Corn Hybrids and Planting Dates Affect Yield Losses by *Helicoverpa zea* and *Spodoptera frugiperda* (Lepidoptera: Noctuidae) Feeding on Ears in Mexico[1]

L. A. Rodríguez-del-Bosque[2], M. A. Cantú-Almaguer and C. A. Reyes-Méndez

Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), Campo Experimental Río Bravo, Carretera Matamoros-Reynosa Km 61, Río Bravo, Tam. México 88900

J. Entomol. Sci. 47(2): 177-184 (April 2012)

Abstract The effect of hybrid and planting date on yield losses by the corn ear insects *Helicoverpa zea* (Boddie) and *Spodoptera frugiperda* (J.E. Smith) was determined in northeastern México, from 2006 - 2009. Eight corn hybrids (white and yellow) were planted each year during early January, February and March. Regardless of year, hybrid, or planting date, the most abundant ear insect was *H. zea* (61 - 99%). Yield losses varied greatly according to year, hybrid and planting date, with a maximum of 596 kg/ha, equivalent to 10.6% of total yield. Regarding planting dates, yield losses were lower in February, greater in March, and intermediate in January, probably attributed to host plant availability for ear insects in the region. An average of 74% greater yield loss was observed in yellow hybrids as compared with white hybrids for all planting dates, probably because of a differential grain hardness and husk wrap. According to current local value of corn grain and cost of insecticide and aerial application, insecticide treatment of lepidopterans attacking corn ears would have not been justified during this study.

Key Words maize, corn earworm, fall armyworm, kernel color, crop loss assessment

Field corn, *Zea mays* L., is the major crop in Mexico, where an average of 8 million ha are planted each year, about one-third of the country's cultivated land (SIAP 2011). Most area is planted with white corn, and production is destined mainly for human consumption, such as tortillas and other products. Corn yields are limited by a vast array of production systems, agronomic practices, weather conditions, and noxious organisms (Turrent 2008). More than 20 insect pests may attack the crop at different phenological stages, causing an average of 30% yield loss in Mexico (Rodríguez-del-Bosque and Marín 2008).

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith), and the corn earworm, *Helicoverpa zea* Boddie, are the most destructive insect pests of corn and other crops throughout the western hemisphere (Wiseman and Davis 1990, Gueldner et al. 1992, Buntin et al. 2001, Bergvinson 2005, Clark et al. 2007). The most common feeding site for *S. frugiperda* is the whorl in young plants; whereas, *H. zea* prefer to feed from ears. However, both insect pests can damage either the whorl and ear, depending on insect development and plant phenology (Buntin et al. 2001, Chilcutt et al. 2006). Feeding from ears by both species is important because of direct grain loss, quality decrease, and facilitation of mycotoxin-producing fungi invasion (Dowd 2003). In the

[1]Received 29 August 2011; accepted for publication 23 November 2011.

[2]Corresponding author (email: rodriguez.luis@inifap.gob.mx).

southeastern United States yield losses by *H. zea* range from 1.5 - 16.7% in field corn and can be as high as 50% in sweet corn (Wiseman 1999). In northeastern México yield losses by *H. zea* and *S. frugiperda* in field corn averaged 8%, and incidence of damaged ears was positively correlated to abundance of sap beetles (Coleoptera: Nitidulidae) and aflatoxin concentration (Rodríguez-del-Bosque 1996a, Rodríguez-del-Bosque et al. 1998). Corn production in this region has been reported as an important source for *H. zea* and *S. frugiperda* migration to northern latitudes into the U.S. (Wolf et al. 1990, Raulston et al. 1992).

The recommended window to plant corn in northern Tamaulipas, Mexico, is 20 January to 15 February (Rodríguez-del-Bosque et al. 2007). However, nearly 20% of the land is planted earlier or later than this period, which may decrease crop yield and increase incidence of insect pests and pathogenic diseases. During the past few years, growers have tended to plant earlier than 20 January because of a popular belief that winters were becoming warmer than in the past, which was not supported by weather historical data in this region (Silva et al. 2007). Earlier corn planting dates have higher risk of freeze (Rodríguez-del-Bosque et al. 2007).

A recent interest to plant yellow instead white corn hybrids in the region is based on an increasing demand by swine, poultry and snack-food industries. Preference to plant yellow compared with white corn has varied from 52 - 93% during the last years (Cantú et al. 2009, Reyes et al. 2009). However, preliminary observations showed yellow hybrids were more susceptible to ear insect pests and associated diseases than was white corn. The objective of this study was to determine the influence of

Table 1. Ear infestation, mean larvae per ear (± SE), and relative % of *H. zea* and *S. frugiperda* at milk stage in different planting dates. Río Bravo, Tam., México. 2006 - 2009.

Year	Planting date	% Ear infestation	Larvae/ear	Relative %	
				H. zea	*S. frugiperda*
2006	Jan	80.7	1.1 ± 0.1	91	8
	Feb	78.5	1.1 ± 0.1	89	11
	Mar	97.2	1.2 ± 0.1	88	12
2007	Jan	35.0	0.4 ± 0.1	93	7
	Feb	38.8	0.4 ± 0.1	90	10
	Mar	61.3	0.6 ± 0.1	88	12
2008	Jan	96.9	1.1 ± 0.1	99	1
	Feb	98.4	0.8 ± 0.1	90	10
	Mar	98.8	1.2 ± 0.1	61	39
2009	Jan	98.0	1.0 ± 0.1	98	2
	Feb	81.3	1.1 ± 0.1	88	12
	Mar	98.4	1.1 ± 0.1	87	13

hybrids (white or yellow) and planting date on yield losses by *H. zea* and *S. frugiperda* attacking corn ears in northern Tamaulipas, Mexico.

Materials and Methods

This study was conducted at the Campo Experimental INIFAP (Mexican Agricultural Research Service), near Río Bravo, Tamaulipas (25°57′N, 98°01′W) during the spring growing seasons of 2006 - 2009. Eight hybrids were evaluated in 3 planting dates during the first week of January, February, and March, which represented earlier, optimal, and later planting dates, respectively (Rodríguez-del-Bosque et al. 2007). The hybrids evaluated were 5 white corn (H-437, H-439, H-440, Pioneer 3,025, Asgrow Tigre) and 3 yellow corn (Pioneer 31G98, Garst 8,222, Dekalb 697) from 2006 - 2008; and 4 white corn (H-437, H-439, Asgrow Tigre, Asgrow Bisonte) and 4 yellow corn (Garst 8,285, Asgrow Tigre Y, Dekalb 2024, H-443A) during 2009. The experiment was conducted in a randomized complete block design with split-plot arrangement with 4 replications. The whole plot (A) included the planting dates and subplot (B) the 8 hybrids. Subplots were 3.2 m (4 rows) wide × 5 m long. No insecticide was applied, and other agronomic practices were according to local recommendations (INIFAP 2009). Ten plants per subplot in the 2 central rows were randomly sampled each at milk stage and harvest. At milk stage, ears were inspected for identification of *H. zea* and *S. frugiperda*. At harvest, number of damaged kernels per ear was counted, and their weight estimated by weighing the same number of adjacent undamaged kernels. All ears in the 2 central rows were hand shelled, and grain yield was estimated (converted to kg/ha at 12% moisture). Yield loss by ear insects was estimated in kg/ha and percentage of total yield. Yield loss (kg/ha) by ear insects was subjected to a two-way ANOVA, and means were compared using the LSD test ($P < 0.05$) (SAS Institute 2004).

Results and Discussion

Regardless of year, hybrid, or planting date, the most abundant ear insect was *H. zea*, ranging from 61 - 99% of all pest larvae identified (Table 1). Such dominance

Table 2. ANOVA testing effect of planting date and hybrid on yield loss by *H. zea* and *S. frugiperda* on corn ears. Río Bravo, Tam., México. 2006 - 2009.

		2006		2007		2008		2009	
Source	df	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Planting date (A)	2	40.7	0.001	21.0	0.003	76.4	0.001	11.5	0.048
Hybrid (B)	7	77.1	0.001	7.1	0.001	12.9	0.001	31.2	0.001
A x B	14	2.4	0.010	4.7	0.001	4.0	0.001	3.2	0.001
Error	63								
% C.V.		20.2		34.8		27.9		31.0	

Table 3. Average (± SE) yield losses in kg/ha and % of yield by *H. zea* and *S. frugiperda* on corn ears in different hybrids and planting dates. Río Bravo, Tam., México. 2006.

Hybrid	Kernel color	Jan Kg/ha %	Feb Kg/ha %	Mar Kg/ha %
Dekalb 697	Yellow	324 ± 28 a 5.4	357 ± 29 a 6.2	596 ± 31 a 10.6
Pioneer 31G98	Yellow	321 ± 42 a 5.0	310 ± 10 a 5.3	542 ± 34 a 10.5
G-8222	Yellow	177 ± 21 b 3.0	202 ± 9 b 4.0	398 ± 39 b 9.4
Asgrow Tigre	White	125 ± 44 bc 1.9	68 ± 10 cd 1.1	339 ± 37 b 5.7
H-439	White	83 ± 27 c 1.4	134 ± 16 bc 2.4	327 ± 22 b 7.4
Pioneer 3025	White	89 ± 21 c 1.5	119 ± 10 c 2.1	336 ± 15 b 6.0
H-440	White	125 ± 27 bc 3.3	86 ± 25 cd 2.4	208 ± 26 c 5.6
H-437	White	63 ± 30 c 1.1	33 ± 25 d 0.7	196 ± 25 c 3.8

Means within a column followed by the same lower case letter are not significantly different (LSD, $P = 0.05$).

of *H. zea* over *S. frugiperda* and other lepidopterans in corn ears has been previously reported in the region (Rodríguez-del-Bosque 1996a, Rodríguez-del-Bosque and Rosales-Robles 1992, Rodríguez-del-Bosque and Salinas-García 2008). Regardless of planting date, ear infestation was >78% and larval density >0.8 larvae/ear in 2006, 2008 and 2009 (Table 1). The lower infestations (35 - 61%) and larval densities (0.4 - 0.6 larvae/ear) in 2007 were probably a consequence of freezing temperatures on 5 March

Table 4. Average (± SE) yield losses in kg/ha and % of yield by *H. zea* and *S. frugiperda* on corn ears in different hybrids and planting dates. Río Bravo, Tam., México. 2007.

Hybrid	Kernel color	Jan Kg/ha %	Feb Kg/ha %	Mar Kg/ha %
Dekalb 697	Yellow	63 ± 21 b 0.8	49 ± 18 bc 0.6	188 ± 26 ab 2.9
Pioneer 31G98	Yellow	182 ± 21 a 3.0	109 ± 19 a 1.4	161 ± 12 abc 2.3
G-8222	Yellow	38 ± 3 b 0.7	90 ± 10 ab 1.4	172 ± 12 abc 3.0
Asgrow Tigre	White	33 ± 5 b 0.4	104 ± 21 a 1.2	137 ± 14 bcd 2.0
H-439	White	30 ± 9 b 0.4	80 ± 21 ab 1.2	176 ± 24 abc 3.2
Pioneer 3025	White	39 ± 18 b 0.5	48 ± 24 bc 0.6	190 ± 13 a 3.0
H-440	White	51 ± 18 b 1.1	42 ± 19 bc 0.6	89 ± 7 d 1.5
H-437	White	68 ± 15 b 0.9	21 ± 13 c 0.3	128 ± 11 cd 2.4

Means within a column followed by the same lower case letter are not significantly different (LSD, $P = 0.05$).

Table 5. Average (± SE) yield losses in kg/ha and % of yield by *H. zea* and *S. frugiperda* on corn ears in different hybrids and planting dates. Río Bravo, Tam., México. 2008.

		Jan	Feb	Mar
Hybrid	Kernel color	Kg/ha %	Kg/ha %	Kg/ha %
Dekalb 697	Yellow	335 ± 5 b 5.0	191 ± 20 a 2.2	411 ± 44 a 5.0
Pioneer 31G98	Yellow	240 ± 33 c 3.7	158 ± 38 ab 2.0	319 ± 26 b 3.6
G-8222	Yellow	444 ± 20 a 8.9	120 ± 19 abc 1.9	270 ± 28 bc 3.0
Asgrow Tigre	White	187 ± 11 c 4.0	110 ± 30 abc 1.3	208 ± 32 cd 2.3
H-439	White	330 ± 70 b 4.8	48 ± 16 c 0.6	223 ± 13 cd 3.0
Pioneer 3025	White	235 ± 16 c 4.9	83 ± 36 bc 0.9	324 ± 30 ab 3.8
H-440	White	265 ± 47 bc 8.5	33 ± 29 c 0.5	158 ± 13 d 2.9
H-437	White	193 ± 26 c 4.1	57 ± 10 c 0.7	158 ± 20 d 1.8

Means within a column followed by the same lower case letter are not significantly different (LSD, $P = 0.05$).

2007, which apparently diminished the overwintering populations (Rodríguez-del-Bosque 1996b).

The two-way ANOVA showed that the main effects and interaction between planting date and hybrid on yield losses by ear insects were significant ($P < 0.05$) in all years (Table 2). Yield losses varied greatly according to year, hybrid and planting date (Tables 3 - 6). In 2006, yield losses ranged from 33 - 596 kg/ha, equivalent to 0.7 and 10.6% of total yield, respectively (Table 3). In 2007, yield losses varied from 21 (0.3%)

Table 6. Average (± SE) yield losses in kg/ha and % of yield by *H. zea* and *S. frugiperda* on corn ears in different hybrids and planting dates. Río Bravo, Tam., México. 2009.

		Jan	Feb	Mar
Hybrid	Kernel color	Kg/ha %	Kg/ha %	Kg/ha %
Garst 8285	Yellow	291 ± 5 a 3.3	210 ± 10 a 2.5	191 ± 7 a 3.8
Asgrow Tigre Y	Yellow	78 ± 16 bc 0.9	125 ± 24 bc 1.5	155 ± 17 ab 3.9
Dekalb 2020Y	Yellow	63 ± 6 bc 0.7	84 ± 22 c 0.9	84 ± 19 cde 2.3
H-443A	Yellow	65 ± 19 bc 0.8	84 ± 9 c 1.0	54 ± 8 e 1.0
H-439	White	57 ± 19 bc 0.6	116 ± 10 bc 1.2	113 ± 26 bcd 2.4
Asgrow Tigre	White	101 ± 25 b 1.1	137 ± 17 b 1.5	131 ± 27 bc 2.5
Asgrow Bisonte	White	71 ± 15 bc 0.8	110 ± 9 bc 1.1	74 ± 9 de 1.5
H-437	White	36 ± 15 c 0.4	86 ± 21 bc 0.9	74 ± 20 de 1.8

Means within a column followed by the same lower case letter are not significantly different (LSD, $P = 0.05$).

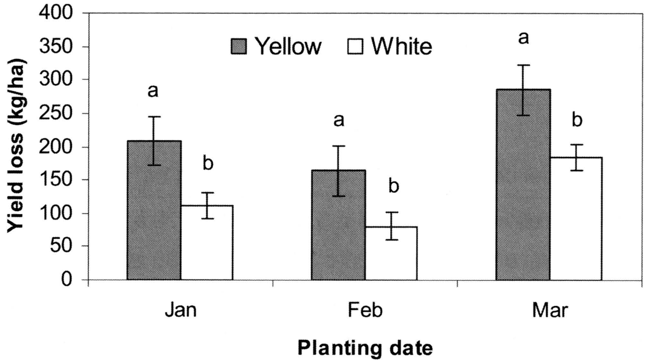

Fig. 1. Average (± SE) yield losses by *H. zea* and *S. frugiperda* on corn ears in hybrids with yellow or white kernels at different planting dates. Pooled data (2006 - 2009). Different letters in each planting date indicate means are significantly different as determined by LSD means separation procedures (*P* = 0.05). Río Bravo, Tam., México.

to 190 kg/ha (3.0%) (Table 4). In 2008, yield losses ranged from 33 (0.5%) to 444 kg/ha (8.9%) (Table 5). In 2009, yield losses varied from 36 (0.4%) to 291 kg/ha (3.3%) (Table 6).

Regarding planting dates, yield losses were lower in February, greater in March, and intermediate in January (Fig. 1). This is probably due to host plant availability for *H. zea* and *S. frugiperda* in the region. Most corn is planted during late January and early February. When the plantings reach the silking stage, moths have a large availability of host plants, diluting incidence and damage by larvae. Conversely, planting corn during early January and March is rare in the region, so host plants are scarce

Table 7. Average (± SE) yield losss (kg/ha) by *H. zea* and *S. frugiperda* on corn ears in different hybrids. Pooled data of planting dates (Jan, Feb, Mar) and years (2006 - 2009). Río Bravo, Tam., México.

Hybrid	Kernel color	Testing Years	Kg/ha
Dekalb 697	Yellow	3	279 ± 55 a
Pioneer 31G98	Yellow	3	260 ± 41 ab
Garst 8222	Yellow	3	212 ± 43 abc
Pioneer 3025	White	3	163 ± 36 bcd
H-439	White	4	143 ± 28 cd
Asgrow Tigre	White	4	140 ± 22 cd
H-440	White	3	117 ± 25 cd
H-437	White	4	93 ± 17 d

Means within a column followed by the same lower case letter are not significantly different (LSD, *P* = 0.05).

and moths tend to concentrate on those plants with a subsequent increase in abundance and yield losses by larvae.

Yield losses by ear insects was significantly greater in yellow hybrids than in white hybrids (Table 7, Fig. 1). An average of 74% greater yield loss was observed in yellow hybrids as compared with white hybrids for all planting dates (Fig. 1). There was a 3-fold difference in yield losses by ear insects between the hybrids with the highest (DK-697) and lowest (H-437) average loss (Table 7). Apparently, *H. zea* and *S. frugiperda* moths preferred to oviposit on yellow hybrids and/or larvae caused more damage to yellow hybrids, probably as a result of softer endosperm and comparatively loose husk. Yellow hybrids tested in this study were developed in the U.S. Corn Belt, and have fewer husk leaves and less husk tightness compared with the white hybrids developed for northeastern México. Husk characteristics are important for resistance to ear insects (Brewbaker and Kim 1979, Rector et al. 2002, Xinzhi et al. 2008).

Effective control of *H. zea* in corn requires at least 5 insecticide applications (Burkness et al. 2009). According to current local value of corn grain ($297 dlls/ton) and cost of insecticide and aerial application ($34 dlls/ha), the total cost of 5 insecticide applications ($170 dlls/ha) would be the equivalent of 572 kg/ha of corn. In only one of the 96 cases (combinations of years, hybrids, and plantings dates) cost of insecticide control was less than the value of yield loss: 596 kg/ha for Dekalb 697 planted late in 2006 (Table 3). However, the profit of insecticide application would be only 24 kg/ha ($7 dlls/ha) in that case, a highly risky economic operation for any grower. Therefore, insecticide treatment of lepidopterans attacking corn ears would have not been justified in any case in this study, corroborating reports for field corn elsewhere (Buntin et al. 2004).

References Cited

Bergvinson, D. J. 2005. *Heliothis/Helicoverpa* problem in the Americas: biology and management, pp. 7-37. In H. C. Sharma (ed.), *Heliothis/Helicoverpa* Management Emerging Trends and Staregies for Future Research. Science Publishers Inc., Plymouth, UK.

Brewbaker, J. L. and S. K. Kim. 1979. Inheritance of husk numbers and ears insect damage in maize. Crop Sci. 19: 32-36.

Buntin, G. D., R. D. Lee, D. M. Wilson and R. M. McPherson. 2001. Evaluation of YieldGard transgenic resistance for control of fall armyworm and corn earworm (Lepidoptera: Noctuidae) on corn. Fla. Entomol. 84: 37-42.

Buntin, G. D., J. N. All, R. D. Lee and D. M. Wilson. 2004. Plant-incorporated *Bacillus thuringiensis* resistance for control of fall armyworm and corn earworm (Lepiodoptera: Noctuidae) in corn. J. Econ. Entomol. 97: 1603-1611.

Burkness, E. C., T. L. Galvan and W. D. Hutchison. 2009. Optimizing *Helicoverpa zea* (Lepidoptera: Noctuidae) insecticidal efficacy in Minnesota sweet corn: a logistic regression to assess timing parameters. J. Econ. Entomol. 102: 677-684.

Cantú, M. A., C. A. Reyes, M. de la Garza and G. Vázquez. 2009. H-443A, Híbrido de maíz amarillo para el noreste de México. Folleto Técnico No. MX-0-310302-25-03-13-09-42. INIFAP, CIRNE, Campo Experimental Río Bravo. México.

Chilcutt, C. F., G. N. Odvody, J. C. Correa, J. Remmers and R. D. Parker. 2006. Decreased whorl and ear damage in nine mon810 *Bacillus thuringiensis* (Bt)-transgenic corn hybrids compared with their non-Bt counterparts. J. Econ. Entomol. 99: 2164-2170.

Clark, P. L., J. Molina-Ochoa, S. Martinelli, S. R. Skoda, D. J. Isenhour, D. J. Lee, J. T. Krumm and J. E. Foster. 2007. Population variation of the fall armyworm, *Spodoptera frugiperda,* in the Western Hemisphere. J. Insect Sci. 7: 1-10.

Dowd, P. F. 2003. Insect management to facilitate preharvest mycotoxin management. J. Toxicol. Toxin Rev. 22: 327-350.

Gueldner, R. C., M. E. Snook, N. W. Widstrom and B. R. Wiseman. 1992. TLC screen for maysin, chlorogenic acid, and other possible resistance factors to the fall armyworm and the corn earworm in *Zea mays.* J. Agric. Food Chem. 40: 1211-1213.

INIFAP. 2009. Paquete tecnológico para maíz de riego ciclo agrícola otoño-invierno. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Campo Experimental Río Bravo. www.inifapcirne.gob.mx/Biblioteca/Paquetes/110.pdf.

Raulston, J. R., S. D. Pair, J. Loera, A. N. Sparks, W. W. Wolf, J. K. Westbrook, G. P. Fitt and C. E. Rogers. 1992. *Helicoverpa zea* (Lepidoptera: Noctuidae) pupa production in fruiting com in Northeast Mexico and South Texas. Environ. Entomol. 21: 1393-1397.

Rector, B. G., M. E. Snook and N. W. Widstrom. 2002. Effect of husk characters on resistance to corn earworm (Lepidoptera: Noctuidae) in high-maysin maize populations. J. Econ. Entomol. 95: 1303-1307.

Reyes, C. A., M. A. Cantú, M. de la Garza, G. Vázquez and H. Córdoba. 2009. H-443A, Híbrido de maíz de grano amarillo para el noreste de México. Revista Fitotecnia Mexicana 32: 331-333.

Rodríguez-del-Bosque, L. A. 1996a. Impact of agronomic factors on aflatoxin contamination in preharvest field corn in northeastern Mexico. Plant Dis. 80: 988-993.

1996b. Survival of *Helicoverpa zea* (Lepidoptera: Noctuidae) larvae as affected by subfreezing temperatures in the subtropics. Southwest. Entomol. 21: 209-211.

Rodríguez-del-Bosque, L. A. and E. Rosales-Robles. 1992. Corn insect pests and pathogenic diseases in relationship to shattercane populations. Southwest. Entomologist 17: 210-214.

Rodríguez-del-Bosque, L. A. and A. Marín. 2008. Insectos plaga y su control, pp. 29-46. *In* C. de León and R. Rodríguez (eds.), El cultivo del maíz, Mundi-Prensa, México City, México.

Rodríguez-del-Bosque, L. A. and J. Salinas-García. 2008. Effects of tillage, irrigation and fertilization on infestation of corn ears by lepidopteran larvae and fungi in northeastern Mexico. J. Entomol. Sci. 43: 254-256.

Rodríguez-del-Bosque, L. A., C. A. Reyes-Méndez and M. A. Cantú-Almaguer. 2007. FESI-M: Modelo para determinar la fecha de siembra del maíz en el norte de Tamaulipas. Desplegable para Productores No. 28. INIFAP, Campo Experimental Río Bravo. Río Bravo, Tam., México.

Rodríguez-del-Bosque, L. A., J. Leos-Martínez and P. F. Dowd. 1998. Effect of ear wounding and cultural practices on abundance of *Carpophilus freemani* (Coleoptera: Nitidulidae) and other microcoleopterans in maize in northeastern Mexico. J. Econ. Entomol. 91: 796-801.

SAS Institute. 2004. STAT/SAS User's Guide, release 9.1 ed. SAS Institute, Cary, NC.

SIAP (Sistema de Información Agroalimentaria y Pesquera). 2011. Secretaría de Agricultura, Ganadería, Pesca y Alimentación (SAGARPA), México. www.siap.gob.mx.

Silva, M. M., G. Medina, J. A. Ruiz, V. Serrano, G. Díaz and M. A. Cano. 2007. Estadísticas climatológicas básicas del estado de Tamaulipas (período 1961-2003). Libro T.écnico No. 2. INIFAP, Campo Experimental Río Bravo. México.

Turrent, A. 2008. Producción bajo temporal, pp. 107-113. In C. de León and R. Rodríguez (eds.), El cultivo del maíz, Mundi-Prensa, México City, México.

Wiseman, B. R. 1999. Corn earworm, pp. 59-61. *In* K. L. Steffey, M. E. Rice, J. All, D. A. Andow. M. E. Gray, and J. W. Van Duyn (eds.), Handbook of corn insects. Entomological Society of America, Lanham, MD.

Wiseman, B. R. and F. M. Davis. 1990. Plant resistance to insects attacking corn and sorghum. Fla. Entomol. 73: 446-458.

Wolf, W. W., J. K. Westbrook, J. Raulston, S. D. Pair, S. E. Hobbs, J. R. Riley, P. J. Mason and R. J. V. Joyce. 1990. Recent airborne radar observations of migrant pests in the United States. Philos. Trans. R. Soc. Lond. B Biol. Sci. 328: 619-630., doi: 10.1098/rstb.1990.0132.

Xinzhi, N., M. D. Krakowsky, G. D. Buntin, B. G. Rector, G. Baozhu and M. E. Snook. 2008. Identification of multiple ear-colonizing insect and disease resistance in CIMMYT maize inbred lines with varying levels of silk maysin. J. Econ. Entomol. 101: 1455-1465.