Legreve A and Duveiller E. 2010. Preventing potential disease and pest epidemics under a changing climate. *In:* Climate change and crop production, Series: CABI Climate Change,. v. 1 (Reynolds MP, Ed). CABI, Oxfordshire, UK. p. 50-70.

Lepoint P, Renard ME, Legreve A, Duveiller E, and Maraite H. 2010. Genetic diversity of the mating type and toxin production genes in *Pyrenophora tritici-repentis*. Phytopathology 100:474-483.

Mergoum M, Glover KD, Anderson JA, Gigax D, Berg J, Singh PK, Ransom JK, and Isakson PJ. 2010. Agronomic performance of transgenic roundup® ready spring wheat in the north central plains of USA. Agron J 102:1462-1467.

Neupane AC, Sharma RC, Duveiller E, and Shrestha SM. 2010. Sources of *Cochliobolus sativus* inoculum causing spot blotch under warm wheat growing conditions in South Asia. Cereal Res Commun 38(4):541-549.

Rosyara UR, Subedi S, Duveiller E, and Sharma RC. 2010. Photochemical efficiency and SPAD value as indirect selection criteria for combined selection of spot blotch and terminal heat stress in wheat. J Phytopathology 158:813-821.

Rosyara UR, Subedi S, Duveiller E, and Sharma RC. 2010. The effect of spot blotch and heat stress on variation of canopy temperature depression, chlorophyll fluorescence and chlorophyll content of hexaploid wheat genotypes. Euphytica 174:377-390.

Savary S, Duveiller E, Forbes G, Willocquet L, and Hijmans R. 2010. Food security and plant disease epidemics: Modeling potential epidemics on rice, potato, and wheat. Phytopathology 100:S156.

Schlang N and Duveiller E. 2010. Current approaches and utilization of new screening techniques for evaluation of FHB resistance at CIMMYT. *In:* Proc 11th Eur Fusarium Sem, 20-23 Sept. 2010, IHAR, Radzikow, Poland. Book of Abstracts, pp. 87-88.

Singh PK, Duveiller E, Crossa J, and Singh RP. 2010. Breeding for resistance to tan spot of wheat at CIMMYT, Mexico (Plenary Talk). *In:* Proc 8th Internat Wheat Conf, 1-4 June, 2010, St Petersburg, Russian Federation.

Singh RP, Huerta-Espino J, Bhavani S, Herrera-Foessel SA, Singh D, Singh PK, Velu G, Mason RE, Jin Y, and Njau P. 2010. Non-race specific resistance to rusts in CIMMYT spring wheats: breeding advances (Invited Speaker). In: Borlaug Global Rust Initiative 2010 Technical Workshop. 30-31 May, 2010, St. Petersburg, Russian Federation.

Singh PK, Singh RP, Duveiller E, Mergoum M, Adhikari TB, and Elias EM. 2010. Genetics of wheat-*Pyrenophora tritici-repentis* interactions. Euphytica 171:1-13.

Singh PK, Mergoum M, Adhikari TB, Shah T, Ghavami F, and Kianian SF. 2010. Genetic and molecular analysis of tan spot of wheat resistance effective against *Pyrenophora tritici-repentis* races 2 and 5. Mol Breed 25:369-379.

Singh PK, Mergoum M, Adhikari TB, Ghavami F, and Kianian SF. 2010. Genetics and mapping of resistance to spore inoculum and culture filtrate of *Phaeosphaeria nodorum* in spring wheat line ND 735. Crop Prot (*Online*) DOI:10.1016/j.cropro.2010.09.010.

Singh RP, Huerta-Espino J, Bhavani S, Herrera-Foessel SA, Singh D, Singh PK, Velu G, Mason RE, Jin Y, and Njau P. 2010. Non-race specific resistance to rusts in CIMMYT spring wheats: breeding advances. Euphytica (*Online*). DOI 10.1007/s10681-010-0322-9.

Velu G, Singh RP, Huerta-Espino J, Peña RJ, Ortiz-Monasterio I, Bhavani S, Herrera-Foessel SA, and Singh PK. 2010. Breeding for enhanced grain-zinc and iron concentrations in CIMMYT spring bread wheat germplasm. *In:* Proc 8th Internat Wheat Conf, 1-4 June, 2010, St Petersburg, Russian Federation.

Velu G, Singh RP, Huerta-Espino J, Ortiz-Monasterio I, Peña RJ, Herrera-Foessel SA, and Singh PK. 2010. Breeding progress and G x E interaction for grain Zn concentration in CIMMYT spring wheat germplasm. *In:* Proc 1st Global Conf on Biofortification, 9-11 November, 2010, Washington DC, USA.

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Identification of genes of agricultural importance in bread wheats for the state of Sonora, Mexico.

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Introduction. Southern Sonora is characterized by having a large area sown with irrigated wheat every year. Farmers, through their economic contributions to agricultural research, demand wheats with high yield potential, quality, and resistance to diseases; however, leaf rust caused by *Puccinia triticina* Eriks. is an endemic and highly destructive disease in this region. The pathogen has the capacity to mutate (Rajaram and Campos 1974), and multiply rapidly (Singh et al. 2001). A severe infection reduces the photosynthetic area, there is water loss which debilitates the radical system, plant growth stops, kernels are shriveled, and the plant may die (Roelfs 1978). This disease is the main cause of cultivar replacement and the increase in the use of fungicides making the wheat crop less profitable. A more recent threat to the wheat crop is the TTKS or Ug99, a variant of stem rust. Although there is no records of its presence in the American continent, research has been intensified looking for resistance genes for this and other diseases.

Materials and methods. Experimental plots were established at the Norman E. Borlaug Experimental Station, which belongs to the Northwest Regional Research Center of the National Institute for Forestry, Agriculture and Livestock Research (CENEB-CIRNO-INIFAP), during the crop season autuman–winter 2009–10. The station is located in block 910 of the Yaqui Valley at 27°22' latitude north and 109°55' longitude west, 37 masl. Seven commercial cultivars released by INIFAP were evaluated (Onavas F2009, Tepahui F2009, Villa Juarez F2009, Navojoa M2007, Roelfs F2007, Kronstad F2004, and Tacupeto F2001), as well as 29 advanced lines from the CIMMYT bread wheat breeding program, for the presence of genes *Lr34*, *Sr22*, *Sr24*, *Sr26*, and *Sr36* (Table 1, continued on p. 60). DNA was extracted from plant material following the method described by Saghai-Maroof et al. (1984). PCR reactions were carried out in the Biotechnology Laboratory of CIMMYT in El Batan, state of Mexico. For gene *Lr34*, a final volume of 9.5 μl were used for the reaction (6.5 μl of RED Sigma TAQ, 1.5 μl of primer CSLV34, and 1.5 μl of L34PLUS), and 5 μl of DNA for genes *Sr22* (CFA2123), *Sr24* (Sr24#12), *Sr26* (Sr26#43), and *Sr36* (STM773-2). PCR products obtained were separated by horizontal electrophoresis in 2.5 and 3.0% agarose gels, depending on the gene; separation was in TBE1X buffer, then stained with ethidium bromide, visualized under UV light, and documented with digital photography.

Table 1. Bread wheat advanced lines and commercial cultivars evaluated during the 2009–10 crop season in the Yaqui Valley, Sonora, Mexico.

#	Cultivar/line	Selection history
1	Chewink	CGSS03B00074T-099Y-099M-099Y-099M-6WGY-0B-3B
2	Navojoa M2007	CMSS97Y04045S-040Y-050M-040SY-030M-14SY-010M-0Y
3	Villa Juarez F2009	CGSS01B00062T-099Y-099M-099M-099Y-099M-12Y-0B
4	KEA/TAN/4/TSH/3/KAL/BB//TQFN/5/ Pavon/6/SW89.3064/7/Sokoll	CMSS04Y00153S-099Y-099ZTM-099Y-099M-5WGY-0B
5	Becard	CGSS01B00063T-099Y-099M-099M-099Y-099M-33WGY-0B
6	Onavas F2009	CGSS01B00069T-099Y-099M-099M-099Y-099M-20Y-0B
7	PBW343//CAR422/ANA/3/ELVIRA	CMSS02M00409S-030M-1Y-0M-040Y-10ZTB-0Y-02B-0Y
8	Babax/LR42//Babax*2/4/SNI/TRAP#1/3/ KAUZ*2/TRAP//KAUZ	CGSS01B00045T-099Y-099M-099M-099Y-099M-26Y-0B
9	Roelfs F2007	CGSS00B00169T-099TOPY-099M-099Y-099M-9CEL-0B
10	Whear/Kronstad F2004	CGSS04Y00106S-099Y-099M-099Y-099M-9WGY-0B
11	Whear/Kronstad F2004	CGSS04Y00106S-099Y-099M-099Y-099M-3WGY-0B
12	Tepahui F2009	CMSW00WM00150S-040M-040Y-030M-030ZLM-3ZTY-0M
13	Babax/LR42//Babax/3/ER2000	CMSA01Y00176S-040P0Y-040M-030ZTM-040SY-24M-0Y-0SY
14	TOBA97/Pastor	CMSS97M05756S-040M-020Y-030M-015Y-3M-1Y-3M-0Y
15	PFAU/Milan/3/Babax/LR42//Babax	CMSS02M00056S-030M-28Y-0M-040Y-25ZTB-0Y-01B-0Y
16	Babax/LR42//Babax/3/ER2000	CMSA01Y00176S-040P0Y-040M-030ZTM-040SY-30M-0Y-0SY
17	Whear/Sokoll	CMSS04Y00201S-099Y-099ZTM-099Y-099M-11WGY-0B
18	Thelin/2*WBLL1	CGSS02Y00079T-099B-099B-099Y-099M-6Y-0B
19	TC870344/GUI//Temporalera M 87/ AGR/3/2*WBLL1	CMSA01Y00725T-040M-040P0Y-040M-030ZTM-040SY-10M-0Y-0SY
20	Waxwing*2/Kronstad F2004	CGSS04Y00020T-099M-099Y-099ZTM-099Y-099M-3WGY-0B
21	ROLF07/YANAC//Tacupeto F2001/Brambling	CGSS05B00121T-099TOPY-099M-099NJ-4WGY-0B
22	Kronstad F2004	CMSS92Y01425T-16Y-010M-010Y-010Y-1M-0Y-50EY-0Y
23	PFAU/MILAN//TROST/3/ PBW65/2*SERI.1B	CMSS04M01426S-0TOPY-099ZTM-099Y-099M-3RGY-0B

Table 1. Bread wheat advanced lines and commercial cultivars evaluated during the 2009–10 crop season in the Yaqui Valley, Sonora, Mexico.

#	Cultivar/line	Selection history
24	Tacupeto F2001	CGSS95B00016F-099Y-099B-099Y-099B-15Y-0B
25	CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/WH576/7/WH 542/8/Waxwing	CMSS04Y00364S-099Y-099ZTM-099Y-099M-2WGY-0B
26	CHRZ//BOW/CROW/3/WBLL1/4/CROC_1/*Ae. tauschii* (213)//PGO	CMSA02Y00509T-040M-040P0Y-040ZTM-040SY-040M-6ZTY-03M-0Y
27	Reolfs F2007	CGSS00B00169T-099TOPY-099M-099Y-099M-9CEL-0B
28	CHRZ//BOW/CROW/3/WBLL1/4/CROC_1/*Ae. tauschii* (213)//PGO	CMSA02Y00509T-040M-040P0Y-040ZTM-040SY-040M-15ZTY-03M-0Y
29	OR 9437534/Sokoll//Sokoll	CMSA04Y01203T-040ZTM-040ZTY-040ZTM-040SY-5ZTM-04Y-0B
30	Sokoll/Excalibur	CMSA03Y00010S-3P0Y-0ZTY-010M-010SY-010M-9ZTY-03B-0Y
31	Babax/LR42//Babax/3/ER2000	CMSA01Y00176S-040P0Y-040M-030ZTM-040SY-28M-0Y-0SY
32	CHEN/*Ae. tauschii* (TAUS)//BCN/3/BAV92/4/Berkut	CMSA02Y00104S-040P0Y-040ZTM-040SY-040M-8ZTY-02M-0Y
33	Sokol//Sunco/2*Pastor	CMSA04Y00294S-040ZTY-040ZTM-040SY-8ZTM-01Y-0B
34	CROC_1/*Ae. tauschii* (213)//PGO/3/CMH81.38/2*KAUZ/4/Berkut	CMSA02Y00059S-040P0Y-040ZTM-040SY-040M-5ZTY-01M-0Y
35	VEE/MJI//2*TUI/3/Pastor/4/Berkut	CMSA01M00075S-040P0M-030ZTM-040SY-040M-13Y-0M-0SY
36	MTRWA92.161/Prinia/5/SERI*3//RL6010/4*YR/3/Pastor/4/BAV92	CMSA02M00279S-040ZTM-040ZTY-040ZTM-040SY-2ZTM-03Y-0B
37	KRONSTAD F2004	CMSS92Y01425T-16Y-010M-010Y-010Y-1M-0Y-50EY-0Y
38	CROC_1/*Ae. tauschii* (213)//PGO/3/CMH81.38/2*KAUZ/4/Berkut	CMSA02Y00059S-040P0Y-040ZTM-040SY-040M-7ZTY-03M-0Y
39	Tacupeto F2001	CGSS95B00016F-099Y-099B-099Y-099B-15Y-0B
40	Navojoa M2007	CMSS97Y04045S-040Y-050M-040SY-030M-14SY-010M-0Y

Results. Amplification by PCR indicated that out of the 40 genotypes analyzed (taking into consideration the replication of three cultivars), only three were positive for gen *Lr34* (Fig. 1), which were 'KEA/TAN/4/TSH/3/KAL/BB//TQFN/5/Pavon/6/SW89.3064/7/Sokoll', 'Sokoll / Excalibur', and cultivar Tepahui F2009. Genes such as *Lr34* for nonspecific races called durable resistance or slow-rusting, are expressed in adult plants, and are related to grain yield decrease (Singh and Huerta 1997); on the other hand, other studies indicate that *Lr34* contributes to a significant increment in protein content (Labuschagne et al. 2002). However, the statistical analysis did not show a correlation with yield and protein due to the low number of positives in the amplification of *Lr34*. Gen SR22 was originally identified in the diploid wheat *T. monococcum* subsp. *monococcum* (Gerechter-Amitai 1971) and transferred to tetraploid and hexaploid wheat through interspecific hybridizations. Gene *Sr22* is effective against Ug99, however, its presence has a negative effect on

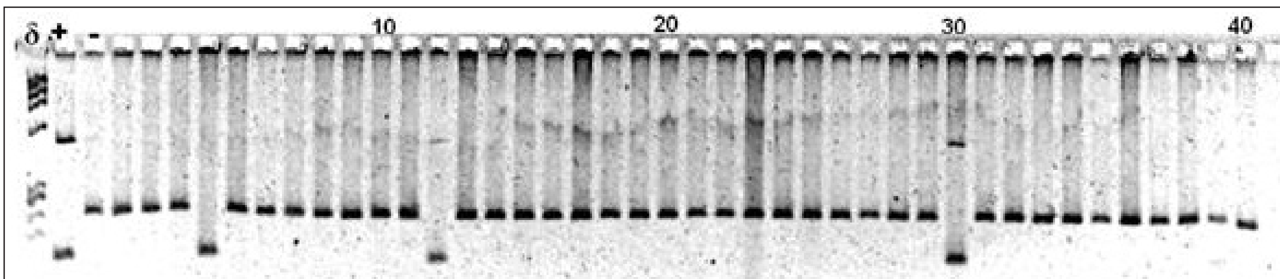

Fig. 1. PCR amplification for gene *Lr34* in bread wheat lines and commercial cultivars evaluated furing the 2009–10 crop season in the Yaqi Valley, Sonora, Mexico. See Table 1 (pp. 59-60) for line identification.

grain yield. Based on results from PCR, the presence of *Sr22* was detected in Chewink, Becard, 'Thelin / 2*WBLL1', 'ROLF07/Yanac//TACUPETOF2001/Brambling', and in the cultivars Tacupeto F2001, Roelfs F2007, and Onavas F2009 (Fig. 2). Gene *Sr24* confers resistance to most races of stem rust, including virulent race Ug99 (TTKSK) established in Eastern Africa and Ethiopia. Resistance of this gene during devastating epidemics of stem rust have been reported in South Africa and India (Mago et al. 2005), however, *Sr24* is not effective against a more recent variant of Ug99, designated as TTKST. Materials that possess *Sr24* are 'Babax/LR42//Babax/3/ER2000', 'TOBA97/Pastor', 'PFAU/Milan/3/Babax/LR42//Babax', 'Sokoll/Excalibur', and 'Sokoll//Sunco/2*Pastor' (Fig. 3). *Sr26* was not found in the materials evaluated; this gene is one of the few with major resistance effective against race TTKSK and its derivatives TTKST, making it ideal for pyramiding resistance. Gene *Sr36* was not found during analysis of the materials evaluated. Previous studies indicate that *Sr36* confers resistance to Ug99, however, other variants of Ug99 affect this gene, so, it is recommended to use it to pyramid with other genes. Genetic resistance is considered the most important strategy for disease management in wheat. This resistance implies an aggregated value to materials when they are released as cultivars; therefore, different breeding programs invest a great deal of their resources to disease management, as a response to a possible event that might occur.

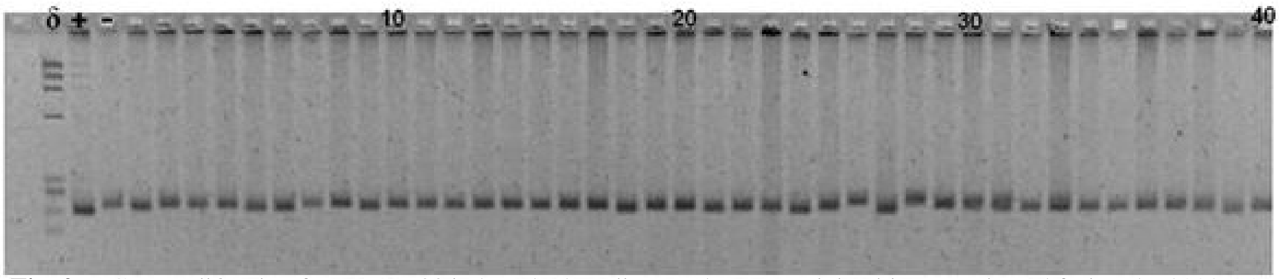

Fig. 2. PCR amplification for gene *Sr22* in bread wheat lines and commercial cultivars evaluated furing the 2009–10 crop season in the Yaqi Valley, Sonora, Mexico. See Table 1 (pp. 59-60) for line identification.

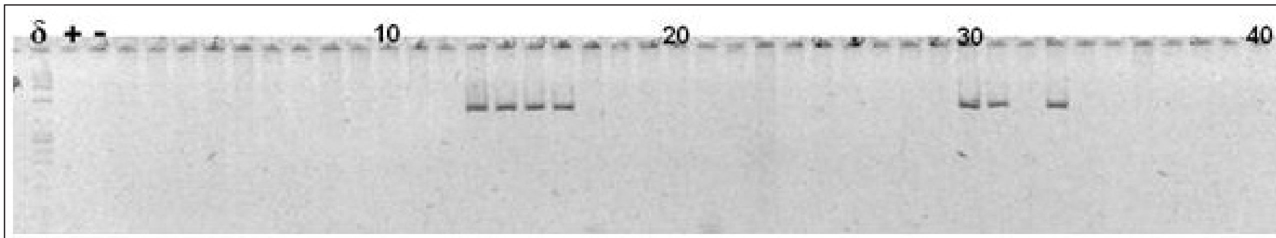

Fig. 3. PCR amplification for gene *Sr24* in bread wheat lines and commercial cultivars evaluated furing the 2009–10 crop season in the Yaqi Valley, Sonora, Mexico. See Table 1 (pp. 59-60) for line identification.

References.

Gerechter-Amitai ZK, Wahl I, Vardi A, and Zohary D. 1971. Transfer of stem rust seedling resistance from wild diploid einkorn to tetraploid durum wheat by means of a triploid hybrid bridge. Euphytica 2:281-285.

Labuschagne MT, Pretorius ZA, and Grobbelaar B. 2002. The influence of leaf rust resistance genes *Lr29*, *Lr34*, *Lr35* and *Lr37* on breadmaking quality in wheat. Euphytica 124:65-70.

Mago R, Bariana HS, Dundas IS, Spielmeyer W, Lawrence GJ, Pryor AJ, and Ellis JG. 2005. Development of PCR markers for the selection of wheat stem rust resistance genes *Sr24* and *Sr26* in diverse wheat germplasm. Theor Appl Genet 111:496-504.

Rajaram S and Campos A. 1974. Epidemiology of wheat rust in the Western Hemisphere. CIMMYT Res Bull. 27:1-27.

Roelfs AP. 1978. Estimated losses caused by rust in small grain cereals in the United States, 1918-1976. Misc Publ US Dept Agric 1363. 1-85 pp.

Saghai-Maroof MA, Soliman K, Jorgensen RA, and Allard RW. 1984. Ribosomal DNA spacer-length polymorphisms in barley: mendelian inheritance, chromosomal location, andpopulation dynamics. Proc Natl Acad Sci USA 81:8014-8018.

Singh RP and Huerta-Espino J. 1997. Effect of leaf rust resistance gene *Lr34* on grain yield and agronomic traits of spring wheat. Crop Science 37:390-395.

Singh RP, Huerta–Espino J, and William M. 2001. Resistencia durable a roya de la hoja y roya amarilla: genética y mejoramiento en el CIMMYT. In: Seminario Internacional: Estrategias y metodologías utilizadas en el mejoramiento de trigo. INIA CIMMYT. INIA La Estanzuela, Colonia Uruguay. 80 pp. (In Spanish).

Effect of tillage methods on wheat grain yield and fuel consumption in the Yaqui, Valley Sonora, Mexico.

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Introduction. In The Yaqui Valley, Sonora, Mexico, about 100,000 ha are managed with equipment for conventional tillage, such as the plough or chisel. The cost of ploughing is $56.50 (11.5 exchange rate), chiseling $47.80, and disk harrowing $30.40. In terms of economic impact, more importance now is focused on the energy cost of agriculture, and agricultural diesel is the primary source of energy for tillage practices. The cost increase derived from tillage and the commitments of the Kyoto Protocol are factors that make more important the use of efficient practices, taking into consideration their influence on competitiveness in agricultural activities. Moreover, greenhouse gases produced by the use of fossil fuels, such as diesel, are one of the most significant environmental problems to be addressed; therefore, agricultural tractors ought to be used more efficiently (Pérez de Ciriza 2004). Deep tillage is considered essential for yield improvement but, with the exception of deep-rooted plants, many crops yield well with 12–15 cm of tillage (Prasad 1996). Reduced tillage in wheat requires less equipment and energy in comparison to conventional tillage, where the plow is used and yields are very similar; an economic advantage to the farmer (Gemtos et al. 1999). However, occasionally plowing is recommended for weed control (Turley et al. 2003). Our objective was to determine the effect of conventional tillage on wheat grain production and diesel consumption in a clay soil in the Yaqui Valley, Sonora, Mexico.

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 period 2006–07 to 2009–10. The station is located at 27°22' north latitude and 109°55' west longitude. The plot size was 5,760 m^2. The soil was prepared with secondary tillage based on the use of disk harrowing during five years (2002 to 2006), and from the sixth year on, the plot was divided into three subplots of 1,920 m^2. In each crop season, one of the subplots was prepared just with disk harrowing, another with disk harrowing followed by plowing, and the third with disk harrowing followed by chiseling. Plowing and chiseling were done to a depth of 40 cm and harrowing to 30 cm. In all cases, there was no summer rotation. Sowing date and agronomic management followed the recommendations of INIFAP for the region. During 2009 and 2010, diesel consumption was measured from the time the tractor started with a full tank in each treatment. Tractor brand and models for this study were New Holland 7610, John Deere 6403, and 4455.

Results. Plowing or chiseling did not produce a higher wheat grain yield as compared to disk harrowing in any of the years of evaluation (Table 2), which indicates that primary tillage based on plowing and chiseling only contributed to unnecessary increase in production costs. Only after four years of plowing, there was a slight increase in wheat grain yield; however, this increase was not sufficient to pay for the cost of this tillage method.

Table 2. Wheat grain yield (t/ha) obtained in conventional and secondary tillage in the Yaqui Valley, Sonora, Mexico, during four crop seasons.

	Crop season			
Tillage method	**2007**	**2008**	**2009**	**2010**
Plowing	6.450	7.643	6.460	8.220
Chiseling	6.710	7.660	6.888	7.663
Disk harrowing	6.724	8.085	7.758	8.013

Diesel consumption for each tillage method evaluated and tractors used are reported in Table 3. The levels of consumption were consistent with those reported by manufacturers; however, some variations are expected depending on the type of tractor, equipment size, and operating conditions such as depth, speed, size, and shape of the field. In this study, diesel consumption for the disk harrowing method was half the amount used with chiseling, and from 26 to 32% with plowing, depending on the type of tractor.

Table 3. Fuel consumption in conventional and secondary tillage methods in wheat in the Yaqui Valley, Sonora, Mexico (NH = New Holland; JD = John Deere tractors).

	2009 season		2010 season	
Tillage method	**L/ha**	**Tractor**	**L/ha**	**Tractor**
Plowing	24.3	NH 7610	32.2	JD 6403
Chiseling	16.3	JD 4455	16.4	JD 6403
Disk harrowing	7.9	NH 7610	8.5	NH 7610

Conclusions. The use of secondary tillage based on disk harrowing showed greater grain yield and profitability as compared with conventional tillage based on plowing or chiseling, under conditions of the Yaqui Valley, Sonora. The elimination of conventional tillage practices in wheat management, reduced diesel consumption and therefore the emission of greenhouse gases like carbon dioxide, without affecting grain yield.

References.

Gemtos TA, Galanopoulou S, and Kavalaris C. 1999. Wheat establishment after cotton with minimal tillage. Eur J Agron 8:137-147.

Pérez de Ciriza GJJ. 2004. Las Cumas y el ahorro energético. Navarra Agraria 147:11-18, http://dialnet.unirioja.es/servlet/articulo?codigo=1058671.

Prasad J. 1996. A comparison between a rotavator and conventional tillage equipment for wheat-soybean rotations on a vertisol in Central India. Soil & Tillage Res 37:191-199.

Turley DB, Phillips MC, Johnson P, Jones AE, and Chambers BJ. 2003. Long-term straw management effects on yields of sequential wheat (*Triticum aestivum* L.) crops in clay and silty clay loam soils in England. Soil & Tillage Res 71:59-69.

Evapotranspiration as a tool to predict quantity of water for wheat irrigation in the Yaqui Valley, Sonora, Mexico.

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Abstract. The evapotranspiration data used in this study was taken from the weather station network in the Yaqui Valley from 1 December, 2008, to 15 April, 2009, which corresponded to the wheat crop season. A database created in an Excel spreadsheet was imported into the Idrisi Kilimanjaro program, in order to convert it into a digital file, and through interpolation by the nearest neighboring method, the value of evapotranspiration was projected for the entire Yaqui Valley. The total value for the period of evaluation was 507 mm, however, evapotranspiration values were different throughout the whole region. Therefore, we concluded that it cannot be generalized the application of the same quantity of irrigation water to wheat across the Valley.

Introduction. Evapotranspiration is a key parameter for establishing the frequency and amount of water to be applied in an irrigated crop (Gurovich 1985). Evaporation is affected by climate, crop characteristics, and management (FAO 1998). In the Yaqui Valley, where wheat has occupied the largest area during the autumn-winter for many years, evapotranspiration is higher than precipitation, therefore, irrigation is necessary in order to make agriculture a profitable business (Cortés et al. 2009). The FAO (1998) recommends to study evapotranspiration in this type of regions to monitor crop water demand. The objective of this evaluation was to identify the evapotranspiration reference values in the Yaqui Valley through data recorded by the weather station network,and to determine whether these values could be used as a general criterion for irrigated wheat scheduling.

Materials and methods. Evapotranspiration data was taken from the weather station network in the Yaqui Valley, Sonora (PIEAES 2009) reported from 1 December, 2008, to 15 April, 2009. An Excel spreadsheet data base was created for each of the stations with their respective coordinates. The data base was saved as text (tab delimited) and imported into the Idrisi Kilimanjaro program, which created a map of points (known as vector) (Eastman 2003). The map was taken to a process of interpolation (nearest neighboring method), and it also was added the minimum and maximum limit in X, Y, of the Yaqui Valley, in order to get the map with the spatial distribution of evapotranspiration. The accumulated monthly evapotranspiration was used to make graphs.

Results and discussion. The evapotranspiration value is a very important tool for agricultural irrigation programming. However, it should be considered that even within the same region, values are not equal (Fig. 4, p. 64). The region where the highest evapotranspiration was recorded is located in block 2920 near the coast known as Siari Island. Evaporation is higher in coastal areas, because there is more area with bare soil and the evaporation from a soil under this condition is greater than a soil with a vegetative cover, because solar radiation is mitigated by the plant cover (Miliarum.com 2009).

During the wheat season of evaluation, the highest value of evapotranspiration (143 mm) occurred in March (Fig. 5). However, the evaluation covered just 15 days in April, so if sowing was carried out after the first day of December, the physiological crop cycle would be shifted so that more days would be considered in April for the purpose of this study. Therefore, the value of evapotranspiration would increase as this month reported a total value of 162 mm.

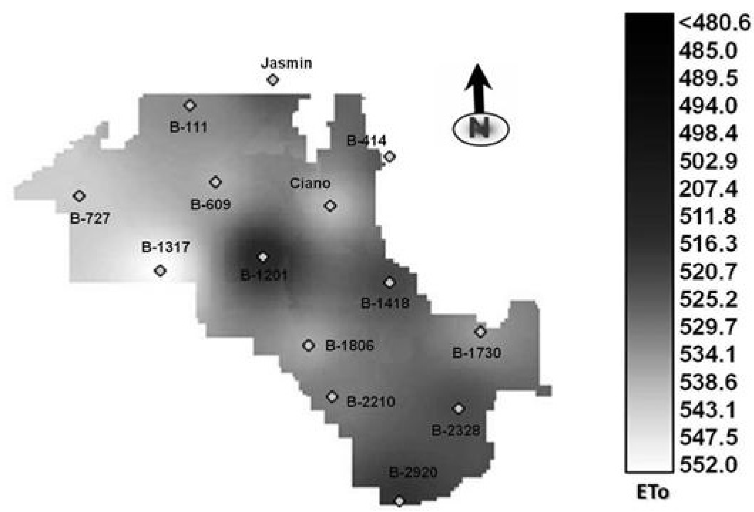

Fig. 4. Evapotranspiration (mm) recorded in the Yaqui Valley, Mexico, from Novermber 2008 to April 2009.

In irrigated agriculture, optimizing water management is necessary to increase the efficiency of using water resources through technical procedures, which provide the necessary information to irrigate a crop with an optimal frequency and timing (Singh and Chauman 1996). Although evapotranspiration is a useful tool for irrigation scheduling, it can not predict its application, therefore, it is necessary to incorporate other values such as rainfall, crop type and phenological stage, type and quality of soil, soil moisture, and water quality (FAO 1998).

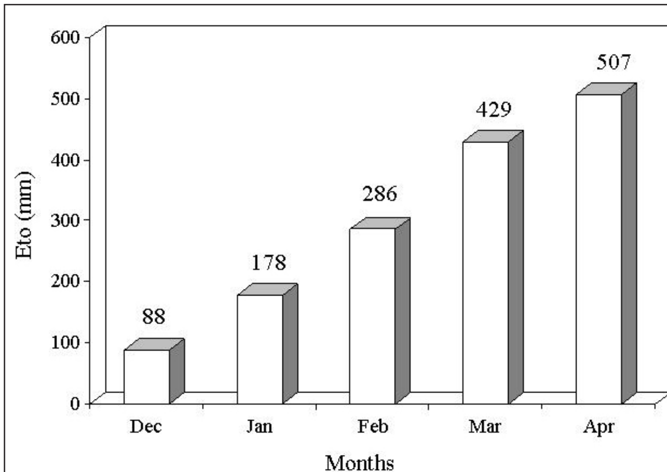

Fig. 5. Evapotranspiration (mm) accumulated from 1 December, 2008, to 15 April, 2009, in the Yaqui Valley, Mexico.

Conclusions. Results of the average spatial distribution of evapotranspiration for the Yaqui Valley are not the same across the region, so that the value of evapotranspiration can not be taken as a single criterion for irrigation scheduling.

References.

Cortés JJM, Troyo DE, Garatuza PJ, Ortiz AAA, and Rivera GM. 2009. Estrategias de mitigación ante el cambio climático, para la siembra de maíz de verano en el Valle del Yaqui, Sonora. *In:* Memoria de la XXI Semana Internacional de Agronomía en Gómez, Palacio, Durango, México. pp. 915-923.

Eastman JR. 2003. Idrisi Kilimanjaro, Guide to GIS and image processing. Clark Labs, Clark University, Worcester, MA, USA. 306 pp.

FAO. 1998. Evapotranspiración de cultivo, Guía para los requerimientos de agua en los cultivos. Estudio FAO 56 Riego y Drenaje. 300 pp.

Gurovich L. 1985. Fundamentos y diseños de sistemas de riego. Instituto Interamericano de Cooperación para la Agricultura, San José de Costa Rica. 433 pp (In Spanish).

Miliarum.com. Ingeniería Civil y Medio Ambiente. 2009. http://www.miliarium.com/Proyectos/ EstudiosHidrogeologicos/Memoria/Evapotranspiracion/Evaporacion.asp (In Spanish).

Patronato para la Investigación y Experimentación Agrícola del Estado de Sonora (PIEAES). 2009. Red de estaciones Climatológicas. http://pieaes.dyndns.org/~yaqui/ datos.php?dts=D (In Spanish).

Singh RV and Chauman HS. 1996. Irrigation scheduling in wheat under shallow water table conditions. *In:* Evapotranspiration and Irrigation Scheduling (Camp C, Sadler E, and Yoder R, Eds). ASAE, San Antonio, Texas, USA. pp. 103-108.

Effect of two biofertilizers on wheat grain yield in the Yaqui Valley, Sonora, Mexico.

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Abstract. The use of biofertilizers is a practice that has generated great interest in recent years. In this process, the seed is inoculated with beneficial microorganisms that exist naturally in soil, thus increasing its concentration in the rhizosphere. In general, their effects reside in promoting plant growth, developing tolerance to moderate stress, and increasing the efficiency of nutrient absorption. In this study, the simple effects and interactions between nitrogen, phosphorus, *Glomus arbuscular*, and *Azospirillum brasilense* as fertilizers on wheat yield were evaluated. Results from simple interactions indicated that plots with a nitrogen application produced greater grain yield than untreated ones, a phosporus application did not increase yield, and the highest yield was obtained with *Azospirillum* in plots treated with just biofertilizers. The highest grain yield from chemical fertilizer + biofertilizer interactions was obtained with the treatment nitrogen + the mixture *Glomus* + *Azospirillum*.

Introduction. Research and technology contributed to increase crop yields during the 1960s and 1970s, but the ecological price has been high (FAO 1995). The conventional agricultural model adopted by the middle of last century was based on a production system that was highly efficient, but dependent on elevated synthetic inputs (FIDA-RUTA-CATIE-FAO 2003), as well as the use of methods that caused soil erosion, salinization, pollution, desertification, and loss of biodiversity (FAO 1995). Twenty-first century agriculture in Mexico and the world will have to use science as an alternative to generate a revolution in agricultural production systems that overcome all areas (economy, productivity, and ecology) of the production systems used during the last century. Agriculture in Mexico is promoting the use of *Rhizobium etli* and *Azospirillum brasilense*, bacteria that fix atmospheric nitrogen in conjunction with the mycorrhizal fungus (*Glomus arbuscular*) are the basis for the production of the so-called biofertilizers (Morales 2007). Biofertilizer is a product that contains one or more soil microorganisms and can be applied to the seed or soil in order to increase their population; it can be associated directly or indirectly to the plant root system, encourage its interaction, and increase growth and reproduction of the host plant (Aguirre et al. 2010). These microorganism-biofertilizers are normally distributed in the soil, but its concentration is insufficient (between 103–104 cells/g of soil) to cause the desired beneficial effect on plants, hence, the importance of increasing their population size (between 106–108 cells/g of soil) (Dibut 2009). In addition, these biofertilizers are environmentally friendly and low cost.

In the Yaqui Valley, Sonora, fertilization represents the main cost of wheat production, which affects the profitability of this crop. In this study, the simple effects and interactions between nitrogen, phosphorus, *Glomus*, and *Azospirillum*, as fertilizers on wheat yield were evaluated.

Materials and methods. The study was carried out at the Norman E. Borlaug Experimental Station (INIFAP) during the 2008–09 crop season. A factorial experimental design was used with the following factors: A) nitrogen rates 0 and 200 kg/ha as urea; B) phosphorus rates 0 and 52 kg P_2O_5/ha in the form of monoammonium phosphate; and C) biofertilizers control, *Glomus*, *Azospirillum*, and *Glomus* + *Azospirillum*. Experimental plots were 4.8 m^2 and treatments had three replications. Mean comparisons used Tukey's test (0.05). Planting date and agronomic management of durum wheat cultivar Samayoa C2004 followed recommendations of INIFAP for the region.

Results and discussion. The single addition of 200 kg/ha of nitrogen produced on average 756 kg of grain/ha more than the control (Table 4); a greater yield was obtained in plots without phosphorus application than in treated plots. In the case of biofertilizers, the highest grain yield was obtained with the application of *Azospirillum*, which was 699 kg/ha more than the con-

Table 4. Effect of biofertilizers, phosphorus, and nitrogen on grain yield of the durum wheat cultivar Samayoa C2004 during the 2008–09 crop season at the Norman E. Borlaug Experimental Station. Grain yield was evaluated at 12% humidity content. Tukey (p = 0.05) = 0.172.

	Grain yield (t/ha)				
	Rate of fertilizer N–P (kg/ha)				
Treatment	0–0	0–52	200–0	200–52	Average
Control	6.560	6.385	7.773	7.594	7.078 a
Glomus	6.895	6.573	7.600	7.452	7.130 a
Azospirillum	7.259	6.918	7.287	7.738	7.301 a
Glomus + *Azospirillum*	6.760	6.381	7.839	7.273	7.063 a
Average	6.869 b	6.564 b	7.625 a	7.514 a	

trol. The interaction that produced the highest yield was the mixture of *Glomus* + *Azospirillum* with a N–P rate of 200–0, respectively; however, the difference with respect to the control was only 66 kg/ha.

A greater response to biofertilizers was observed in treatments without chemical application (Fig. 6), plots treated with *Azospirillum* showed a yield increase of 9.6%, *Glomus* 4.9%, and 3.0% with the mixture *Glomus* + *Azospirillum*. Plots treated with nitrogen and the mixture *Glomus* + *Azospirillum* showed a yield increase of 0.8%, whereas those treated with nitrogen, phosphorus, and *Azospirillum* 1.9%. This type of response can be attributed the lack of fixation of atmospheric nitrogen by the biofertilizers, because nitrogen availability in the soil is high and therefore the symbiotic process is not established (Aguirre et al. 2010).

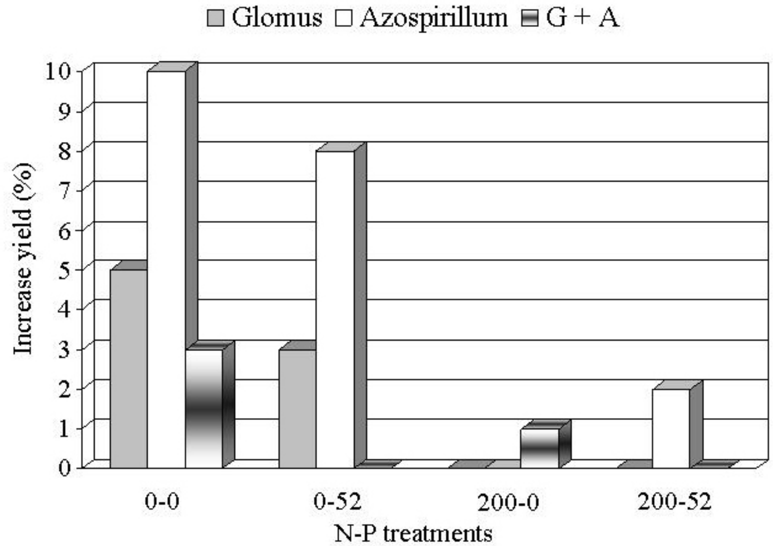

Fig. 6. Wheat yield increase by interactions between biofertilizers and urea (N) and monoammonium phosphate (P).

References.

Aguirre MJF, Irizar GMB, Durán PA, Grajeda CO, Peña del RM de los A, Loredo OC, and Gutiérrez BA. 2010. Los Biofertilizantes microbianos: alternativa para la agricultura en México, Segunda edición. Folleto Técnico No. 5, Centro de Investigación Regional Pacífico-Sur-INIFAP, Campo Experimental Rosario Izapa. Tuxtla Chico, Chiapas, México. 68 pp (In Spanish).

Dibut AB. 2009. Biofertilizantes como insumos en la agricultura sostenible. Editorial Universitaria, La Habana, Cuba, 113 pp (In Spanish).

FAO Corporate Document repository. 1995. The Green Revolution Revisited: New Needs, New Strategies. CERES No 154. (http://www.fao.org/docrep/V6640S/v6640s00.htm# Contents (December 2010).

FIDA-RUTA-CATIE-FAO. 2003. El concepto de certificación orgánica, conceptos básicos. Agricultura Orgánica: una herramienta para el desarrollo rural sostenible y la reducción de la pobreza. Memorias del Taller celebrado en Turrialba, Costa Rica. 115 pp (In Spanish).

Morales IM. 2007. Los biofertilizantes. Una alternativa productiva, económica y sustentable. Revista de la Procuraduría Agraria, Estudios Agrarios. No. 36. México, D.F. pp. 93-119 (In Spanish).

Characteristics and descriptions of phenotypic components of Huatabampo Oro C2009, a new durum wheat cultivar for southern Sonora, Mexico.

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

Introduction. Before the 1990s, bread wheat was the dominant class in northwest Mexico. In the state of Sonora, bread wheat occupied more than 50% of the area dedicated to wheat from the agricultural season of 1983–84 to 1993–94. However, many wheat producers have turned to durum wheat since the implementation of the domestic quarantine No. 16 (SARH, 1987), which limited the cultivation of bread wheat in fields where Karnal bunt had been detected at levels greater than 2% infected grains. Other important factors were that durum wheat showed greater grain yield than bread wheat and that, during that period of time, this crop did not have problems with leaf rust. In addition, there were opportunities for export of durum wheat.

Durum wheat was consolidated as the dominant class grown in Sonora beginning with the agricultural season 1994–95. Altar C84 was the most cultivated cultivar up to 2002–03, despite the fact that its resistance to leaf rust had already been overcome by a wheat race, which caused production losses during 2000–01 and 2001–02. Seed production of cultivar Júpare C2001 (Camacho-Casas et al. 2004) (resistant to leaf rust) through the collaborative project between the Mexican National Institute For Forestry, Agriculture, and Livestock Research (INIFAP) and the International Maize and Wheat Improvement Center (CIMMYT) with support by the farmer's union (PIEAES) of the Yaqui Valley, made it the most widely grown cultivar in southern Sonora from 2003–04 to 2008–09 (Table 5, Fuentes-Dávila et al. 2010a). Átil C2000, a high-yielding cultivar released in 2001 that became susceptible to leaf rust in 2001–02 (Figueroa-López et al. 2002), occupied 53,106.07 ha.

Table 5. Area (ha) grown with wheat during the 2008–09 agricultural season in southern Sonora, Mexico.

Cultivar	Area (ha)	% of total area
Durum wheat		
Júpare C2001	119,327.38	42.34
Átil C2000	53,106.07	18.84
Samayoa C2004	29,062.75	10.31
Banámichi C2004	13,652.76	4.84
Platinum	7,741.92	2.75
Aconchi C89	1,067.14	0.38
Altar C84	491.66	0.17
Rafi C97	478.20	0.17
Nácori C97	10.00	0.004
TOTAL	224,937.90	
Bread wheat		
Kronstad F2004	29,818.81	10.58
Tacupeto F2001	23,733.23	8.42
Tarachi F2000	1,615.60	0.57
Rayón F89	1,045.33	0.37
Abelino F2004	638.18	0.23
Navojoa M2007	9.60	0.003
Roelfs F2007	9.60	0.003
TOTAL	56,870.34	

Table 6. Area (ha) grown with wheat during the 2009–10 agricultural season in southern Sonora, Mexico.

Cultivar	Area (ha)	% of total 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	178,806	
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	

Júpare C2001 did not comply with the expected protein content in the grain and color, which are very important parameters of quality. In addition, new races of leaf rust present during 2008–09 overcame its resistance, and the area occupied with this cultivar decreased significantly in 2009–10, while that for Átil C2000 increased (Table 6, Fuentes-Dávila et al. 2011). Therefore, options for cultivars resistant to leaf rust for this region must be increased so that they contribute to help the long-lasting use by wheat producers in Sonora and in northwest Mexico and at the same meet current minimum quality requirements for export.

Pedigree, history selection and description of Huatabampo Oro C2009. After evaluation of grain yield since the 2007–08 agricultural season at the Yaqui Valley Experimental Station (renamed as Norman E. Borlaug Experimental Station, CENEB, since March 2010), we proposed the release the experimental durum wheat line 'GUAYACAN INIA/POMA_2//SNITAN/4/D86135/ACO89//PORRON_4/3/SNITAN' as cultivar Huatabampo Oro C2009 (Fuentes-Dávila et al. 2010b). Huatabampo Oro C2009 is a spring-type durum wheat cultivar that originated from hybridizations made in the Durum Wheat Breeding Program of CIMMYT. The cross number and history selection is CDSS02B00562S-0Y-0M-2Y-1M-04Y-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 7).

Table 7. Selection history and localities where cultivar Huatabampo Oro C2009 was evaluated. Yield trials at INIFAP were at the following plant dates: 15, 30 November, 15 December, and 1 January. For season, F–W = autumn–winter, S–S = spring–summer; For irrigation conditions, RR = regular rainfed, NI = normal irrigation.

Activity	Locality	Season	Irrigation conditions
Simple genetic cross	El Batan, Mexico	S–S / 2002	RR
F_1 generation	Cd. Obregon, Sonora	F–W / 2002–03	NI
F_2 generation	Cd. Obregon	F–W / 2003–04	NI
F_3 generation	Atizapan, Mexico	S–S / 2004	RR
F_4 generation	Cd. Obregon	F–W / 2004–05	NI
F_5 generation	Atizapan	S–S / 2005	RR
F_6 generation	Cd. Obregon	F–W / 2005–06	NI
F_7 generation yield trials by CIMMYT	El Batan	S–S / 2006	RR
Yield trials by INIFAP	Cd. Obregon	F–W / 2007–08	NI
		F–W / 2008–09	NI

The most important phenotypic characteristics of this cultivar, according to the International Union for the Protection of New Varieties of Plants (UPOV 1994), are given in Table 8 (p. 69). Cultivar Huatabampo Oro C2009 has an average of 78 days-to-heading with a range of 68 to 86. The cultivar has an average of 118 days to physiological maturity; however, the cycle may be shortened due to the lack of cold hours if planting is late, and may average 107 days when sowing is done at the end of December. Huatabampo Oro C2009 has an average height of 86 cm (Fig. 7), a maximum of 100 and minimum of 75. Plant growth habit is erect,and shows no or low frequency of recurved flag leaves.

Fig. 7. Huatabampo Oro C2009 durum wheat cultivar has an average height of 86 cm. Plants are erect and present no or very low frequency of recurved flag leaves.

Fig. 8. The grain shape of Huatabampo Oro C2009 durum wheat cultivar is elongated. In the dorsal view, pubescence is of medium length. Grain coloratin after treatment with phenol is absent or very light.

Spike shape in profile view is tapering, density is medium, and the length excluding awns is medium; awns are longer than the spikes. Spike glaucosity is strong, and awns are distributed the whole length and have a brown color. At maturity, spikes become pigmented. Glume shape is ovoid (spikelet in mid-third of spike), and hairiness on the external surface is present. The shape of the shoulder is rounded and the width is narrow; length of the beak is short and slightly curved. Grain shape is elongated (Fig. 8), and the length of brush hair in dorsal view is medium. Grain coloration when treated with phenol is absent or very light.

Acknowledgements. The authors wish to thank Dr. Karim Ammar, Head of the Durum Wheat Breeding Progam of the International Maize and Wheat Improvement Center (CIMMYT), for providing the advanced lines from which Huatabampo Oro C2009 originated.

References.

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

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

Table 8. Characteristics and description of phenotypic components of cultivar Huatabampo Oro C2009.

Structure	Characteristic	Description
Coleoptile	Anthocyanin coloration	Strong
First leaf	Anthocyanin coloration	Absent or very weak
Plant	Growth habit	Erect
	Frequency of plants with recurved flag leaves	Absent or very low
	Seasonal type	Spring
Spike	Time of emergence	Early
	Glaucosity	Strong
	Length (stem, ear and awns)	Medium
	Distribution of awns	Whole length
	Awns at tip of spike in relation to spike	Longer
	Length excluding awns	Medium
	Hairiness of margin of first rachis segment	Absent or very weak
	Color (at maturity)	Pigmented
	Shape in profile view	Tapering
	Density	Medium
Flag leaf	Glaucosity	Strong
	Glaucosity of blade	Weak
Awn	Anthocyanin coloration	Absent or very weak
	Color	Brown
Culm	Hairiness of uppermost node	Weak
	Glaucosity of neck	Medium
Lower glume	Shape (spikelet in mid-third of ear)	Ovoid
	Shape of shoulder	Rounded
	Shoulder width	Narrow
	Length of beak	Short
	Shape of beak	Slightly curved
	Hairiness on external surface	Present
Straw	Pith in cross section (half way between base of ear and stem node below)	Medium
Grain	Shape	Elongated
	Length of brushhair in dorsal view	Medium
	Coloration with phenol	Absent or very light

Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, Figueroa-López P, and Mendoza-Lugo JA. 2010a. CEVY ORO C2008, variedad de trigo cristalino para el noroeste de México. INIFAP, Centro de Investigación Regional del Noroeste, Campo Experimental Valle del Yaqui. Folleto Técnico No. 70. Cd. Obregón, Sonora, México. 28 pp. ISBN 978-607-425-307-8 (In Spanish).

Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, Figueroa-López P, and Mendoza-Lugo JA. 2010b. Huatabampo Oro C2009, nueva variedad de trigo cristalino para el noroeste de México con resistencia a roya de la hoja, alto potencial de rendimiento y alto contenido de pigmento. *In:* Memoria: Día del Agricultor 2010. Publicación Especial No. 17, INIFAP, CIRNO, Campo Experimental Norman E. Borlaug, Cd. Obregón, Sonora, México. P. 11 (In Spanish).

Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, Félix-Fuentes JL, Figueroa-López P, and Mendoza-Lugo JA. 2011. Huatabampo Oro C2009, variedad de trigo cristalino para el noroeste de México. INIFAP, Centro de Investigación Regional del Noroeste, Campo Experimental Valle del Yaqui, Cd. Obregón, Sonora, México. 28 pp (In Spanish).

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

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

Evaluation of grain yield of durum wheat cultivar Movas C2009.

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Introduction. Northwest Mexico, comprised by the states of Sonora, Sinaloa, and South and North Baja California, is the main wheat-producing region of Mexico with approximately 460,000 ha. In this region, wheat producers have a high demand for cultivars with important agronomic and quality characteristics; this, in turn, forces and maintains dynamic breeding programs that evaluate experimental germ plasm under different environments. Every crop season, wheat lines that show stability in main parameters, such as grain yield, quality, and disease resistance, are proposed for commercial release. After several crop seasons of evaluation, the experimental spring durum wheat CIMMYT line 'CMH83.2578/4/ D88059//WARD/ YAV79/3/ACO89/5/2*SOOTY_9/RASCON_37/6/1A.1D5+106/3*MOJO/3/AJAIA_12/ F3LOCAL (SEL.ETHIO. 135.85)//PLATA_13' was released as the commercial cultivar Movas C2009 (Félix-Fuentes et al. 2010). The cross number and selection history is CDSS02B00720S-0Y-0M-8Y-1M-04Y-0B. Evaluations of grain yield of Movas C2009 and the check cultivar Júpare C2001 are presented here.

Materials and methods. This study was at the Norman E. Borlaug Experimental Station (CENEB), which belongs to the Northwest Regional Research Center (CIRNO) of the Mexican National Institute for Forestry, Agriculture and Livestock Research (INIFAP), located in block 910 of the Yaqui Valley (27°22' latitude north, 109°55' longitude west, at 38 masl). Grain yield of Movas C2009 and the check cultivar Júpare C2001 was evaluated in four sowing dates with two and three complementary irrigations during the crop season autumn–winter 2008–09 (Table 9), with two and four complementary irrigations during the 2009–10 crop season (Table 10), and with drip irrigation (full irrigation) during crop seasons 2005–06 to 2008–09 on one sowing date (1 December), in block 810 at CIMMYT area. Experimental plots were 5-m long on two beds with two rows; space between beds was 0.8 m. Sowing dates were 15 November, 1 and 15 December, and 1 January, in dry clay soil using 100 kg of seed/ha. Fertilization consisted of 100 units of N (as urea) and 100 units of P (as monomonium phosphate) before seeding. The trial was irrigated right after seeding and later during the season complementary irrigations were provided as indicated (Tables 9 and 10). Also, 100 units of N were applied before the first complementary irrigation and 50 before the second. The herbicide Situi® xl at 25 g/ha of commercial product was sprayed over the trial 30 days after sowing. Statistical analysis was performed using SAS, and mean comparison with Tukey's test (0.05).

Table 9. Dates of application of the two and three complementary irrigations for cultivars Movas C2009 and Júpare C2001 at four sowing dates during the autumn–winter crop season 2008–09, at the Norman E. Borlaug Experimental Station in Sonora, Mexico (D = sowing, IR = two and three complementary irrigations, days after sowing are indicated in parentheses following date).

1D 2IR	6 January (50)	17 February (92)	
1D 3IR	31 December (44)	5 February (80)	2 March (107)
2D 2IR	23 January (53)	3 March (90)	
2D 3IR	14 January (44)	18 February (79)	12 March (103)
3D 2IR	6 February (53)	10 March (87)	
3D 3IR	28 February (44)	4 March (81)	27 March (104)
4D 2IR	26 February (56)	26 March (86)	
4D 3IR	13 February (43)	10 March (67)	3 April (93)

Table 10. Dates of application of the two and three complementary irrigations for cultivars Movas C2009 and Júpare C2001 at four sowing dates during the autumn–winter crop season 2009–10, at the Norman E. Borlaug Experimental Station in Sonora, Mexico (D = sowing, IR = two and three complementary irrigations, days after sowing are indicated in parentheses following date).

1D 2IR	6 January (50)	18 February (93)		
1D 4IR	24 December (37)	22 January (67)	18 February (93)	5 March (110)
2D 2IR	10 January (50)	3 March (90)		
2D 4IR	8 January (38)	9 February (70)	4 March (95)	19 March (110)
3D 2IR	10 February (57)	23 March (100)		
3D 4IR	22 January (38)	24 February (71)	19 March (96)	29 March (106)
4D 2IR	23 February (54)	26 March (91)		
4D 4IR	11 February (42)	17 March (76)	29 March (91)	15 April (107)

Results and discussion. The results of the evaluation during the 2008–09 crop season with two and three complementary irrigations indicated that the best sowing date, in order to obtain the highest yield potential of both cultivars Movas C2009 and Júpare C2001, was 1 December, which produced an average of 6.1 ton/ha, followed by the first sowing date with 5.8 (Table 11, p. 71). In general, sowing between 15 November and 1 December 1 allows the accumulation of more cold units (CU) that render better grain yield by wheat cultivars in the Yaqui Valley. Félix-Valencia et al. (2009)

reported that with an accumulation of 340 CU, wheat grain yield would be approximately 4,630 kg/ha, and for each increment of 100 CU, yield will increase by 330 kilograms. The average grain yield of Movas C2009 in four sowing dates with two complementary irrigations registered 0.7 ton/ha greater than that of the check cultivar Júpare C2001, although the highest yield difference was recorded in the 1st sowing date with 0.9 ton/ha (Table 12). The average difference in grain yield was 0.8 ton/ha in favor of Movas C2009 with three complementary irrigations, and the highest difference was recorded again in the 1st sowing date with 2.6 ton/ha. The effect generated by water stress on a wheat crop depends on the phenological stage of the plant, pre- and post-anthesis being the most susceptible to this abiotic factor. During the evaluation in 2008–09, the average temperature during this stage was 16°C (Fig. 9). Most of the assimilates that are stored in the grain are generated during grain filling, therefore, a preanthesis reserve does not increase with water stress, as expressed as the proportion of dry weight of the crop during anthesis, but increases as yield proportion.

Table 11. Average grain yield of cultivars Movas C2009 and Júpare C2001 with two and three complementary irrigations during autumn-winter 2008–09 crop season, at the Norman E. Borlaug Experimental Station in Sonora, Mexico. For grain yield, columns with the same letter are statistically similar (Tukey, p = 0.05).

Sowing date	Grain yield (ha)
1st	5.8 ab
2nd	6.1 a
3rd	5.4 bc
4th	5.1 c

Table 12. Grain yield of cultivars Movas C2009 and Júpare C2001 in four sowing dates with two and three complementary irrigations during autumn-winter 2008–09 crop season, at the Norman E. Borlaug Experimental Station in Sonora, Mexico.

Number / date of irrigation	Cultivar	
	Movas C2009	Júpare C2001
Two irrigations		
15 November	6.8	5.9
1 December	6.2	5.4
15 December	6.0	5.6
1 January	5.3	4.7
Average	6.1	5.4
Three irrigations		
15 November	6.7	4.1
1 December	7.0	5.9
15 December	4.4	5.7
1 January	5.4	4.8
Average	5.9	5.1

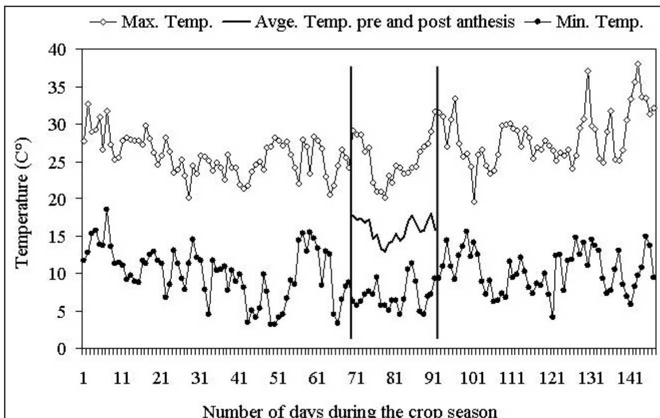

Fig. 9. Maximum, minimum, and average termerature during pre- and post-anthesis during the 2008–09 autumn-winter wheat season at the Norman E. Borlaug Experimental Station, Sonora, Mexico.

Table 13. Grain yield of cultivars Movas C2009 and Júpare C2001 in four sowing dates with two and four complementary irrigations during autumn-winter 2009–10 crop season, at the Norman E. Borlaug Experimental Station in Sonora, Mexico.

Number / date of irrigation	Cultivar	
	Movas C2009	Júpare C2001
Two irrigations		
15 November	6.6	6.6
1 December	7.1	6.5
15 December	6.4	5.5
1 January	6.3	5.3
Average	6.6	6.0
Four irrigations		
15 November	7.0	6.7
1 December	8.4	7.9
15 December	7.7	7.3
1 January	7.2	5.7
Average	7.6	6.9

Movas C2009 expressed its grain yield potential with four complementary irrigations during the 2009–10 crop season with an average of 7.6 ton/ha and a maximum of 8.4 in the second sowing date (Table 13). The yield difference ranged from 1 to 1.7 t/ha when Movas C2009 had two or three complementary irrigations during crop seasons 2008–09 and 2009–10. Movas C2009 showed a higher grain yield than that of Júpare C2001, with an average difference of 0.65 t/ha with two and four complementary irrigations during 2009–10.

The difference in grain yield for Movas C2009 between the average of the first two sowing dates and the average of the third and fourth ones, was 0.850 t/ha with two irrigations in 2008–09 and 0.500 in 2009–10 in favor of the first two sowing dates. The same trend was found in 2008–09 with three irrigations (1.950 t/ha difference) and in 2009–10 with four irrigations (0.250 t/ha). The low grain yield obtained on the dates considered as late (third and fourth) can be attributed to the high temperatures registered in the region when plants were in a vegetative stage and under this stress and represents a decrease in grain number. Fokar et al. (1998) and Savin et al. (1997) have reported significant variation in reduction of grain number and weight/spike under heat stress. The environmental stress may be different but most have a common effect on the hydric status of the plant (Bohnert et al. 1995).

Moderate water stress in a wheat plant causes a foliar reduction and, according to Abbate et al. (1997), anthesis takes place earlier than normal. Anthesis is delayed when a more severe stress occurs, being able to be modified on the day spike growth ends, however, Abbate and Cantarero (2001) reported that the duration of spike growth is not affected in a significant way by drought. The way in which a plant responds under such conditions depends on the species, because the mechanisms that confer tolerance to stress in many instances have evolved in a specific way for certain plant groups. Ortiz (2009) reported that only the first complementary irrigation can be delayed without affecting normal plant development; this irrigation is applied during tillering, 35 to 40 days after sowing. The second irrigation is applied during heading or flowering, 74 to 85 days after sowing, and can affect grain yield if delayed. The third and fourth irrigations are applied during the milky stage; the number of days to reach this stage is about 100 days, depending on the sowing date.

The grain yield of Movas C2009 and the check cultivar Júpare C2001 was similar during the different crop seasons of evaluation under drip irrigation (Fig. 10). Movas C2009 showed a greater grain yield than that of Júpare C2001 in a range of 0.14 to 0.28 t/ha during 2008–09 and 2006–07, respectively. The highest yield by Movas C2009 was 7.17 t/ha during crop seasons 2007–08 and 2005–06. Grain yield of Júpare C2001 was greater than that of Movas C2009, 0.170 to 0.290 t/ha, respectively. The highest yield by Júpare C2001 was 8.79 t/ha. Although this type of irrigation maintains a hydric status in the soil, which avoids water stress in the plant, environmental conditions vary from season to season and may have an effect on grain yield, as it was shown in contrasting crop seasons 2007–08 and 2008–09; grain yield difference in Movas C2009 in both seasons was 1.92 t/ha and 2.23 t/ha for Júpare C2001.

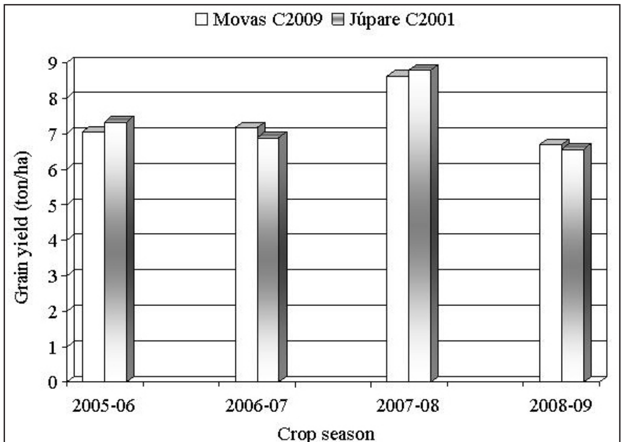

Fig. 10. Grain yield of cultivars Movas C2009 and Júpare C2001 under drip irrigation in block 810 at CIMMYT, during the autumn–winter 2005–06 to 2008–09 crop seasons in the Yaqui Valley, Sonora, Mexico.

References.

Abbate PE, Andrade FH, Culot JP, and Bindraban PS. 1997. Grain yield in wheat: Effects of radiation during spike growth period. Field Crops Res 54:245-257.

Abbate PE and Cantarero MG. 2001. Efecto del stress hídrico en trigo. *In:* EEA-INTA Balcarce-FCA, Univ Nac de Córdoba, V Congreso Nacional de trigo, Villa Carlos Paz, Córdoba (In Spanish).

Bohnert H, Nelson D, and Jensen R. 1995. Adaptation to environmental stresses. The Plant Cell 17:1099-1111.

Félix-Fuentes JL, Figueroa-López P, Fuentes-Dávila G, Valenzuela-Herrera V, Chávez-Villalba G, and Mendoza-Lugo JA. 2010. Movas C2009, nueva variedad de trigo cristalino con resistencia a roya del tallo. *In:* Memoria: Día del Agricultor 2010, Publicación Especial No. 17, INIFAP, CIRNO, Campo Experimental Norman E. Borlaug. Cd. Obregón, Sonora, México, p. 12 (In Spanish).

Félix-Valencia P, Ortíz-Enríquez JE, Fuentes-Dávila G, Quintana-Quiróz JG, and Grageda-Grageda J. 2009. Horas frío en relación al rendimiento de trigo: áreas de producción del estado de Sonora. *In:* Folleto Técnico No. 63, INIFAP, Centro de Investigación Regional del Noroeste, Campo Experimental Valle del Yaqui, Cd. Obregón, Sonora, México. 40 p.

Fokar M, Nguyen HT, and Blum A. 1998. Heat tolerance in spring wheat. I. Estimating cellular thermotolerance and its heritability. Euphytica 104:1-8.

Ortiz EJ. 2009. Seminario sobre tecnología para la producción de trigo. Centro de Investigación Regional del Noroeste, Campo Experimental Valle del Yaqui, Ciudad Obregón, Sonora, México. Pp. 70-71 (In Spanish).

Savin R, Stone PJ, Nicolas ME, and Wardlaw IF. 1997. Grain growth and malting quality of barley. 1. Effects of heat stress and moderately high temperature. Aus J Agric Res 48:615-624.

Effect of green manure crops and inoculation with Glomus intraradices on the quality and yield of wheat in the Yaqui Valley, Sonora, Mexico.

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Abstract. The effect of inoculating wheat seed with *Glomus intraradices* and the interaction with incorporation of maize (*Zea mays*), *Sesbania exaltata*, *Clitoria ternatea*, and sorghum (*Sorghum bicolor*) as green manure on wheat grain yield and quality was studied. Green manure treatments were compared with a control treatment that consisted of a fallow plot during the summer. A randomized complete block split-plot design with three replications was used to evaluate the treatments. Significant statistical differences were detected for grain yield, between green manure treatments, and the interaction between green manure and inoculation treatments. Grain yield was 7.690, 7.653, 7.590, 7.433, and 7.115 t/ha for *Clitoria*, sorghum, *Sesbania*, the control, and maize, respectively. There was a significant and positive interaction between *Glomus* and sorghum. The average grain yield of the biofertilizer treatment was 7.632 t/ha and 7.36 for the control. Wheat grain yield was 7.394 t/ha when green manure crops were established under irrigation, and 7.597 t/ha under rainfed conditions. For grain protein, the only significant difference was between irrigation treatments for green manure crops; a greater grain protein content (10.32%) was found in treatments where green manure crops were irrigated than those where green manure crops grew under rainfed conditions (9.67%). An average of 10.16% was obtained when seed was inoculated with *Glomus*, and 9.83% when it was not.

Introduction. The use of biological fertilizers is a practice of great interest in the last few years. The practice consists in inoculating seed with beneficial, natural soil microorganisms, increasing its concentration in the rhizosphere (Ferraris and Couretot 2006). Macias (2004) evaluated the use of biofertilizers in wheat during three crop seasons in northern Sinaloa, Mexico, and reported a 700 to 1,280 kg/ha increase with the use of the rhizobacterium *Azospirillum brasilense*, and from 300 to 820 kg/ha with the use of the fungal mycorrhiza *Glomus intraradices*, with respect to a control without nitrogen fertilization. In soil in the Yaqui Valley with 166 kg/ha of nitric nitrogen and 30 kg/ha of phosphorus available, Cortés (2000) did not find significant differences between the inoculation with *A. brasilense* and *G. intraradices*, fertilization with the formula NPK 200-52-0, and the absolute control; grain yield was 6.406, 6.696, and 6.128 t/ha, respectively. When *G. intraradices* or *A. brasilense* were used separately, grain yield was lower than that of the absolute control. Treatment with the rhizobacterium accumulated 28.3 kg/ha of additional nitrogen in relation to the absolute control. According to the information available, associations with *A. brasilense* are capable of fixing from 12 to 313 kg of nitrogen per ha per year depending on the conditions. In the case of the *Glomus* spp., it is generally accepted that this type of microorganisms increases the absorption of those nutrients that have very low mobility in the soil, such as phosphorus (Marschner 1986). Ferraris and Couretot (2006) reported an additive behavior without the interaction of inoculation by chemical fertilization in relation to yield, which coincides with the results obtained in northwest Mexico (Manjarrez 2002; Manjarrez et al. 2002; Macias 2002).

On the other hand, green manure is a type of cover crop grown primarily to add nutrients and organic matter to the soil. Typically, a green manure crop is grown for a specific period and then plowed under at the flowering stage and incorporated into the soil. In general, green manure crops are decomposed in and on the soil and are an ideal food-stuff for soil microorganisms (Kulmans and Vásquez 1999). They also increase the resistance to abrupt pH modification, provide substances such as phenols that contribute to plant respiration, and facilitate greater absorption of phosphorus and a better plant health (Guerrero 1993). Incorporation of green manure crops also is very important in crop rotation, because they increase production, incorporate residues, improve the soil cover, and interrupt the life cycles of pests, diseases, and weeds (Altieri and Nicholls 2000). The use of green manure is an option that will depend upon the objectives proposed, the area, weather conditions, and the main crop to be cultivated. In the case of the Yaqui Valley, it is possible to establish a green manure leguminous crop after wheat harvest, from July to September, in order to take advantage of the rainy period, by which the production of green material rises and nitrogen is delivered into the soil (García and Martínez 2011). This study evaluated the effect of inoculating wheat seed of durum cultivar CIRNO C2008 with the fungal mycorrhiza *G. intraradices* and the incorporation of green manure crops during the summer on grain yield and quality of the same cultivar.

Materials and methods. A study on the effect of green manure crops maize, *S. exaltata*, *C. ternatea*, sorghum, and a control treatment on wheat grain yield and quality was carried out at the Norman E. Borlaug Experimental Station during 2009–10. A randomized complete block split-plot design with three replications was used to evaluate treatments. The main plot corresponded to the green manure crops, the subplot to the irrigation treatments in the green manure crops, and the sub-subplot to seed inoculation with *G. intraradices*. The experimental plot consisted of four beds with two 50-m rows each with a separation of 0.80 m (160 m^2), whereas the experimental unit consisted of two 3-m long beds. Mean comparison was performed with Tukey's multiple range test (p = 0.01 and 0.05). Weed control was carried out manually.

Crops were established in the month of June and incorporated as green manure in September of 2009. They were irrigated for germination and, later, half the area of each plot was irrigated twice on 30 July and 14 August, and the other half was left under rainfed conditions. The durum wheat cultivar CIRNO C2008 was sown in humid soil on 7 December, 2009, in those plots where the green manure crops had previously been incorporated. The seed that was inoculated with *G. intraradices* was treated at the rate of 1.0 kg/ha/30 kg of seed. Three complementary furrow irrigations were applied 46, 75, and 94 days after sowing.

Results and discussion. Significant statistical differences were detected between the green manure treatments, and the interaction between green manure and inoculation treatments for grain yield. In all cases, greater yield was detected in plots where the seed was inoculated with *G. intraradices*, except when maize was established as green manure crop under rainfed conditions. Incorporation of leguminous crops grown under irrigation or rainfed conditions, produced greater wheat grain yield with or without inoculation with the mycorrhiza; this phenomenom was not observed with incorporation of gramineous crops. In the case of maize, its incorporation as green manure caused a reduction in grain yield under all the different conditions of evaluation, whereas sorghum caused a reduction in yield when CIRNO C2008 was not inoculated with *G. intraradices*, but it significantly increased when inoculated with the mycorrhiza. The treatment with the greatest average wheat grain yield (7.690 t/ha) was obtained with the incorporation of *C. ternatea*, whereas the lowest yield was obtained with incorporation of maize. The significant statistical interaction between green manure crops and inoculation treatments indicated that inoculation with *G. intraradices* produced greater wheat grain yield, only when the green manure crop incorporated was sorghum (Table 14).

Table 14. The effect of green manure crops and inoculation with *Glomus intraradices* on the grain yield (t/ha) of durum wheat cultivar CIRNO C2008. Inoculation x green manure crop, Tukey 0.05 = 0.536; green manure crop, Tukey 0.05 = 0.473.

Green manure crop	Without *G. intraradices*		With *G. intraradices*		Mean
	Irrigated	Rainfed	Irrigated	Rainfed	
Sorghum	7.127 a	7.167 a	8.153 b	8.163 b	7.653 a
Clitoria	7.523 a	7.700 a	7.587 a	7.950 a	7.690 a
Control	7.290 a	7.497 a	7.320 a	7.623 a	7.433 ab
Sesbania	7.363 a	7.660 a	7.367 a	7.970 a	7.590 ab
Maize	7.017 a	7.257 a	7.197 a	6.990 a	7.115 b
Mean	7.264 a	7.456 a	7.525 a	7.739 a	

For grain protein, the only significant difference was between irrigation treatments for green manure crops; there was a positive effect when crops were established under irrigation compared to rainfed conditions, because the percentage of protein increased (Table 15). During this first study, the grain yield obtained without fertilizers, including the control, indicated a great amount of residual nitrogen in the soil from trials carried out in previous wheat seasons. This also indicates the low efficiency of wheat for taking up this element. The greater wheat grain yield obtained when green manure crops were established under rainfed conditions could be explained by the fact that under this condition they produce a small amount of biomass, which in turn requires less time to be mineralized, and the nitrogen becomes immovable for a shorter period of time.

Table 15. The effect of green manure crops and inoculation with *Glomus intraradices* on the gran protein content (%) of the durum wheat cultivar CIRNO C2008. Inoculation x irrigation, Tukey 0.05 = 0.634.

Green manure crop	Without *G. intraradices*		With *G. intraradices*		Mean
	Irrigated	Rainfed	Irrigated	Rainfed	
Sorghum	9.94	9.71	10.12	10.07	9.96
Clitoria	10.12	9.25	10.45	10.08	9.97
Control	10.44	9.85	10.71	9.82	10.24
Sesbania	9.91	8.08	10.28	9.87	9.54
Maize	10.68	10.25	10.46	9.67	10.27
Mean	10.22 a	9.43 b	10.41 a	9.90 a	

Conclusions. The incorporation of leguminous crops as green manure helps to increase wheat grain yield. The use of mycorrhizae such as *G. intraradices* as seed inoculants must continue being investigated in order to determine the interactions that provide its optimum use on wheat, as well as the use of irrigation on the production of green manure.

References.

Altieri M and Nicholls CI. 2000. Agroecología. Teoría y práctica para una agricultura sustentable. 1a edición. *In:* Programa de la Naciones Unidas para el Medio Ambiente. México, D.F. 250 pp (In Spanish).

Cortés JJM. 2000. Efectividad biológica de Azospirillum y micorrizas como biofertilizantes para el suministro de NP en el cultivo de trigo. *In:* Informe técnico, Campo Experimental Valle del Yaqui-CIRNO-INIFAP, Cd. Obregón, Sonora, México. 9 pp (In Spanish).

Ferraris GN and Couretot LA. 2006. Evaluación de la inoculación con micorrizas en trigo bajo diferentes condiciones de fertilidad. Campaña 2005/06. *In:* Proyecto Regional Agrícola Desarrollo Rural INTA, Pergamino, República Argentina. 4 pp (In Spanish).

García CJS and Martínez MMR. 2011. Abonos Verdes, SAGARPA, Subsecretaria de Desarrollo Rural, Dirección General de Apoyos para el Desarrollo Rural. 8 pp. http://www.sagarpa.gob.mx/desarrolloRural/Documents/fichasCOUSSA/Abonos20%Verdes.pdf.

Guerrero J. 1993. Abonos Orgánicos. Tecnología para el Manejo Ecológico del suelo, RAAA, Lima, Perú. 90 pp (In Spanish).

Kulmans E and Vásquez D. 1999. Manual de Agricultura Ecológica. Una introducción a los principios básicos y su aplicación, Segunda edición. Grupo de Agricultura Orgánica, Asociación Cubana de Técnicos Agrícolas y Forestales, La Habana, Cuba. 157 pp (In Spanish).

Macias CJ. 2002. Evaluación de la biofertilizacion sobre la eficiencia de la fertilización con nitrógeno y fósforo en trigo. *In:* INIFAP-CIRNO-Campo Experimental Valle del Fuerte, Informe Técnico de Investigación, Los Mochis, Sinaloa. México (In Spanish).

Macias CJ. 2004. Informe global período enero 1994 a septiembre del 2004 proyecto 702: Nutrición del cultivo de trigo para la obtención de máximo rendimiento económico en el norte de Sinaloa. *In:* Campo Experimental Valle del Fuerte-CIRNO-INIFAP, Los Mochis, Sinaloa, México. 14 pp (In Spanish).

Manjarrez SJR. 2002. Validación de Azospirillum y micorrizas inoculados en la semilla de maíz en terrenos de un productor del Valle de Culiacán OI-2001-2002. *In:* Informe técnico, Campo Experimental Valle de Culiacán, CIRNO-INIFAP, Culiacán, Sinaloa, México. 5 pp (In Spanish).

Manjarrez SJR, Zamora J, and Velázquez MA. 2002. Validación de biofertilizantes en frijol en el Valle de Culiacán CE-VACU 2001-2002. *In:* Informe técnico, Campo Experimental Valle de Culiacán, CIRNO-INIFAP, Culiacán, Sinaloa, México. 6 p.

Marschner H. 1986. Mineral nutrition of higher plants. Institute of Plant Nutrition, Federal Republic of Germany., Academic Press., London, UK. 325 pp.

Evaluation of the biological effectiveness of BTN+ in rainfed wheat.

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Introduction. Intensive agricultural activities constantly deteriorate soil fertility, therefore, the theories of minimum tillage and the use of plant residues after harvest aim to partially reëstablishing the fertile condition of soils. Soil bacteria form part of this biological complex and have a key role in production of organic matter. The soil is an ecosystem that harbors five main groups of microorganisms: bacteria, actinomycetes, fungi, algae, and protozoa are considered inhabitants of the community. Bacteria have a wide biochemical diversity, so they are the most abundant of the groups. The bacterial population in the soil is large, although individuals measure a few micrometers in length.

The commercial product BTN+ is distributed and commercialized by the company GrowGreen Mexico, a subsidiary of Bio Tech Nutrients LLC, from Las Vegas, NV, U.S., and it is publicized as 'plant feed'. BTN+ is composed of carbon, hydrogen, oxygen, micronutrients, humic acid, fulvic acid, kelp, soil microbia, and enzymes. BTN+ utilizes energized carbon and bacteria, which according to the company, reduce salts in the soil and consequently reduce the soil electrical conductivity (EC), making nutrients available to the plant. Our objective was to evaluate the biological effectiveness of BTN+ on wheat cultivar Arandas F90 under rainfed conditions.

Materials and methods. A randomized complete block design with three treatments and six replication was used for this study, using bread wheat cultivar Arandas F90 under rainfed conditions. The study was carried out at the Centro-Altos de Jalisco Experimental Station, in Tepatitlan, Jalisco, Mexico, during the summer 2009. The soil type where the experiment was established was a loam-clay, pH 5.0–5.6, with a deficient organic matter content of 0.84–0.90%. The sowing date was 9 July, 2009, once the rainfall period was established. The treatments were as follows: 1. BTN+, 2. fertilization formula according to INIFAP`s technical recommendation, and 3. control without any fertilization (Table 16).

Table 16. Application of BTN+ and INIFAP recommended fertilizer formula on bread wheat cultivar Arandas F90 at the Centro-Altos de Jalisco Experimental Station, in Tepatitlan, Jalisco, Mexico, during summer 2009.

Treatment	Application	Date
BTN+	1st application: 41 L/ha of the liquid product, sprayed during sowing and on the seed.	9 July
	2nd application: 18 L/ha of Carbon Burst solution to the foliage.	14 August
	3rd application: 25 oz/ha (750 mL/ha) of fungicide Quadris two weeks after the 2nd application.	27 August
	4th application: two weeks later, 18 L/ha of Carbon Burst + 10 oz (300 mL) of Quadris.	14 September
INIFAP's technical recommendation (160-60-00)	The formula 80-60-00 was applied during sowing.	9 July
	Complementary application 80-00-00	9 August
Control	No fertilizer application.	

Foliar applications were made with a manual sprayer with a 20 L capacity and a Tee Jeet 8004 flat nozzle using a rate proportional to 200 L/ha of water. For the INIFAP treatment, the fertilization formula 180-60-00 was obtained by a physical mixture of 130.5 kg of the formula 18-46-00 + 145 kg of urea. The experimental plot was 8.0 m x 8.0 m with a proportional quantity of fertilizer (835.2 g + 928 g of 18-46-00 + urea/experimental plot (64 m^2), for the first application, and 1,248 g of urea for the second application. The experimental unit was 4.0 m x 4.0 m (16 m^2), according to the protocol.

The variables evaluated were days to flowering, days to physiological maturity, and grain yield (kg/ha). Harvest was carried out with a Pullman stationary thresher. Three soil samples were taken randomly during sowing; they were made up of six sub-samples obtained at 0–15 cm depth, which represents the arable horizon.

Results and discussion. Although the experiment was established once the rainfall period started, three weeks later there was a two week interval of drought, which somewhat effected the overall development of the wheat plant, with a consequent delay in the application of treatments. Because of this drought, weed control practices were limited, but days to flowering, heading, height, and physiological maturity were the same, because the same cultivar was used in all treatments; therefore, data on those parameters is not presented.

Table 17. Grain yield (kg/ha) of the bread wheat cultivar Arandas F90 under different nutrient treatments, at the Centro-Altos de Jalisco Experimental Station, in Tepatitlan, Jalisco, Mexico, during summer 2009.

	Replication					
Treatment	I	II	III	IV	V	VI
BTN+	3,687.50	4,859.38	4,218.75	3,765.63	2,468.75	3,750.00
INIFAP (160-60-00)	3,250.00	3,187.50	1,531.25	1,765.63	2,937.50	5,500.00
Control	937.50	3,250.00	2,187.50	2,000.00	2,000.00	1,875.00
Mean	2,625.00	3,765.63	2,645.83	2,510.42	2,468.75	3,708.33

Grain yield with BTN+ ranged from 2,468.75 to 4,859.38 kg/ha, INIFAP's treatment ranged from 1,531.25 to 5,500, and the control was 937.50 to 3,250.00 (Table 17). BTN+ showed the highest yield in four of the six replications; whereas INIFAP's treatment was highest in two, which included the overall highest yield of 5,500 kg/ha in the sixth replication. The yield average of the six replications ranged from 2,468.75 to 3,765.63 kg/ha. Average grain yield of the BTN+ treatment was 3,791.67 kg/ha (Fig. 11), but it was not statistically different from INIFAP's treatment (3,028.65) (Table 18, p. 77). Average yield of the control was 2,041.67 kg/ha, statistically different from the BTN+ treatment, but not from the INIFAP treatment. The grain yield of the control

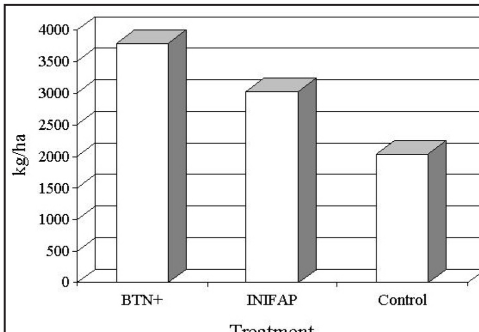

Fig. 11. Average grain yield of the bread wheat cultivar Arandas F90 under three different nutrient treatments at the Centro-Altos de Jalisco Experimental Station in Tepatitlan, Jalisco, Mexico, during summer 2009.

Table 18. Analysis of variance and mean comparison of grain yield (kg/ha) of the bread wheat cultivar Arandas F90 under different nutrient treatments at the Centro-Altos de Jalisco Experimental Station, in Tepatitlan, Jalisco, Mexico, during summer 2009.

SV	df	SS	MS	Fc	Pr>F	
Treatments	2	9,237,657.335	4,818,828.668	4.50	0.0403	*
Replications	5	5,589,586.046	1,117,917.209	1.09	0.4225	NS
Error	10	10,255,506.730	1,025,550.670			
Total	17	25,082,750.110				

Treatment	kg/ha	Significance
BTN+	3,791.67	a
INIFAP	3,028.65	ab
Control	2,041.67	b

indicated a normal soil fertility, either due to residue from the previous crop or other factors not considered in this study.

The study of the rhizosphere is complicated, because three important components converge: soil, plants, and microorganisms. Microorganisms are highly influenced by plant exudates, soil pH, and the physico-chemical condition. Exudates reported include carbohydrates of different types, nucleotides, flavonoids, enzymes, plant hormones, and aminoacids. These compounds are generated by the photosynthetic and metabolic activity of the plant (carbon compounds, H^+, inorganic ions, organic acids, or reducing agents). To conclude that BTN+ was the best treatment for wheat grain yield under rainfed conditions in Tepatlitan, Jalisco, Mexico would be biased, because it is not known its composition and the specific effects on the wheat plant or on the microorganisms present in the soil at the experimental station. Although, the average yield obtained with the BTN+ treatment was the highest, we do not know which factors or elements are induced or those that are inhibited or eliminated. On the other hand, the highest yield in this study was obtained with the INIFAP treatment (5,500 kg/ha).

Because several aspects were not included in this study, such as the pH behavior in the soil through time in the different treatments, the identification of population dynamics of the soil microorganisms more representative of the location, or the characterization with greater precision of the plant phenology under the different treatments, repeating the experiment taking into consideration the parameters that were not recorded in this study would be important.

References.

Bago B, Pfeffer PE, and Schachar-Hill Y. 2002. Metabolismo del Carbono y su Regulación en Hongos Formadores de Micorrizas Arbusculares. *In:* Memoria in extenso, Primera Reunión Iberoamericana y III Reunión Nacional de la Simbiosis Micorrízica (Olalde-Portugal V and Ferrera-Cerrato R, Eds). CINVESTAV-IPN, Irapuato, Guanajuato, México (In Spanish).

Bautista MN and Díaz GO. 2001. Bases para realizar estudios de efectividad biológica de plaguicidas. Colegio de Postgraduados, Montecillo, Texcoco, Edo de México, México. 148 pp (In Spanish).

Fuentes-Dávila G and Ferrera-Serrato R (Eds). 2007. Ecología de la Raíz. Sociedad Mexicana de Fitopatología, AC Cd. Obregón, Sonora, México. 153 pp (In Spanish).

Gómez KA and Gómez AA. 1984. Statistical procedures for agricultural research, 2nd Ed. John Wiley and Sons, Los Baños, Laguna, Philippines. 680 pp.