28, pp. 128-129). DNA was extracted from developing leaves of lines and cultivars during heading, based on the methodology by Saghai-Maroof et al. (1984). PCR reactions were carried out at the CIMMYT Biotechnology Laboratory in El Batan, state of Mexico. For gene *Lr34*, a final volume of 9.5 µl was used for the reaction (6.5 µl de RED taq sigma, 1.5 µl of primer CSLV34, and 1.5 µl of L34PLUS), and 5 µl of DNA. For the rest of the genes, the amount of primer changed in order to adjust to 9.0 µl per reaction: *Sr2* (2.5 µl of BSPH1), *Sr24* (2.5 µl of Sr24#12), *Sr25* (1.5 µl of WMC221), and *Sr26* (2.5 µl of Sr26#43). The PCR products obtained were separated by horizontal electrophoresis in agarose gels at 2.5% and 3.0 % depending on the gene. The separation was done in 1X TBE buffer, stained in ethidium bromide, visualized under UV light, and documented with digital photography.

Table 28. Commercial bread wheat cultivars and elite advanced lines evaluated for the presence of genes *Lr34*, *Sr22*, *Sr24*, *Sr26*, and *Sr36*, during the 2010–11 fall–winter agricultural season at the Norman E. Borlaug Experimental Station, Sonora, México.

Entry	Line	Selection history
1	Tacupeto F2001	
2	Kronstad F2004	
3	Navojoa M2007	
4	Roelfs F2007	
5	RSM-Norman F2008	
6	Thelin/2*WBLL1	CGSS02Y00079T-099B-099B-099Y-099M-6Y-0B
7	PBW343//CAR422/ANA/3/Elvira	CMSS02M00409S-030M-1Y-0M-040Y-10ZTB-0Y-02B-0Y
8	ROLF07*2/5/REH/HARE//2*BCN/3/CROC_1/*Ae. tauschii* (213)//PGO/4/HUITES	CMSS06B00704T-099TOPY-099ZTM-099Y-099M-23WGY-0B
9	Tacupeto F2001/Brambling*2/5/KAUZ//Altar 84/AOS/3/MILAN/KAUZ/4/HUITES	CMSS06B00707T-099TOPY-099ZTM-099Y-099M-2WGY-0B
10	WBLL1*2/4/YACO/PBW65/3/KAUZ*2/TRAP//KAUZ*2/6/NG8201/KAUZ/4/SHA7//PRL/VEE#6/3/FASAN/5/MILAN/KAUZ	CMSS06Y00619T-099TOPM-099Y-099ZTM-099Y-099M-5WGY-0B
11	UP2338*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/MILAN/KAUZ//CHIL/CHUM18/6/UP2338*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ	CMSS06Y00859T-099TOPM-099Y-099ZTM-099Y-099M-35WGY-0B
12	Becard/5/PGO//CROC_1/*Ae. tauschii* (224)/3/ 2*BORL95 /4/Circus	CMSS06B00411S-0Y-099ZTM-099Y-099M-12WGY-0B

Table 28. Commercial bread wheat cultivars and elite advanced lines evaluated for the presence of genes *Lr34*, *Sr22*, *Sr24*, *Sr26*, and *Sr36*, during the 2010–11 fall–winter agricultural season at the Norman E. Borlaug Experimental Station, Sonora, México.

Entry	Line	Selection history
13	KAUZ//Altar 84/AOS/3/MILAN/KAUZ/4/HUITES/5/ C80.1/3*Batavia//2*WBLL1/6/KAUZ//Altar 84/AOS/3/MILAN/ KAUZ/4/HUITES	CMSS06Y01283T-099TOPM-099Y-099ZTM-099Y-099M-14WGY-0B
14	CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/ 2*KAUZ/6/ Pastor/7/WHEAR/8/CAL/NH//H567.71/3/SERI/4/CAL/NH// H567.71/5/2*KAUZ/6/Pastor	CMSS06Y01284T-099TOPM-099Y-099ZTM-099Y-099M-24WGY-0B
15	PBW343*2/Kukuna*2//FRTL/PIFED	CMSS06Y00831T-099TOPM-099Y-099ZTM-099NJ-099NJ-5WGY-0B
16	WBLL1*2/Kurufu//Kronstad F2004/3/WBLL1*2/Brambling	CMSS06B00720T-099TOPY-099ZTM-099Y-099M-5RGY-0B
17	YAV_3/SCO//JO69/CRA/3/YAV79/4/*Ae. tauschii* (498)/5/ LINE1073/6/KAUZ*2/4/CAR//KAL/BB/3/NAC/5/KAUZ/7/Krpm-stad F2004/8/KAUZ/Pastor//PBW343	CMSS06B00762T-099TOPY-099ZTM-099Y-099M-11RGY-0B
18	MILAN/KAUZ//Prinia/3/BAV92/4/Pastor*2/BAV92/5/Tacupeto F2001*2/Kukuna	CMSA05Y01021T-040M-040ZTP0Y-040ZTM-040SY-14ZTM-01Y-0B
19	SOKOLL*2/TROST	CMSA05Y01186T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-03Y-0B
20	SOKOLL*2/3/BABAX/LR42//BABAX	CMSA05Y01225T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-01Y-0B
21	WBLL1*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/KAUZ// ALTAR84/AOS/3/MILAN/KAUZ/4/HUITES	CMSS05B00060S-099Y-099M-099Y-099ZTM-14WGY-0B
22	KAUZ//ALTAR84/AOS/3/MILAN/KAUZ/4/HUITES/7/CAL/NH// H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/Pastor	CMSS05B00581S-099Y-099M-099Y-099ZTM-2WGY-0B
23	TRCH/SRTU/5/KAUZ//Altar 84/AOS/3/MILAN/KAUZ/4/HU-ITES	CGSS05B00189T-099TOPY-099M-099NJ-099NJ-7WGY-0B
24	MONR/3/GAV/ROM//BAR	TC-060024-10R-0OAX-0R-6C
25	PAMDOLY-PABG	SRGD(1erCSR06.06)-55R-0OAX-0R-1C

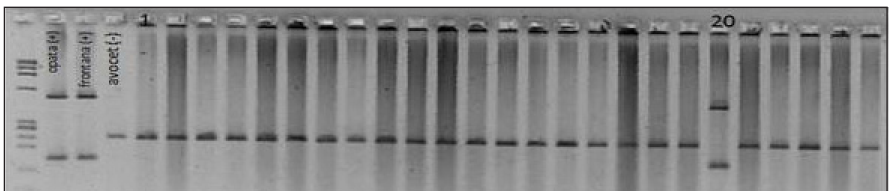

Fig. 22. Amplification by PCR for gene *Lr24* in bread wheat lines and commercial cultivars evaluated during the 2010–11 wheat season in the Yaqui Valley, Sonora, Mexico, using Red taq Sigma primer *Lr34* plus – SCLV24, with the positive parents Opata and Frontana and the negative Avocet (3% agarose gel).

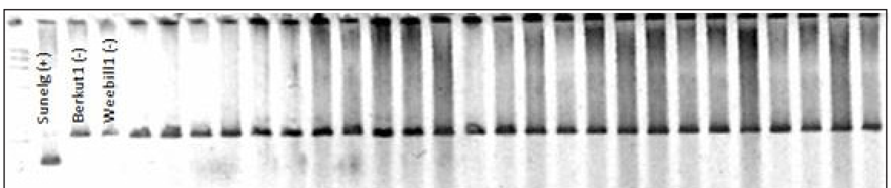

Fig. 23. Amplification by PCR for gene *Sr26* in bread wheat lines and commercial cultivars evaluated during the 2010–11 wheat season in the Yaqui Valley, Sonora, Mexico, using Red taq Sigma primer BES186379–Sr26#43, with the positive parents Sunelg and the negative Berkut 1 and WBLL1 (2.5% agarose gel).

Results. From the PCR products, only the line SOKOLL*2/3/BABAX/LR42//BABAX was positive for gene *Lr34* (Fig. 22). This line produced the highest grain yield in experimental trials, which differs from a report by Singh and Huerta-Espino (1997) who indicate that genes such as *Lr34* for nonspecific races, called durable resistance or low rusting, are expressed in adult plants and are related with a reduction in grain yield. For gene *Sr24*, a positive band was produced for line PBW343*2/KUKUNA*2//FRTL/PIFED, which confers resistance to most races of stem rust, including virulent race Ug99 (TTKSK). No positives for genes *Sr25* and *Sr26* were observed (Fig. 23). *Sr26* is effective against the family of TTKS races. The low frequency of this gene in modern cultivars make it ideal for use in breeding programs as a strategy for accumulation of genes. *Sr2* is a rust resistance gene that has been used for more than 60 years as a durable source and with a broad spectrum that includes resistance to Ug99. The incorporation of *Sr2* has been difficult, because its reccesive nature and to the fact that its phenotype is only evident in adult plant, which can be influenced by the genetic background and the environment (Spielmeyer et al. 2003). Gene *Sr2* was present in only the following lines: TRCH/SRTU/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES and WBLL1*2/4/YACO/PBW65/3/KAUZ*2/TRAP //KAUZ*2/6/NG8201/KAUZ/4/SHA7//PRL/VEE#6/3/FASAN/5/MILAN/KAUZ. With the incorporation of molecular marker-assisted selection within the traditional breeding system, it is possible to solve specific demands and problems of susceptibility to certain pathogens in advanced lines, which would be discarded otherwise. Genomic-molecular information published about wheat in relation to characters of agronomic interest is increasing. The most simple and efficient way to incorporate this information for developing new wheat cultivars is through breeding with molecular marker-assisted selection.

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Effect of the irrigation lamina on grain yield, 1,000-kernel weight, protein content, and pigment in four durum wheat cultivars in the Yaqui Valley, Sonora, México.

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Summary. The effect of two, three, and four complementary irrigations (CI) applied in 4.8, 6.0, and 7.1 x 10^3 m^3/ha, respectively, on the industrial quality and grain yield of durum wheat cultivars Huatabampo Oro C2009, Movas C2009, CIRNO C2008, and Samayoa C2004 was evaluated during the 2010–11 wheat season. Sowing was carried out in moist soil, using 100 kg of seed/ha. Each cultivar occupied three strips 90-m long consisting of six beds 0.80 m apart, each with two rows, and with three replications. The highest grain yield was shown by Huatabampo Oro C2009 with 6.099 ton/ha when provided with four CI, followed by CIRNO C2008 with 6.067. The application of four and three CI or the increment on the lamina caused a reduction in grain protein content. The highest grain protein content was shown by CIRNO C2008 with 14.98% when provided with two CI, followed by Movas C2009 with 14.52. All cultivars showed a consistently greater 1,000-kernel weight when they were provided with a greater irrigation lamina. The highest 1,000-kernel weight was shown by Huatabampo Oro C2009 with 53 g when provided with four CI, followed by CIRNO C2008 with 51.20. The highest b value was shown by Samayoa C2004 with 28.27 when provided with two CI, followed by Huatabampo Oro C2009 with 27.43 when provided with four CI, CIRNO C2008 with 24.63 and Movas C2009 with 22.90 when provided with two CI.

Introduction. The many investigations about the effect of irrigation on wheat production all conclude that irrigation is necessary in order to achieve the grain yield potential. However, in nature, there is a negative physiological association between grain yield and its protein content. Wheat cultivars with the highest yield potential have the tendency to produce grain with lower protein levels, and as a consequence lower aptitude to produce pasta or bread of quality and vice versa. Protein content is of great industrial interest, because it is directly related to the bread-making, pasta-making, and nutritional values of the wheat (Caputo et al. 2009). In the irrigated areas of Sonora, Mexico, the percentage of grain protein content in general is moderate, because the agronomic management practiced is focused on obtaining the highest grain yield. However, recently more interest has been given to the industrial quality aspects or processes, primarily on durum wheat, since this type of wheat is grown in 80% of the area. There are few investigations related to the effects of irrigation on the characteristics of the industrial quality; however, Nasseri et al. (2009) demonstrated that nitrogen translocation is favored with a good irrigation, but limited with excess water; they also mentioned that during the grain-filling period, nitrogen assimilation by cereals is an important process which determines yield and quality, and is also associated with the genotype and the agronomic practices, among them, the availability of water. The nitrogen required for protein synthesis, which is accumulated in the developing wheat grain, comes primarily from the nitrogen previously assimilated and accumulated in the leaves (Feller and Fisher 1994). Kouchaki et al (1997) found that increasing the number of irrigations caused an increase in grain yield and a reduction in grain weight and protein content. There is the need to generate information about the effect of the factors involved in the main parameters of the industrial quality; therefore, our objective was to carry out a preliminary study to determine the effect of different water lamina on grain yield and on some parameters of industrial quality, such as protein, pigment, and 1,000-kernel weight, in four durum wheat commercial cultivars grown in northwest Mexico.

Materials and methods. We evaluated three irrigation levels, 4.8, 6.0, and 7.1 x 10^3 m^3/ha, on grain yield and the quality of cultivars Huatabampo Oro C2009, Movas C2009, CIRNO C2008, and Samayoa C2004 at the Norman E. Borlaug Experimental Station which belongs to the Mexican National Institute for Forestry, Agriculture, and Livestock Research located in block 910 in the Yaqui Valley, Sonora (27º22´3.01" N and 109º55´40.22" W, at 38 masl), during the 2010–11 wheat season. Sowing was carried out on 8 December in moist soil irrigated on 16 November, 2010, using 100 kg of seed/ha; each cultivar occupied three strips 90-m long consisting of six beds 0.80 m apart, each with two rows, and with three replications. The first strip was irrigated with a total of 4.8 x 10^3 m^3/ha, the second with 6.0, and the third with 7.1. The first lamina was administered in two irrigations 64 and 91 days after sowing (das), the second in three 55, 79, and 104 das, and the third in four irrigations 44, 71, 96, and 114 das. From each strip, three samples from the two central 8-m beds were analyzed to determine grain yield. Fertilization was done during presowing using urea and monoammonium phosphate (MAP) to complete the formula 280–80–00 of NPK/ha for all combinations. The variables evaluated were grain yield (ton/ha), protein content (percentage at 12.5% of grain humidity), semolina pigment, and 1,000-kernel weight (g). The protein content was estimated using a NIR equipment model 1488 Perten, and the pigment with a reflectance colorimeter model CR 300 Minolta.

Results and discussion. ***Grain yield.*** In general, the results obtained agree with the reports by Kouchaki et al. (1997) and Nasseri et al. (2009), because all cultivars showed greater yield when they were provided four complementary irrigations (CI), and a consistent reduction with lower total lamina. The average yield of all cultivars with four CI was 5.59 ton/ha, 5.14 with three, and 3.86 with two (Table 29). The average difference for all cultivars between four and three CI was 458 kg, and 1,741.5 between four and two. CIRNO C2008 showed the highest differences, 1,467 (four CI) and 1,934 kg (two CI). The highest grain yield was shown by Huatabampo Oro C2009 with 6.099 ton/ha when provided with four CI, followed by CIRNO C2008 with 6.067, Movas C2009 with 5.433, and Samayoa C2004 with 4.800.

Table 29. Grain yield (ton/ha) of four durum wheat cultivars evaluated under different irrigation regimes at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, México, during the 2010–11 wheat season.

Cultivar	Complementary irrigations			
	Two	Three	Four	Average
Huatabampo Oro C2009	6.099	5.900	4.333	5.433
CIRNO C2008	6.067	4.600	4.133	4.933
Movas C2009	5.433	5.367	3.867	4.889
Samayoa C2004	4.800	4.700	3.100	4.200
Average	5.592	5.142	3.858	4.864

Grain protein. The wheat market in Mexico is almost 80% for human consumption and for the industry (CANIMOLT 2008), which requires wheat of high protein content for the regional and for the export market. Average grain protein content of cultivars with four CI was 13.66%, 14.09 with three, and 14.59 two (Table 30). The application of four and three CI or the increment on the lamina caused a strong reduction in protein content in the grain. These results corroborate the report by Kouchaki et al. (1997), who indicated that the increase in the number of irrigations caused a grain yield increase and a reduction in the protein content. The highest grain protein content was shown by CIRNO C2008 with 14.98% when provided with two CI, followed by Movas C2009 with 14.52, and Huatabampo Oro C2009 and Samayoa C2004 both with 14.42.

Table 30. Grain protein content (%) of four durum wheat cultivars evaluated under different irrigation regimes at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, México, during the 2010–11 wheat season.

Cultivar	Complementary irrigations			
	Two	Three	Four	Average
CIRNO C2008	13.82	14.35	14.98	14.38
Movas C2009	13.71	13.96	14.52	14.06
Samayoa C2004	13.40	14.30	14.42	14.04
Huatabampo Oro C2009	13.71	13.76	14.42	13.96
Average	13.66	14.09	14.59	14.11

1,000-kernel weight. all cultivars showed consistently greater weight when they were provided with a greater irrigation lamina (Table 31). The average 1,000-kernel weight of all cultivars with four CI was 50.80 g, 46.98 with three, and 42.62 with two. The highest 1,000-kernel weight was shown by Huatabampo Oro C2009 with 53 g when provided with four CI, followed by CIRNO C2008 with 51.20, Movas C2009 with 50.73, and Samayoa C2004 with 48.27. The highest difference in 1,000-kernel weight between four and two CI was shown by Movas C2009 with 14.33 g, followed by CIRNO C2008 with 11.53.

Table 31. 1,000-kernel weight (g) of four durum wheat cultivars evaluated under different irrigation regimes at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, México, during the 2010–11 wheat season.

	Complementary irrigations			
Cultivar	**Two**	**Three**	**Four**	**Average**
Huatabampo Oro C2009	53.00	50.27	48.93	50.73
Samayoa C2004	48.27	46.47	45.47	46.73
CIRNO C2008	51.20	48.07	39.67	46.31
Movas C2009	50.73	43.13	36.40	43.42
Average	50.80	46.98	42.62	46.80

Semolina pigment. The accumulation of carotenoids confers the yellow color to flour and semolina. This trait is negative for the bread-making industry because the consumer prefers white bread, but on the contrary, it is a very important characteristic for the pasta-making industry, because this feature is sought by the consumer. Genetic studies have demonstrated that the yellow color of the endosperm is highly heritable (65–90%) (Cenci et al. 2004). With the exception of Huatabampo Oro C2009, the other cultivars showed greater pigment b value when provided with two CI (Table 32). The b value remained at 27 for Huatabampo Oro C2009. The average b value of all cultivars with four CI was 24.59, 25.07 with three, and 25.80 with two. The highest b value was shown by Samayoa C2004 with 28.27 when provided with two CI, followed by Huatabampo Oro C2009 with 27.43 when provided with four CI, CIRNO C2008 with 24.63 and Movas C2009 with 22.90 when provided with two CI. In general, cultivars did not show great differences when managed with different irrigation lamina. Movas C2009 consistently showed lower pigment values with all irrigation lamina.

Table 32. Semonlina pigment (Minolta b value) of four durum wheat cultivars evaluated under different irrigation regimes at the Norman E. Borlaug Experimental Station in the Yaqui Valley, Sonora, México, during the 2010–11 wheat season.

	Complementary irrigations			
Cultivar	**Two**	**Three**	**Four**	**Average**
Huatabampo Oro C2009	27.43	27.10	27.40	27.31
Samayoa C2004	26.23	27.20	28.27	27.23
CIRNO C2008	23.90	23.90	24.63	24.14
Movas C2009	22.40	22.07	22.90	22.46
Average	24.99	25.07	25.80	25.29

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