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Corn borer resistance of maize races

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Corn borer (Lepidoptera: Noctuidae and Crambidae) resistance of the main races of maize from North America

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ABSTRACT Resistance to the European corn borer (*Ostrinia nubilalis* Hübner) and the pink stem borer (*Sesamia nonagrioides* Lefebvre) in maize (*Zea mays* L.) populations is partial, and more resistant populations are needed. The objective of this research was to compare resistance to corn borers of the main maize races from North America. Twenty open-pollinated maize populations belonging to the races Southern Dent, Corn Belt Dent, and Northern Flint, and three check populations, were evaluated under artificial infestation with *S. nonagrioides* and *O. nubilalis*. None of the populations had complete resistance. Northern Flint had the lowest yield under corn borer infestation, while Southern Dent had the highest yield, but also the largest damage. Corn Belt Dent had a shorter growing cycle and similar yield of infected plants than Southern Dent. The checks had intermediate yield and resistance and were not significantly different from Corn Belt Dent for any trait. The Southern Dent populations Tennessee Red Cob and White Dent (PI221885 and PI311232) could be used as sources of tolerance to corn borers, though they are not expected to provide great gains compared to the levels of tolerance already present in some Corn Belt Dent and European Flint populations and would require adaptation to short growing cycle. The Corn Belt Dent synthetic BS17 had the highest yield and general agronomic performance under corn borer infestation, along with Rustler and Silver King, and the European Flint composite EPS13.

Key words: *Zea mays*, *Sesamia nonagrioides*, *Ostrinia nubilalis*.

1 The main maize (*Zea mays* L.) pests in temperate areas are the corn borers European corn borer
2 (*Ostrinia nubilalis* Hübner) and pink stem borer (*Sesamia nonagrioides* Lefebvre). Due to the
3 wider distribution of *O. nubilalis* and to its presence in the U.S.A. several authors have searched
4 sources of resistance to *O. nubilalis* since the 1970s among many adapted and exotic maize
5 populations (Sullivan et al. 1974, Ordás et al. 1988, Reid et al. 1991). Efforts to find resistance to
6 *S. nonagrioides* among maize populations started in the 1990s focusing on field maize
7 populations (Malvar et al. 1993, 2004) and then on sweet maize populations (Velasco et al. 1999,
8 2002). Partial resistance to these pests has been identified in several open-pollinated populations,
9 but the levels of resistance identified so far are not high enough to guarantee insignificant yield
10 losses. Besides, several maize varieties present resistance to *O. nubilalis* first-generation, but the
11 progress on second-generation resistance has not been so successful (Guthrie and Barry 1987).

12 Most authors focus on damage either on leaf feeding by the first generation or on stalk
13 tunneling by the second generation of corn borers, but few studies have been published
14 considering yield under corn borer infestation (Anglade et al. 1996, Butrón et al. 1999).
15 According to these authors, performance of a genotype under infestation depends on several
16 traits, none of which estimates resistance or tolerance. Therefore, the trait to look at in breeding
17 programs facing corn borer damage is yield under infestation.

18 Since no complete resistance has been found or developed, searching for new sources of
19 resistance is still necessary. As this search moves apart from adapted germplasm, the new
20 sources of resistance found in evaluations under temperate conditions could be biased and the
21 potential use of those sources could be burdened by the lack of adaptation (Kim et al. 1989).
22 Consequently, the search of new sources of resistance should continue with populations adapted

1 to the target conditions. The objective of this research was to compare the resistance to corn
2 borers of the main maize races from North America.

3

MATERIAL AND METHODS

Twenty open-pollinated maize populations belonging to three North American maize races: Southern Dent, Corn Belt Dent, and Northern Flint, along with three checks, were evaluated under artificial infestation with *S. nonagrioides* and *O. nubilalis* eggs (Table 1). The choice of populations for these trials could influence the results because the Northern Flint and Southern Dent populations were chosen from the few samples of these races available at the North Central Regional Plant Introduction Station (NCRPIS) of Iowa, according to the classifications published by Doebley et al. (1986, 1988), while several Corn Belt Dent populations are selected populations or synthetics. Most Corn Belt Dent populations were chosen from the collection maintained at the Misión Biológica de Galicia (CSIC). The check population EPS12(T)C2 is a breeding population derived by three cycles of S₁ recurrent selection for yield from the composite EPS7 (Ordás 1991, Vales et al. 2001), previously identified as corn borer resistant (Malvar et al. 1993). EPS13 is a breeding population derived by three cycles of S₁ recurrent selection for yield from the composite EPS6 (Ordás 1991, Vales et al. 2001). Finally, EPS20 and EPS21 are a Reid and a non-Reid composite, respectively, made from inbred lines resistant to corn borers (Butrón et al. 2003).

The experiment consisted in a randomized complete block design with two replications that was carried out two years. *S. nonagrioides* and *O. nubilalis* evaluations were carried out in two adjacent trials. The number of environments and replications was restricted by the limited amount of seed available from the NCRPIS. Trials were sown the 18th of May in 2001 and the 15th of May in 2002 at Pontevedra (42° 30'N, 8° 46'W), a coastal location in northwestern Spain, approximately at the sea level. Natural infestation with *S. nonagrioides* is so high in Pontevedra

1 that often, at the end of the season, all maize plants are attacked (Malvar et al. 1993, Cordero et
2 al. 1998). Each experimental plot consisted of one row with 25 two-kernel hills. Rows were
3 spaced 0.80 m apart and hills in the row were spaced 0.21 m apart. After thinning, the final
4 density was approximately 60 000 plants ha⁻¹. At silking, 10 plants in each plot received a mass
5 of about 40 eggs of *S. nonagrioides* or *O. nubilalis*, depending on the trial. The rearing and
6 infestation methods followed usual procedures (Butrón et al. 1999). The infestation was made by
7 inserting a mass of about 40 eggs between the main ear and the stem in ten plants per plot, after
8 half of the plants in the plot have shown silks.

9 Days to pollen shedding, silking and stem lodging, were recorded at the entire plot.
10 Besides, on the infected plants, we recorded number of ears per plant, grain yield (Mg ha⁻¹),
11 grain moisture (g kg⁻¹), ear appearance of the main ear, taken on a subjective rate (1 = ear
12 completely damaged, 5 = average damage, 9 = no damage) (Malvar et al., 2004), tunnel length
13 (cm), proportion of stem damaged (%), and number of *S. nonagrioides* and *O. nubilalis* larvae
14 per plant. Individual and combined-over-years analyses of variance were computed. Fisher's
15 protected LSD was used for comparisons of populations' means, and least squares means for
16 comparisons of races. The sources of variation were years, replications, populations and the
17 appropriate interactions for analyses of populations; and the same model was used for the
18 analyses of races, except that populations was replaced by races. Years and replications were
19 considered as random factors. All analyses were made with the PROC GLM of the SAS package
20 (SAS Institute 2000).

RESULTS AND DISCUSSION

Races

The individual analyses of variance showed that races were significantly different under infestation with *O. nubilalis* in 2001 and in 2002 for all traits except stem tunnel length, proportion of stem damaged and ears per plant (data not shown). While under infestation with *S. nonagrioides*, races significantly differed in 2001, as well as in 2002, for all traits except proportion of stem damaged, number of *O. nubilalis* larvae per plant and ears per plant.

The combined-over-years analyses of variance showed significant differences among races under infestation with *O. nubilalis* for pollen shedding, silking, ear appearance and grain moisture (Table 2). The genotype $\times$ environment interaction was significant for grain yield and moisture, but interactions were of magnitude rather than rank (data not shown). Under infestation with *S. nonagrioides*, races significantly differed for all traits except proportion of stem damaged, number of *O. nubilalis* per plant and ears per plant, and the genotype $\times$ environment interaction was significant for ear appearance and grain moisture, although interactions were of magnitude rather than rank (data not shown). Given that the genotype $\times$ environment interaction did not affect the rank of races, the following comparisons will be based on the combined-over-year analyses of variance.

Southern Dent had later flowering time and more moisture than the other races (Table 3). When infested with *O. nubilalis*, Northern Flint had more lodging than Southern Dent and the checks, the worst ear appearance, less *S. nonagrioides* larvae per plant than Southern Dent, less *O. nubilalis* larvae per plant than Corn Belt Dent, and lower grain yield than Corn Belt Dent and Southern Dent. When infested with *S. nonagrioides*, Northern Flint had the highest lodging,

worse ear appearance than Southern Dent, the shortest tunnel length, fewer *S. nonagrioides* larvae than Southern Dent, and lower grain yield than Corn Belt Dent and Southern Dent.

None of the races had complete resistance, and differences on corn borer damage were more often significant when infested with *S. nonagrioides* than with *O. nubilalis*. Although comparisons could be biased for differences on growing cycle among races, Northern Flint had the poorest performance under corn borer infestation, while Southern Dent had the largest *S. nonagrioides* attack but the highest yield under corn borer infestation. Corn Belt Dent did not significantly differ from Southern Dent for yield under infestation, while it had a shorter growing cycle. These results agree with the relative contribution of Northern Flint and Southern Dent on the origin of Corn Belt Dent, according to Doebley et al. (1986, 1988), Corn Belt Dent comes from crosses among Northern Flint and Southern Dent, with larger contributions from the Southern Dent. Finally, the checks had intermediate performance and were not significantly different from Corn Belt Dent for any trait.

Populations

The combined-over-years analyses of variance showed that populations were significantly different under infestation with *O. nubilalis* for all traits except proportion of stem damaged, number of *O. nubilalis* and number of ears per plant (Table 2). The genotype $\times$ environment interaction was significant for pollen shedding, proportion of stem damaged, number of *S. nonagrioides* per plant, and grain yield (data not shown). Under infestation with *S. nonagrioides*, races significantly differed for all traits except for number of *O. nubilalis* larvae per plant and ears per plant, and the genotype $\times$ environment interaction was significant for Pollen shedding, silking, ear appearance, and grain moisture. The genotype $\times$ environment interaction slightly

affects the rank of populations, therefore, the following comparisons will be based on the combined analyses of variance, and the individual analyses will be commented when necessary.

Under *O. nubilalis* infestation, the best ear appearance was for BS17 along with other 15 populations that did not differ significantly (Table 4). Only EPS20, ASA and the five Northern Flints had significantly worse ear appearance than BS17. Assiniboine had the shortest tunnels, along with eight populations that did not differ significantly. Populations differed significantly for proportion of stem damaged in 2001, when BS17 had the shortest damage, along with other 13 populations that did not differ significantly. Five Corn Belt Dent populations were among those with the best ear appearance and shortest tunnels: BS17, BS5, Minnesota No. 13, Rustler, and Northwestern Dent. Grier and Davis (1980) and Butrón et al. (1998) found low correspondence between resistance to stem and ear attack by *S. nonagrioides* and *O. nubilalis*.

The Southern Dent populations were among those having the largest number of *S. nonagrioides* larvae and the lowest lodging; other populations with low lodging were BS17, EPS12(T)C2, EPS20, BSL(S)C6, EPS13, and BS5. The number of *S. nonagrioides* larvae was significantly different among populations in 2001 and in 2002, with large genotype $\times$ environment interaction that affected the rank of populations. Generally the Northern Flint and some Corn Belt Dent populations had few larvae, while the populations with more larvae were Southern Dent. Differences among populations for lodging and number of larvae could be biased by growing cycle because earlier populations were drier and, therefore, should be more affected by lodging, while larvae would have migrated to earlier populations.

Yield of infested plants was largest for the Southern Dent populations White Dent (PI221885 and PI311232) and Tennessee Red Cob. Other populations not differing significantly from these last two were White Dent (PI233001), BS17, BSL(S)C6, Rustler, EPS13,

1 EPS12(T)C2 and Silver King. In 2001, the Corn Belt Dent populations Silver King, BSL(S)C6
2 and BS17 did not differ significantly from the Southern Dent populations with the highest yield

3 Under infestation with *S. nonagrioides*, the best ear appearance was for White Dent
4 (PI311232 and PI233001), BS17, Gourdseed, Tennessee Red Cob, Rustler, and Smut Nose
5 (Table 5). All of them, except Smut Nose, had also good ear appearance under *O. nubilalis*
6 infestation. In 2002, most Corn Belt Dent populations and all checks were among those with the
7 best ear appearance.

8 Mandan Blue Flour and Assiniboine had the shortest tunnels and the lowest proportion of
9 stalk damaged. The Southern Dents have the longest tunnels, along with BSL(S)C6 and AS-
10 (HT)C3, but their figures were intermediate for proportions of stem damaged, due to their long
11 stems (Reid et al. 1991). BS17 had the lowest lodging and EPS20, AS-3(HT)C3, EPS12(T)C2,
12 BSL(S)C6, and BS5 did not differ significantly. Grain yield under infestation was highest for
13 White Dent (PI311232 and PI221885), BS17, and Tennessee Red Cob, followed by other
14 populations including Silver King, EPS13, EPS21, and Rustler, that had also high yield under *O.*
15 *nubilalis* infestation. The populations with high yield were EPS13, Rustler, Tennessee Red Cob,
16 White Dent (PI221885 and PI311232), Silver King, and BS17.

17 Given the significant differences in growing cycle, the superiority of Southern Dents,
18 compared to Northern Flints, could be overestimated for moisture, ear appearance and lodging.
19 Populations resistant to corn borer attack are not necessarily the highest yielders under corn borer
20 infestation (Malvar et al. 2004), then agronomic performance under corn borer infestation should
21 be preferred over proportion of stem damaged as selection criterion (Anglade et al. 1996, Butrón
22 et al. 1998). Actually, the Northern Flint populations had short tunnel length, while Southern
23 Dent had longer tunnels, but the Southern Dents had much higher yields than the Northern Flints.

1 The Southern Dent populations Tennessee Red Cob and White Dent (PI221885 and PI311232)
2 could be used as sources of high yield under infestation, though they are not expected to provide
3 great gains compared to the levels already present in some Corn Belt Dent and European Flint
4 populations.

5 The synthetic EPS12(T)C2 comes from a germplasm that was previously identified as corn
6 borer resistant (Malvar et al. 1993), but, after selection for corn borer resistance in EPS12, the
7 second cycle (EPS12(T)C2) is still surpassed on performance under corn borer infestation by
8 BS17, a Corn Belt Dent population than was released from crosses among synthetics resistant to
9 *O. nubilalis* and other pests (Russell 1979).

10 Considering altogether earliness, agronomic performance, and corn borer damage, the best
11 population was the Corn Belt Dent population BS17; other Corn Belt Dent populations
12 performed relatively well, particularly Rustler and Silver King, along with the European Flint
13 EPS13. In order to capitalize the potential value of BS17 for areas with short growing seasons, a
14 recurrent selection program with sequential selection for earliness and yield under infestation is
15 being carried out.

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10

Table 1. Maize races and populations analyzed.

Race	Population ^a	Acc. No.	Origin
Northern Flint	Pampa (NF2)	PI213749	Oklahoma
	Mandan Blue Flour (NF4)	PI213763	N. Dakota
	Winnebago Mixed (NF7)	PI213774	Nebraska
	Assiniboine (NF8)	PI213793	N. Dakota
	Smut Nose (NF11)	PI222490	Michigan
Southern Dent	Gourdseed (SD2)	PI217405	Iowa
	White Dent (SD3)	PI221885	Missouri
	White Dent (SD5)	PI233001	Missouri
	White Dent (SD7)	PI311232	Virginia
	Tennessee Red Cob (SD8)	PI311235	Virginia
Corn Belt Dent	EPS20		Corn Belt
	Minnesota No. 13		Minnesota
	Northwestern Dent		Minnesota
	Rustler		Corn Belt
	Silver King		Corn Belt
	AS-A		Minnesota
	AS-3(HT)C3		Minnesota
	BSL(S)C6		Iowa
	BS5		Minnesota
Checks	BS17		Iowa
	EPS12(T)C2		Spain

1	EPS13	Spain
2	EPS21	Europe + U.S.A.
3	^a Seed of Northern Flint (Doebley et al. 1986) and Southern Dent (Doebley et al. 1988)	
4	accessions was provided by the North Central Regional Plant Introduction Station (NCRPIS), US	
5	Department of Agriculture, Ames, Iowa. AS-A (Ordás and Stucker 1977), and AS-3(HT)C3	
6	(Peterson et al. 1976) are field corn synthetics from Minnesota. BSL(S)C6 (Eberhart et al. 1972),	
7	BS5, and BS17 (Russell 1979) are field corn synthetics from Iowa. EPS12(T)C2 is the second	
8	cycle of S ₁ -selection for <i>S. nonagrioides</i> resistance from EPS7(S)C3, that was the third cycle of	
9	S ₁ -selection for agronomic performance from a synthetic made from four corn populations	
10	collected in the South of Spain (Ordás 1991, Vales et al. 2001). EPS13 is the third cycle of S ₁ -	
11	selection for agronomic performance from a synthetic made from four maize populations	
12	collected in the North of Spain (Ordás 1991, Vales et al. 2001). EPS20 is a synthetic made from	
13	the <i>S. nonagrioides</i> resistant Reid inbred lines CM109, CM139, CM151, A634, A639, A652,	
14	A664, and W64A. EPS21 is a synthetic made from the <i>S. nonagrioides</i> resistant U.S. inbred lines	
15	APS17, CO125, and A509, and the European inbred lines EP43, EP53, PB60, PB130, and F473	
16	(Butrón et al. 2003).	
17		

Table 2. Mean squares from the analyses of variance combined over environments for four maize races represented by 23 populations grown for two years under infestation with *Ostrinia nubilalis* and *Sesamia nonagrioides*.

Trait	Sources of variation					
	Races			Populations		
	d.f.	<i>O. nubilalis</i>	<i>S. nonagrioides</i>	d.f.	<i>O. nubilalis</i>	<i>S. nonagrioides</i>
Pollen shedding	3	3063.27**	2715.58**	22	711.57**	667.67**
Silking	3	3121.85**	2849.43**	22	651.13**	637.97**
Stem lodging	3	5626.88	7374.30**	22	1533.52**	2053.43**
Ear appearance	3	28.87*	49.93*	22	6.05**	11.10**
Tunnels length	3	496.53	4294.61**	22	315.37**	1473.76**
Stem damaged	3	0.01	0.02	22	0.06	0.03**
<i>S. nonagrioides</i> /plant	3	1.41	9.20*	22	0.42**	2.15**
<i>O. nubilalis</i> /plant	3	0.31	0.02	22	0.11	0.03
Ears per plant	3	0.13	0.03	22	0.15	0.08
Grain yield	3	120.95	72.14*	22	29.57**	20.65**
Grain moisture	3	727.39*	602.73*	22	163.65**	137.84**

*, ** Significant at P = 0.05 and 0.01, respectively.

Table 3. Means for four maize races grown for two years under infestation with *Ostrinia nubilalis* and *Sesamia nonagrioides*.

	Corn Belt	Northern	Southern	
Trait	Dent	Flint	Dent	Checks
<i>Ostrinia nubilalis</i>				
Pollen shedding (days)	71b	68b	89a	68b
Silking (days)	74b	72b	93a	72b
Stem lodging (%)	36ab	53a	22b	22b
Ear appearance (1 - 9) ^a	7.4a	5.5b	7.5a	7.7a
Tunnels length (cm)	22a	17a	27a	24a
Stem damaged (%)	16a	16a	14a	17a
<i>S. nonagrioides</i> per plant (No)	0.21b	0.09b	0.58a	0.18ab
<i>O. nubilalis</i> per plant (No)	0.54a	0.33b	0.47ab	0.48ab
Ears per plant (No)	1.06a	1.15a	1.00a	1.03a
Grain yield (Mg ha ⁻¹)	2.4a	1.1b	3.1a	2.4ab
Grain moisture (g kg ⁻¹)	244b	285ab	346a	263ab
<i>Sesamia nonagrioides</i>				
Pollen shedding (days)	71b	68b	88a	68b
Silking (days)	74b	72b	92a	72b
Stem lodging (%)	35b	57a	19c	29bc
Ear appearance (1 - 9) [†]	6.1ab	4.1b	7.2a	6.3ab
Tunnels length (cm)	46b	33c	63a	50b
Stem damaged (%)	32a	29a	33a	37a

1	<i>S. nonagrioides</i> per plant (No)	0.91b	0.51b	1.84a	1.05ab
2	<i>O. nubilalis</i> per plant (No)	0.13a	0.12a	0.18a	0.13a
3	Ears per plant (No)	1.04a	1.05a	1.01a	1.11a
4	Grain yield (Mg ha ⁻¹)	2.2a	1.2b	2.9a	2.2ab
5	Grain moisture (g kg ⁻¹)	251b	281ab	345a	264ab

6 ^a Ear appearance was estimated on a subjective visual scale from 1 (ear totally damaged) to 9
7 (without ear damage). Means followed by the same letter within the same row are not
8 significantly different, according to least square means (P = 0.05).

Table 4. Means for 20 maize populations belonging to three North American races and three checks, grown for two years under infestation with *Ostrinia nubilalis*.

	Pollen		Stem	Ear	Tunnel	Stem	<i>S. nonagrioides</i>	<i>O. nubilalis</i>	Ears per	Grain	Grain
Population	shedding	Silking	lodging	appearance	length	damaged	plant ⁻¹	plant ⁻¹	plant	yield	moisture
	days	days	%	(1 - 9) ^a	cm	%	No	No	No	Mg ha ⁻¹	g kg ⁻¹
Pampa	86dc	87de	32e-i	6.6c	31abc	22	0.38b-e	0.44	1.18	1.8ef	276c-h
M. B. Flour	58k	63m	59ab	4.5d	12gh	17	0.00e	0.21	0.88	0.4h	341b
W. Mixed	78f	80gh	45fb-e	4.7d	13fgh	12	0.02e	0.33	1.56	0.5gh	303b-f
Assiniboine	56k	63m	77a	5.2d	9h	12	0.00e	0.15	1.08	0.4h	292b-g
Smut Nose	64j	69l	53bcd	6.8bc	25b-f	19	0.10de	0.55	1.02	2.3def	225ij
Gourdseed	94a	98a	29e-i	7.3abc	27b-e	15	0.66bc	0.66	0.74	1.9ef	442a
WD PI221885	89abc	92bc	18ghi	7.0abc	39a	19	1.07a	0.39	0.95	4.3a	323bc
WD PI233001	86bcd	90cd	14i	7.0abc	21c-g	12	0.33b-e	0.53	0.94	2.7b-e	333b
WD PI311232	90ab	94b	25f-i	8.2ab	25b-f	13	0.50bcd	0.45	1.07	3.5ab	313b-e
T. Red Cob	88bc	92bc	25f-i	8.0ab	24b-f	12	0.35b-e	0.35	1.28	3.4abc	321bcd
EPS20	71g	74ij	20ghi	6.8bc	19d-g	14	0.12de	0.56	1.06	2.2def	221ij

1	Minn. No 13	67hij	71jkl	43b-f	7.5abc	18d-h	13	0.11de	0.56	1.23	2.2ef	236hij
2	NW Dent	65ij	70jkl	43b-f	7.5abc	16e-h	13	0.08e	0.70	1.04	2.1ef	221j
3	Rustler	67hij	71jkl	54bc	7.5abc	17e-h	16	0.03e	0.66	1.02	2.5b-f	225ij
4	Silver King	70gh	73ijk	38c-g	7.5abc	24b-g	16	0.32b-e	0.56	1.01	2.4b-f	245g-j
5	AS-A	65j	69l	46b-e	6.8bc	21c-h	19	0.08e	0.47	1.15	1.5fg	223ij
6	AS-3(HT)C3	77f	80h	35c-h	7.7abc	31a-d	21	0.26cde	0.57	0.98	2.4c-f	269e-j
7	BSL(S)C6	81ef	83fg	21ghi	7.3abc	35ab	18	0.72ab	0.39	0.97	2.8b-e	282c-h
8	BS5	67hij	71jkl	33d-i	7.3abc	21c-h	17	0.20de	0.57	1.04	2.3def	236hij
9	BS17	82de	84ef	16hi	8.3a	21c-h	14	0.22de	0.44	1.07	3.2bcd	294b-g
10	EPS12(T)C2	70ghi	75i	17hi	7.7abc	27b-e	19	0.26cde	0.49	1.06	2.3c-f	271d-i
11	EPS13	66hij	70kl	27e-i	7.7abc	22c-g	16	0.10de	0.47	1.00	2.5b-f	256f-j
12	EPS21	68hi	71jkl	45b-f	7.2abc	17e-g	15	0.13de	0.48	1.09	2.3fde	238hij
13	LSD (0.05)	4	4	20	1.4	12		0.40			1.0	59

^a Ear appearance was estimated on a subjective visual scale from 1 (ear totally damaged) to 9 (without ear damage). Means followed by the same letter within the same column are not significantly different according to the Fisher's protected LSD (0.05).

Table 5. Means for 20 maize populations belonging to three North American races and three checks, grown for two years under infestation with *Sesamia nonagrioides*.

	Pollen		Stem	Ear	Tunnel	Stem	<i>S. nonagrioides</i>	<i>O. nubilalis</i>	Ears per	Grain	Grain
Population	shedding	Silking	lodging	appearance	length	damaged	plant ⁻¹	plant ⁻¹	plant	yield	moisture
	days	days	%	(1 - 9) ^a	cm	%	No	No	No	Mg ha ⁻¹	g kg ⁻¹
Pampa	86b	87cd	31e-h	5.2d	57b-e	43a	1.04e-g	0.23	1.09	1.4fgh	272hfgde
M. B. Flour	58i	62j	71ab	2.8e	10j	13g	0.05kl	0.10	1.11	0.8h	367b
W. Mixed	77d	80f	57bc	2.5e	42fgh	39abc	0.79g-j	0.03	0.89	0.6h	329cb
Assiniboine	56i	62j	83a	3.4e	11j	17fg	0.03l	0.09	1.09	0.6h	15cd
Smut Nose	65h	68i	50cd	6.5ab	42ghi	30b-e	0.56h-k	0.15	1.05	2.1d-g	239hfg
Gourdseed	93a	97a	19ghi	7.2abc	55fcde	33a-e	1.55b-e	0.15	0.74	2.0efg	426a
WD PI221885	88b	92b	21ghi	6.3bcd	69ab	35a-e	2.17a	0.26	0.94	3.2ab	339cb
WD PI233001	86b	89c	21ghi	7.6ab	64abc	34a-e	2.01ab	0.11	0.96	2.3b-f	335cb
WD PI311232	89b	93b	18ghi	8.0a	63a-d	30b-e	1.63bcd	0.24	1.22	4.0a	317cd
T. Red Cob	86b	89c	16hi	7.2abc	63a-d	32b-e	1.90abc	0.15	1.22	3.0abc	307cde
EPS20	70ef	73g	23ghi	5.3d	41ghi	28cde	0.68g-j	0.07	1.17	2.1c-g	230hg

1	Minn. No 13	67gh	70ghi	48cde	6.3bcd	35hi	29b-e	0.48i-l	0.10	1.00	2.8b-e	242hfg
2	NW Dent	66gh	68hi	59bc	6.0cd	38ghi	28de	0.72g-j	0.33	0.99	2.1c-g	243hfg
3	Rustler	67gh	71gh	52c	6.5a-d	43fgh	31b-e	0.59hij	0.08	1.11	2.4cde	229h
4	Silver King	71e	73g	44c-f	6.2bcd	45e-h	34a-e	0.95ghi	0.15	0.98	2.5b-e	257hfg
5	AS-A	66gh	69hi	48cde	5.8cd	29li	25ef	0.31jkl	0.16	1.02	1.3gh	238fg
6	AS-3(HT)C3	77d	80f	26ghi	6.0cd	63a-d	42a	1.49c-f	0.09	1.09	2.4b-e	266hfg
7	BSL(S)C6	81c	83e	14hi	5.3d	72a	39ab	1.75abc	0.07	0.87	2.1c-g	283fde
8	BS5	67gh	70ghi	29f-i	6.0cd	41ghi	33a-e	0.67g-j	0.21	1.14	2.1c-g	241hfg
9	BS17	82c	85de	13i	7.3abc	58b-e	36a-d	1.61bcd	0.20	1.02	3.0abc	303cde
10	EPS12(T)C2	69efg	73g	27f-i	6.3bcd	50d-g	37a-d	0.97f-i	0.21	1.13	2.0efg	275fgde
11	EPS13	67fgh	70ghi	31e-h	6.3bcd	51d-g	37a-d	1.13d-g	0.05	1.10	2.4b-e	253hfg
12	EPS21	67gh	71ghi	34d-g	6.2bcd	40ghi	32b-e	0.76g-j	0.04	1.09	2.5b-e	233hg
13	LSD (0.05)	4	3	18	1.6	13	11	0.52			1.0	46

^a Ear appearance was estimated on a subjective visual scale from 1 (ear totally damaged) to 9 (without ear damage). Means followed by the same letter within the same column are not significantly different according to the Fisher's protected LSD (0.05).

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