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Ear Feeding Resistance of Sweet Corn Inbreds to Pink Stem Borer

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Abstract. **Pink stem borer (*Sesamia nonagrioides* Lef.) is one of the most important insect pests of corn (*Zea mays* L.) in southern Europe. The objectives of this work were to determine the level of resistance in different sweet corn inbreds and to identify sources of resistance to ear feeding by the pink stem borer. Twenty-eight sweet corn (su^1 and su^1se^1) inbreds and four resistant field corn (Su^1Se^1) inbreds were evaluated for ear resistance at different sowing dates, under two methods of artificial infestation. There were significant differences between infestation methods for ears with damaged grain, husks, cobs, and shanks. The inbred × infestation method interaction was significant for general appearance of the ear. The most resistant inbreds were identified by using mean comparisons and principal component analysis of ear damage traits. All inbreds were damaged. Hence, resistance was incomplete and in need of improvement. EP59, H3, I5125, IL767b, and V7726 were the most resistant sweet corn inbreds, which did not differ significantly from A635, the most resistant field corn inbred. General appearance of the ear appears to be a good indicator of pink stem borer resistance and can be used in preliminary evaluation. Variability exists in the resistance of these sweet inbreds to the pink stem borer and the use of field corn inbreds may not be necessary in the improvement of resistance, although further research is needed to determine if the sources differ in the pertinent genes conferring resistance.**

In Spain and other Mediterranean countries, a major insect pest of corn is the pink stem borer (*Sesamia nonagrioides* Lef.) (Anglade, 1972; Cordero et al., 1998; Larue, 1984). *Sesamia nonagrioides*, a pest of subtropical origin, was found as early as the XIX century in Spain (Prota, 1965). It has two generations per year in most Mediterranean countries, but can complete five in warmer areas (Özpinar and Kornosor, 1998). Winter temperatures below 0 ºC limit the population levels (Galichet, 1982). First generation larvae attack young plants, feeding on the leaves, and can kill the plant. In northwestern Spain, first generation larvae are not a problem since there is no maize sown when first oviposition occurs. Moths of the second generation lay the eggs among stalks and leaves of corn plants. Second generation larvae attack stalk and ears, causing significant yield losses due to lodging as well as ear and grain damage. Up to 95% of plants may be damaged (Hilal, 1981), and yield losses may reach 30% in field corn (Larue, 1984).

There are no reports on resistance to the pink stem borer in sweet corn and limited information in field corn. Malvar et al. (1993), Cartea et al. (1994), and Butrón et al. (1999) studied the resistance of field corn inbreds and populations to pink stem borer. They identified some inbreds and populations that have good levels of resistance to both stem and ear feeding. The inheritance of the ear resistance was investigated (Butrón et al., 1998) and found to be primarily additive. Four of the inbreds evaluated which displayed some resistance in these previous studies (A509, A635, A662, and PB130) were included in our experiments.

Resistance in sweet corn to the European corn borer (*Ostrinia nubilalis* Hbn), has been extensively investigated. In general, less resistance to ear damage has been found in sweet corn from temperate areas than in field corn, although significant differences are reported among sweet corn inbreds and hybrids (Andrew and Carlson, 1976; Grier and Davis, 1980; Jarvis, 1988; Pounders et al., 1975).

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Damage to sweet corn ears is more important than stalk damage, since an ear will be unacceptable with only very minor damage to husks or kernels. Sweet corn has achieved economic importance in Europe, justifying research to identify sources of resistance to pink stem borer. Recently, sweet corn was introduced in northwestern Spain. Due to adaptation problems, only a few inbreds have been maintained (Ordás et al., 1994). These inbreds were the material used in this work.

The objectives of this work were to determine the comparative resistance of a collection of adapted sweet corn inbreds to the attack of the pink stem borer in northwestern Spain, to identify sources of resistance, and to determine which traits are the best indicators of ear damage.

Materials and Methods

Twenty-eight sweet corn (23 su^1 and five su^1se^1) inbreds and four field (Su^1Se^1) corn inbreds (Table 1) were evaluated for ear resistance to pink stem borer under artificial infestation. The 28 sweet corn inbreds constitute the collection adapted to the northwestern Spain. The four field corn inbreds were used because they had shown resistance to pink stem borer in a previous study (Butrón et al., 1999). The experiments were conducted at Pontevedra, on the Atlantic coast of northwestern Spain. The experimental field was at ≈20 m above sea level, and the area has a humid, mild climate with an annual rainfall of ≈1600 mm.

The inbreds were sown on 5 May 1995 (early sowing) and 6 June 1995 (late sowing) in a split-plot experimental design with two replications at each sowing date. Whole plots consisted of 32 inbreds and subplots were the infestation methods. Seeds were sown in two-row plots, with each row consisting of 10 two-kernel hills spaced 0.30 m. The distance between rows was 0.80 m. Rows were thinned to one plant per hill.

At flowering, 10 plants were artificially infested with one egg mass of *S. nonagrioides* (≈50 eggs/plant). Flowering was the date when 50% of the plants were silking, and was recorded for each plot. Two methods of infestation were used: 1) five plants per plot were infested following the method of Anglade (1961), except that the egg mass was placed between the shank of the main ear and the stem, instead of at the third leaf below the main ear and 2)

Table 1. Maize inbreds tested for resistance to pink stem borer.

Inbred	Endosperm	Pedigree	Inbred	Endosperm	Pedigree
A509	Su^1Se^1	A78 x A109[z]	H7	su^1	Mainliner
A635	Su^1Se^1	(ND203 x B14)B14^{2}[z]	I453	*su*	(P39 x I45)I45^{2}[z]
A662	Su^1Se^1	AS-A[z]	I5125	su	(IP39 x Tendermost)IP39[z]
C13	su^1	Golden Early Market[z]	I5177	su^1	I45 x I5116[z]
C6	su^1	Whipple (Harris)[z]	I5492	su^1	Me2RT x I5125[z]
CO108	su^1	Sungold[z]	IL27a	su^1	Country Gentleman[z]
EP58	su^1	IL27a x I5125[y]	IL677a	su^1se^1	(Bolivia 1035 x IL44b)IL442a[z]
EP59	su^1	IL27a x I5125[y]	IL731a	su^1se^1	Golden Sensation x IL677a[z]
EP60	su^1	IL27a x P51[y]	IL767b	su^1se^1	IL197a x IL677a[z]
EP61	su^1	I453 x P51[y]	IL778d	su^1se^1	IL557a x IL677a[z]
EP62	su^1	I453 x P51[y]	IL779a	su^1se^1	White Dent x IL677a[z]
H1	su^1	Fanfare	P39	su^1	Golden Bantam[z]
H2	su^1	Spirit	P51	su^1	Golden Bantam[z]
H3	su^1	Aromatnaja	PB130	Su^1Se^1	Rojo Vinoso de Aragón
H5	su^1	Yukon	V7726	su^1	North Star x Gold Cup[z]
H6	su^1	Jubilee	V679	su^1	{[(Me100 x V1) x open] V643} Gold Cup[z]

[z]Gerdes et al., 1993.
[y]Ordás et al., 1994.

the other five plants were infested by placement of the egg mass at the tip of the ear, among the silks. Egg masses were obtained from Misión Biológica de Galicia (CSIC), and were produced by the rearing method of Eizaguirre (1989).

Twenty days after infestation, the infested ears were harvested. Records were made of general appearance of the ear, number of ears per plot with husks, grain, cobs, or shanks damaged by larval feeding. The percentage of ears with all these tissues damaged and ears without damage in the infested plots were also recorded. General appearance of the ear was rated visually on a 5-point scale, where 1 = no ear injury and 5 = >60% of grain damaged. Also, the number and length of ear tunnels per plot were recorded and divided by the cumulative length of collected ears. The number of larvae of *S. nonagrioides*, *O. nubilalis*, and other larvae per ear also were recorded.

Data were analyzed by date of sowing, followed by a combined analysis. Inbreds, sowing dates and infestation methods were considered fixed effects. Comparisons of means among inbreds were made using the minimum significant difference (MSD) from the Waller-Duncan analysis (Waller and Duncan, 1969). Principal component analysis was carried out for all damage traits (Dunn and Everitt, 1982). This analysis creates a new variable that consists of a linear combination of the original ear traits, and can be used in place of the original variables as an index to measure ear damage. Phenotypic correlation coefficients (Johnson et al., 1955) were estimated among ear damage traits on a plot mean basis. All analyses were made with the SAS statistical package (SAS Institute, cary, N.C.).

Results and Discussion

There were significant differences ($P \leq 0.05$) among inbreds for all traits measured (Table 2). Inbred × date sowing interaction was not significant except for ears with damaged cobs (Table 2). There were significant differences ($P \leq 0.01$) between infestation methods for ears with damaged grain, husks, cobs, and shanks (Table 2). With shank infestation, the proportion of ears with shanks and husks damaged was greater than with ear tip infestation. In the latter method larvae did not need to pass through the shank or husks to reach the grain. Ear tip infestation resulted in more damaged grain, because the barriers that protect the grain were bypassed. However, inbred × infestation method interactions for ear damage traits were not significant. Hence, identifying the most resistant inbreds did not depend on infestation method. Only general appearance of the ear was affected by inbred × infestation method interaction. Therefore, data from both meth-

Table 2. Means squares from the analysis of variance for 32 inbreds (L) grown in Pontevedra at two sowing dates (SD) (early and late) and two infestation (I) methods (shank and ear tip infestation).

Sources of variation	SD	L	L × SD	I	L × I	SD × I	L × SD × I
Degrees of freedom	1	31	30	1	31	1	28
General appearance of ear	0.1377	2.8635**	0.7470	0.2206	0.7916*	1.1096	0.3989
Ears with damaged grain	0.2660	0.2020**	0.0605	0.6805**	0.0735	0.1192	0.0766
Ears with damaged husks	0.2929	0.1469**	0.0660	1.0297**	0.0580	0.4863**	0.1027
Ears with damaged cob	0.0002	0.0434**	0.0299*	0.0544**	0.0106	0.0499**	0.0152**
Ears with damaged shank	0.0355	0.0720*	0.0606	0.3431**	0.0437	0.3764**	0.0426
Ears completely damaged	0.0496	0.0290*	0.0177	0.0121	0.0159	0.0111	0.0128
Ears without damage	0.5228	0.1271**	0.0651	0.0011	0.0676	0.0490	0.0686
Number of tunnels	0.0318	0.1334**	0.0570	0.0010	0.0392	0.1114*	0.0205
Length of tunnels	2.0014	3.5707**	1.1033	0.0672	1.2852	4.5999*	1.1468
Sesamia per ear	28.17	11.54**	7.24	0.00	10.26	24.33	5.96

*,**Significant at $P \leq 0.05$ or 0.01, respectively.

Table 3. Means for 8 pink stem borer resistance traits and score of the first principal resistance component for 28 sweet corn and 4 field corn inbreds. Means for general appearance (1 to 5 scale) are shown separately for infestation in the tip of the ear and between the shank and the stem because the inbred × infestation method interaction was significant. The other means are shown with both infestation methods, 1 to 5 scale.

	General appearance of ear											
Inbred	Tip	Between shank and stem	Ears with damaged grain (%)	Ears with damaged husks (%)	Ears with damaged cob (%)	Ears with damaged shank (%)	Ears completely damaged (%)	Ears without damage (%)	Tunnels in ear (no./cm)	Length of tunnels in ear (cm·cm^{-1})	*Sesamia* per ear	Prin 1[z]
A509	3.8	3.5	48	48	3	10	3	37	0.10	0.91	3.46	–0.32
A635	2.0	2.3	20	29	0	31	0	44	0.01	0.05	0.95	–3.13
A662	3.7	3.5	55	54	6	8	5	40	0.09	0.69	2.56	0.27
PB130	3.5	2.5	44	53	3	11	3	48	0.10	0.59	2.26	–1.33
C6	4.8	3.7	71	68	18	39	16	26	0.52	2.75	4.10	5.89
C13	3.8	3.3	60	55	6	31	6	38	0.14	1.02	3.10	0.68
CO108	3.5	4.0	55	33	3	23	13	40	0.13	0.93	3.08	0.25
EP58	3.0	3.3	42	32	10	26	10	44	0.19	1.48	1.37	0.44
EP59	1.8	2.3	15	40	0	13	0	58	0.02	0.10	0.95	–3.76
EP60	2.7	3.0	36	50	6	41	0	33	0.08	0.39	2.37	–0.57
EP61	4.7	4.3	71	52	19	40	13	26	0.22	1.08	2.90	3.70
EP62	2.7	2.3	32	38	3	33	0	48	0.05	0.21	2.39	–2.01
H1	2.0	3.0	41	31	9	9	6	59	0.13	0.82	1.94	–1.76
H2	4.5	3.0	48	73	10	35	23	28	0.46	2.52	5.00	4.07
H3	2.3	2.5	24	18	3	10	0	71	0.02	0.13	1.02	–4.07
H5	4.0	3.3	60	26	4	9	5	38	0.09	0.38	3.04	–0.74
H6	2.8	3.5	49	51	3	24	0	44	0.06	0.27	2.74	–1.08
H7	3.3	3.0	65	34	0	25	0	29	0.04	0.18	2.22	–0.97
I453	3.0	3.0	38	40	13	31	3	45	0.08	0.50	2.01	–1.00
I5125	2.5	2.5	33	28	5	15	0	53	0.05	0.23	1.33	–2.82
I5177	4.7	3.0	61	49	6	36	8	19	0.26	1.28	4.43	1.24
I5492	3.3	4.5	68	49	23	26	4	29	0.22	0.98	2.36	1.55
IL27a	3.0	3.5	61	22	0	42	11	19	0.36	1.28	1.92	2.47
IL677a	4.5	4.3	77	83	33	33	22	12	0.48	2.38	6.83	6.36
IL731a	2.5	3.3	45	43	10	19	0	46	0.05	0.18	2.53	–1.51
IL767b	2.7	2.7	45	17	0	7	0	48	0.04	0.12	0.68	–3.18
IL778d	4.0	3.5	59	39	6	27	4	35	0.18	0.85	3.32	0.38
IL779a	3.7	3.0	72	45	13	28	6	24	0.09	0.35	1.35	0.45
P39	3.8	4.3	76	54	20	25	11	16	0.25	1.80	3.99	3.21
P51	3.0	3.8	53	45	5	18	8	38	0.10	0.76	4.45	0.18
V679	3.0	2.7	57	57	0	7	0	33	0.10	0.53	2.70	–0.98
V7726	2.8	2.8	37	43	3	24	0	42	0.05	0.25	1.57	–1.91
MSD (0,05)	1.2	1.4	29	34	16	27	18	29	0.28	1.06	4.98	

[z]Score of each inbred for the first principal component. (–) Resistance, (+) susceptibility.

ods for this trait were included in the inbred evaluation. There were no differences between sowing dates, possibly because ears were infested artificially.

No inbreds were free of damage (Table 3). Inbred H3 had the largest number of ears without damage (71%). For general appearance of the ear, the comparison of means was made within infestation method (Table 3). Field corn inbred A635 and sweet corn inbreds EP59, EP62, H1, H3, I453, I5125, and V7726 had the least damage for all measurements. Only EP59 and H3 were superior to the worst inbreds for all traits, while A635, I5125, and V7726 were superior for all traits, except for ears with damaged shanks. IL767b, a su^1se^1 inbred, was one of the best inbreds for all traits except for ears with damaged grain. For this trait, IL767b showed intermediate levels of damage.

The best sweet corn inbreds did not differ ($P \leq 0.05$) from A635, the most resistant field corn inbred. We included the field corn inbreds because they had been reported as resistant to pink stem borer by Butrón et al. (1999). Since we found the resistance of some sweet corn inbreds comparable to that of the field corn inbreds, sweet corn can be used as a source of resistance avoiding the problem of introducing unfavorable quality traits if field corn were used as the donor parent in a sweet corn breeding program.

The first principal component explained 66% of the total variability and was the only one with an eigenvalue (6.63) that exceeded 1.0 (Table 4). All traits were indicators of damage, except ears without damage (an indicator of health). The first principal component is an estimate of the overall ear damage produced by *Sesamia*, since all damage traits had positive coefficients (except the proportion of ears without damage) of similar magnitude for the first principal component (Table 4). Therefore, a high value of the first principal component indicates high susceptibility to the attack of the pink stem borer (Table 3). Resistance characterization of the inbreds was represented graphically on the basis of score for first principal component (Fig. 1). EP59, H3, I5125, and IL767b were the most resistant sweet corn inbreds, and A635 was the most resistant field corn. These inbreds

Table 4. Eigenvalues, proportion of total variation described, and eigenvectors for all traits in the first five principal components (Prin1 to Prin5).

Principal component	Prin1	Prin2	Prin3	Prin4	Prin5
Eigenvalue	6.63	0.96	0.77	0.61	0.49
Proportion	0.66	0.09	0.08	0.06	0.05
Eigenvector					
General ear appearance	0.35	–0.19	–0.20	–0.18	0.09
Ears with damaged grain	0.30	–0.21	–0.60	–0.23	0.07
Ears with damaged husks	0.29	–0.41	0.36	0.42	–0.05
Ears with damaged cob	0.30	0.05	0.04	0.32	0.82
Ears with damaged shank	0.25	0.55	–0.15	0.62	0.26
Ears completely damaged	0.34	0.26	0.22	–0.32	–0.00
Ears without damage	–0.33	0.04	0.45	–0.13	0.28
Number of ear tunnels	0.34	0.33	0.19	–0.24	–0.03
Length of ear tunnels	0.35	0.21	0.30	–0.28	0.01
Sesamia per ear	0.29	–0.47	0.27	0.04	–0.41

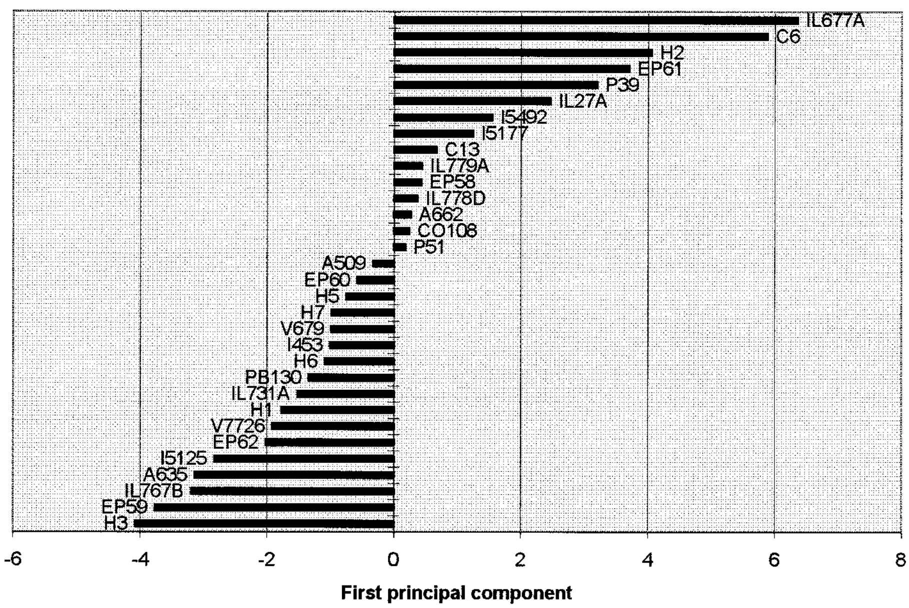

Fig. 1. Pink stem borer resistance of four field corn (A509, A632, A662, and PB130) and 28 sweet corn inbreds based on the first principal component.

may be promising sources of resistance to pink stem borer for sweet corn breeders.

Phenotypic correlations among all ear damage traits were calculated (Table 5). Number and length of tunnels per ear were most closed related (r = 0.97) of all trait pairs. However, general appearance of the ear showed the highest correlation with most traits, regardless of infestation method. Therefore, means for this trait were pooled across infestation methods before calculation of the trait associations. Length of tunnels per ear showed six values for r above 0.60, and number of tunnels per ear, ears with damaged husks and ears completely damaged had five above 0.6. Ears with damaged shanks did not show any correlation above 0.60. General appearance of the ear, a visually scored trait, seems to be the best indicator of resistance and should be used in preliminary tests. We may be able to improve the ear resistance by using this trait as a selection criterion, but its use may not improve the resistance in the shank. Number and length of ear tunnels also could be useful traits for selecting resistant ears. To evaluate the resistance of genotypes to *O. nubilalis*, Grier and Davis (1980) and Joyce and Davis (1995) used a visual scale based on the percentage of damaged grain in the ear, while Shehata et al. (1975) used the percentage of surviving larvae.

In conclusion, there are sweet corn inbreds that show partial resistance to pink stem borer. All inbreds had some damage; thus, the resistance was partial and needs to be improved. EP59, H3, I5125, IL767b, and V7726 were the most resistant sweet corn inbreds and they did not differ from A635, the best field corn inbred. Therefore, the use of field corn inbreds may not be necessary in the improve-

Table 5. Phenotypic correlation coefficients among 10 ear damage traits for pink stem borer on 32 maize inbreds.

n = 32	EDG	EDH	EDC	EDS	ECD	EWD	NTE	LTE	*Sesamia* per ear
General ear appearance	0.87^{**}	0.63^{**}	0.64^{**}	0.41^{*}	0.73^{**}	$–0.80^{**}$	0.69^{**}	0.72^{**}	0.70^{**}
Ears with damaged grain (EDG)		0.45^{**}	0.55^{**}	0.31	0.51^{**}	$–0.84^{**}$	0.53^{**}	0.53^{**}	0.51^{**}
Ears with damaged husks (EDH)			0.55^{**}	0.43^{*}	0.61^{**}	$–0.58^{**}$	0.66^{**}	0.70^{**}	0.70^{**}
Ears with damaged cob (EDC)				0.52^{**}	0.59^{**}	$–0.52^{**}$	0.64^{**}	0.62^{**}	0.37^{*}
Ears with damaged shank (EDS)					0.50^{**}	$–0.55^{**}$	0.56^{**}	0.49^{**}	0.34
Ears completely damaged (ECD)						$–0.55^{**}$	0.89^{**}	0.92^{**}	0.85^{**}
Ears without damage (EWD)							$–0.59^{**}$	$–0.58^{**}$	$–0.58^{**}$
Number of tunnels per ear (NTE)								0.97^{**}	0.55^{**}
Length of tunnels per ear (LTE)									0.61^{**}

*,**Significant at $P \leq 0.05$ or 0.01, respectively.

ment of the resistance of these sweet corn inbreds to corn borers, although further research is needed to determine if the sources differ in the pertinent genes conferring resistance. General appearance of the ear seems to be a good indicator of resistance in the genotypes examined and may be sufficient as the sole indicator in preliminary evaluations of germplasm.

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