

SWEET CORN HYBRID DISEASE NURSERY – 2010

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Sweet corn hybrids have been evaluated for their reactions to prevalent diseases in nurseries at the University of Illinois for 27 consecutive years. This report summarizes the reactions of 439 sweet corn hybrids to common rust, NCLB, Stewart's wilt, MDM, and SLB based on their performance in the 2010 nursery. These hybrids also were evaluated for their responses to two post-emergence herbicides: Capreno (tembotrione + thiencarbazone-methyl), and Accent (nicosulfuron).

Resistance and susceptibility are the two extremes of a continuum of host reactions to diseases. Resistance is a measure of the ability of the host to reduce the growth, reproduction, and/or disease-producing abilities of the pathogen, thus resulting in less severe symptoms of disease. Major genes for resistance, such as *Rp1-D*, *Ht1*, or *Mdm1*, can prevent or substantially limit disease development if specific virulence (i.e., races) is not prevalent in pathogen populations. Hybrids with major gene resistance usually have clearly distinguishable phenotypes. Major gene resistance may be ineffective if specific virulence occurs, such as the *Rp1-D*-virulent race of the common rust fungus.

In the absence of effective major gene resistance, disease reactions often range from partially resistant to susceptible. Hybrids can be grouped into broad classes such as: resistant (R), moderately resistant (MR), moderate (M), moderately susceptible (MS), and susceptible (S) based on severity of disease symptoms. This process produces statistically “overlapping” groups without clear-cut boundaries

(e.g., the hybrid with least severe symptoms in MR class does not differ significantly from the hybrid with the most severe symptoms in the R class). Thus, boundaries between categories of disease reactions are somewhat arbitrary. Nevertheless, a consistent response of a hybrid over several trials produces a reasonable estimate of the disease reaction of that hybrid relative to the response of other hybrids. These reactions can be used to assess the potential for diseases to become severe and affect yield of that hybrid.

Certain post-emergence herbicides also can injure some sweet corn hybrids. Responses of sweet corn hybrids to several cytochrome P450-metabolized herbicides have been associated with a mutation in a specific cytochrome P450 gene on chromosome 5S. Classification of sweet corn responses to herbicides identifies hybrids with the greatest risk of injury.

MATERIALS AND METHODS

Hybrids. The 2010 nursery included 439 entries: 300 *sh2* hybrids, 69 *se* hybrids, 64 *su* hybrids, and 6 *bt2* hybrids. Hybrids with multiple endosperm mutations were placed in the most appropriate of the three categories. Standard hybrids with relatively consistent reactions to common rust, Stewart's wilt, NLB, MDM, and SLB (Table 1) also were included to compare the results of the 2010 nursery to those from previous nurseries. Hybrids known to carry the *Rp1-D*, *Rp1-I* or *Rp-G* rust resistance genes also were included as an aid in the interpretation of responses to different populations of *Puccinia sorghi*.

Table 1. Reactions of sweet corn hybrids included as standards in the 2010 disease nursery

Hybrid	Stewart's wilt			Common rust (races)				NLB (races 0 & 1)				MDM A&B			SLB		
	Prior	10	Rating	Prior	avir	D	G	Prior	r0	r1	Rating	Prior	10	Rating	Prior	10	Rating
277A	3	4	3.7	6	6	6	6	5	6	5	36% 27%	9	8	97%	3	4	3.5
Ambrosia	2	3	3.2	6	5	5	5	5	5	5	31% 29%	9	9	100%	6	5	4.8
Bodacious	5	4	3.7	5	4	4	4	5	5	5	29% 27%	9	9	100%	5	6	5.3
Bonus	1	1	2	Rp	Rp	5	Rp	5*	5*	5	28% 24%	2	2	8%	6	8	6.5
El Toro	3	2	2.3	Rp	Rp	5	Rp	6	5	5	32% 29%	3	4	21%	3	4	3.8
Eliminator	2	2	2.1	Rp	Rp	5	Rp	6	7	6	39% 33%	2	2	9%	6	6	5.1
Garrison	2	2	2.7	Rp	Rp	Rp	Rp	2*	1*	3	11% 16%	2	2	3%	4	6	5.1
Jubilee	9	9	5.9	5	4	5	5	8	8	7	45% 38%	9	9	100%	4	6	4.9
Merit	5	5	4.3	8	6	7	7	6*	8*	5	41% 28%	9	9	98%	5	5	4.5
Merlin	2	2	2.7	3	2	3	2	4	4	5	26% 26%	9	9	97%	1	2	2.3
Miracle	1	3	2.8	3	2	3	3	3	4	4	23% 20%	9	9	100%	4	5	4
Obsession	3	4	3.4	Rp	Rp	4	Rp	3*	2*	3	15% 15%	9	9	100%	3	5	4.1
Sensor	5	6	4.5	4	4	4	3	4	5	5	28% 23%	9	8	87%	5	5	4.3
Tuxedo	3	6	4.5	3	3	4	5	2	3	3	19% 16%	9	9	100%	2	3	2.8

Prior - reaction in previous years (1984-2009).

10 - reaction in 2010: 1 - resistant, 3 - moderately resistant, 5 - moderate, 7 - moderately susceptible, 9 - susceptible, * = Ht-reaction..

Rating -2010 mean rating: 1 to 9 for Stewart's wilt and SLB; 0 to 100% severity of NLB, 0 to 100% incidence of MDM.

Table 2. Criteria for classifying hybrid reactions to diseases in the 2010 nursery

Disease (rating)	Rp	Classification of reaction								
		Resistant 1	Moderately resistant 2	Moderately resistant 3	Moderate 4	Moderate 5	Moderately susceptible 6	Moderately susceptible 7	Susceptible 8	Susceptible 9
Rust (%)										
avirulent	0	< 10	< 16	< 21	< 25	< 30	< 34	< 39	< 43	≥ 43
D-virulent	0	< 9	< 12	< 17	< 21	< 28	< 32	< 37	< 43	≥ 43
G-virulent	0	< 10	< 15	< 20	< 24	< 32	< 36	< 40	> 45	≥ 45
NLB race 0 (%)		< 12	< 17	< 22	< 27	< 33	< 37	< 41	> 46	≥ 46
NLB race 1 (%)		< 11	< 15	< 20	< 23	< 31	< 35	< 39	> 43	≥ 43
Stewart's wilt (1-9)		< 2.1	< 2.8	< 3.4	< 3.9	< 4.4	< 4.9	< 5.4	< 5.9	≥ 5.9
MDM-late (%)		< 5	< 20	< 20	< 40	< 60	< 70	< 80	≥ 80	≥ 90
MDM-early (%)	0	< 10	< 15	< 20	< 40	< 50	< 60			
SLB (1-9)	< 2	< 2.7	< 3.5	< 4	< 4.9	< 5.4	< 6	< 7	≥ 7	
Capreno (% injury)	0	> 0			> 10					> 50
(% ht reduction)	< 20		> 20		> 40					> 50
Accent (% injury)	0	> 0			> 10		> 40			> 50
(% ht reduction)	< 10		> 10							> 40

See text for description of disease and herbicide assessments.

Experimental design and procedures. Each trial of a disease or herbicide was a separate experiment with two replicates of hybrids arranged in randomized complete blocks. Each rep was split into two main blocks: *sh2* hybrids or *su* and *se* hybrids. Each experimental unit was a 12-ft. row with about 18 plants per row. Trials were planted in four different fields (Table 5) from May 24 to June 4 on the University of Illinois South Farms.

Inoculation and disease assessment. Plants at the 3- to 5-leaf stage were inoculated with *Pantoea stewartii* (Stewart's wilt) by wounding leaves in the whorl and introducing bacteria in a 0.1 M saline solution into wounds. For the three foliar fungal diseases, (NLB, SLB, and common rust) spores were sprayed directly into plant whorls from the 2- to 7-leaf stages. Inocula consisted of conidia of either race 0 or race 1 of *Exserohilum turicum*; conidia of *Bipolaris maydis* race O; and urediniospores of one of three isolates of *Puccinia sorghi*: avirulent on Rp genes (avirulent), Rp1-D-virulent (D-virulent), or Rp-G/Rp1-I/Rp1-E-virulent (G-virulent). Plants were inoculated with *Maize dwarf mosaic virus* strain A (MDMV-A) and *Sugarcane mosaic virus* (MDMV-B) at the 2- to 3-leaf stages. A phosphate buffer solution with a mixture of the viruses was sprayed directly onto leaves using a motorized backpack sprayer.

The total number of plants and the number of plants with symptoms of MDM were counted approximately 1 and 3 wk after inoculation (early and late). Incidence (%) of MDM-infected plants was calculated for each hybrid from totals of both replicates. Symptom severity was rated for each of the other diseases.

Stewart's wilt was rated before anthesis using a scale from 1 (symptoms within 2 cm of inoculation wounds) to 9 (severe systemic infection or dead plants). Chlorotic, Rp-resistant reactions were scored

in the rust trials about 2 to 3 wk after the first inoculation. Percent leaf area infected was rated at harvest maturity in all rust and NLB trials. Hybrids with chlorotic NLB-lesions typical of Ht-resistance also were noted. Symptoms of SLB were rated on a 1 to 9 scale (mild to severe).

Herbicide application and assessment. Post-emergence herbicides were applied at twice the registered usage rates when the majority of plants ranged from the 4- to 6-leaf stages and were about 8-18 inches tall. Herbicide treatments were Capreno (tembotriione + thiencarbazone-methyl) at 6.0 oz/A, and Accent (nicosulfuron) at 1.34 oz/A. Adjuvants included 1% crop oil concentrate (COC) and 28% urea ammonium nitrate (UAN) at 2.5% v/v. All fields were treated pre-emergence with metachlor + atrazine.

Percentage corn injury (i.e., chlorosis and necrosis) was rated visually 10-12 days after application. Plant height also was measured and expressed as a percentage of the height of non-treated plants in two replicates of a neighboring trial.

Data analysis. Disease and herbicide injury ratings were analyzed by ANOVA. Hybrid reactions to diseases and herbicides were classified from 1 (highly resistant/tolerant) to 9 (highly susceptible/sensitive) according to standard deviations from the mean (z-scores), Bayesian least significant difference (BLSD) separations ($k=100$), and ranks of standard hybrids.

RESULTS AND DISCUSSION

Symptoms ranged from slight disease to severely infected plants (Tables 6,7). Reactions of standard hybrids to Stewart's wilt, common rust, NLB, MDM, and SLB were relatively similar to mean reactions from previous trials (Table 1). The criteria for classifying hybrid reactions from the 2010 nursery are listed in Table 2. Table 7 includes disease

reactions and ratings of 439 hybrids **based solely on the 2010 trial**. This is the only data available for some of these hybrids. For hybrids that have been evaluated previously, an assessment of disease reactions based on multiple trials is the best estimate of hybrid performance.

Stewart's wilt. Stewart's wilt ratings (1 to 9) ranged from 1.5 to 7 with a mean of 4. Forty-six hybrids that were rated 5.4 or higher (i.e., frequent systemic infection) were classified as moderately susceptible to susceptible. Symptoms of Stewart's wilt were predominately non-systemic (rated less than 2.8) on 36 hybrids classified as resistant or resistant/moderately resistant. An additional 52 hybrids were classified as moderately resistant. Five hybrids rated 2 or below had highly resistant reactions. These included: Bonus, C1-7GFJ, Harvest Gold, Mirai 336 BC, and Sumptuous. If Stewart's wilt infection is non-systemic (i.e., ratings <3), yield is affected minimally, if at all.

Northern leaf blight. Severity of NLB (% leaf area symptomatic) ranged from 3% to 60% in all trials and averaged 30% in the race 0 trial and 27% in the race 1 trial. In the race 0 trial, 158 hybrids had chlorotic lesions indicative of *Ht*-gene resistance. Mean severity of NLB was 23% in both the race 0 and race 1 trials for those 158 hybrids; whereas for the 281 hybrids that did not have an *Ht*-resistant reaction, NLB severity averaged 34% and 29% in the race 0 and race 1 trials, respectively. Therefore, it appears that NLB severity was about 1/5 less severe (about 5% less leaf area infected) on hybrids with *Ht*-reactions in the race 0 as a result of resistance conveyed by an *Ht* gene.

Severity was 11% or less on seven hybrids classified as resistant to both races, including HMX 9349 WS, HMX 9355 S, HMX 9389 S, HMX 9390 S, HMX 9394 S, SEM 132, and Sweet Cynthia. An additional 59 hybrids were classified from R to MR for both races with 21% or less leaf area infected. The effects of NLB on yield are minimal when severity is below 20%. Fifty-eight of the 66 hybrids with R to MR reactions to both races had *Ht*-resistant reactions; 51 were sh2; and 5 each were su, se, or bt endosperm mutants. Of the 32 hybrids with the most severe reactions to both races of NLB ($\geq 43\%$ severity), 23 were sh2 and 9 were su. None of the most susceptible hybrids had an *Ht*-resistant reaction.

Among hybrids that did not have *Ht*-resistant reactions, the correlation between NLB severity in race 0 and race 1 trials was 0.86. Among the hybrids with *Ht* reactions, the correlation between NLB severity in race 0 and race 1 trials was 0.80.

Maize dwarf mosaic. Incidence of MDM-infected plants ranged from 0 to 100% and averaged 67% and 76% at ratings made 1 wk (early) or 2-3 wk (late) after inoculation, respectively. Most hybrids (247) were classified as susceptible with >60% and >90% symptomatic plants at the early and late ratings, respectively. An additional 66 hybrids were classified as moderately susceptible/susceptible with >50% and >80% symptomatic plants at the early and late ratings, respectively. All hybrids classified as MS/S or S probably are completely susceptible (i.e., they do not carry genes for MDM resistance) although a few plants escaped infection.

Most of the 167 hybrids classified from R to M/MS (less than 80% incidence 2-3 wk after inoculation) probably carry the *Mdm1* gene although many may be heterozygous for this gene and/or may not carry additional "modifier" genes necessary for complete resistance to MDM. Consequently, 'MDM-resistant' hybrids displayed a range of responses. MDM-infected plants were not observed for 20 hybrids classified as resistant, including: 0875 5821, Code 1024, Code 1038, Code 1040, DMX 21-06, Enterprise, GH 6225, GH 6377P, GG Code 220, HMX 9389S, Hybrix 51, Legion, Max, SEM 115, SEM 130, SEM 135, SEM 150, Sweet Cynthia, UY 2587 OQ, and UY 2611 OQ. The incidence of symptomatic plants was 5% or less for an additional 12 hybrids classified as resistant. Forty-five hybrids were classified R/MR or moderately resistant with less than 20% incidence. An additional 29 hybrids with 20% to 70% MDM-infected plants were classified from MR/M to M/MS

Hybrids with R to M/MS reactions to MDM ($\leq 60\%$ incidence) were prevalent among su endosperm types (34 of 64), common among sh2 endosperm types (66 of 300) but relatively uncommon among se endosperm types (3 of 69).

Southern leaf blight. SLB ratings (1 to 9 scale) ranged from 1 to 8 and averaged 4.3. SLB was clearly more severe in this trial than in any previous UI disease nursery, probably due to an extended period of high temperatures and humidity. Ratings were 6 or above for 82 hybrids classified as MS to S. Ninety-nine hybrids rated below 3.5 were classified from R to MR. Nine of 11 hybrids rated below 2 and classified as resistant are adapted for tropical rather than temperate climates.

Common rust. Low levels of D-virulent and G-virulent *P. sorghi* occurred in all rust trials but this contamination was not prevalent early in the season when Rp-resistant reactions were rated soon after inoculation. However, as a consequence of the spread

of contaminant inocula, rust severity at fresh market harvest was not necessarily 0% on all Rp-resistant hybrids. For example, the hybrid Bonus, which carries the *Rp1-D* gene, had 10% and 7% leaf area infected in the avirulent and G-virulent trials as a result of D-virulent inocula spreading to those trials (Table 3). In comparison, rust severity was 21% on Bonus in the D-virulent trial in which the *Rp1-D* gene was ineffective against the virulent race. Similar reactions were observed on other hybrids with *Rp1-D* resistance, such as GSS 1477. Likewise, hybrids with *Rp-G* or *Rp1-I* genes, such as GH 2171 or GH 4927, were infected by contaminant inocula that was virulent against those genes (Table 3). Rust did not occur on hybrids that carried multiple Rp genes, such as Winstar (*Rp1-D* + *Rp1-I*) and Garrison (*Rp1-D* + *Rp-G*).

Table 3. Reactions of hybrids with known Rp genes in trials inoculated with different isolated of *Puccinia sorghi*

Hybrid (Rp genes)	Rust severity (%)		
	avirulent	D-virulent	G-virulent
Bonus (<i>Rp1-D</i>)	10	21	7
GSS 1477 (<i>Rp1-D</i>)	13	23	11
GH 2171 (<i>Rp-G</i>)	5	0	26
GH 4927 (<i>Rp1-I</i>)	6	0	23
Winstar (<i>Rp1-D</i> + <i>Rp-G</i>)	0	0	0
Garrison (<i>Rp1-D</i> + <i>Rp1-I</i>)	0	0	0

shaded areas - should be 0, rust due to contaminant inocula

Eighty hybrids were Rp-resistant in all three trials. Most of these hybrids probably carry the *Rp1-D* gene that conveys resistance to G-virulent isolates and an Rp gene that conveys resistance to D-virulent isolates (e.g., *Rp-G*, *Rp1-E*, or *Rp1-I*). Each inbred parent may contribute a different Rp gene or one inbred may contribute multiple Rp genes via “compound rust resistance” in which combinations of various Rp genes are closely linked in coupling phase, e.g., *Rp1-DGJ*, *Rp1-JFC*, or *Rp-GFJ*. Hybrids that segregated for Rp reactions to one or more isolates of *P. sorghi* are designated Rp* in Table 7.

An additional 62 hybrids were Rp-resistant to avirulent and D-virulent isolates, but susceptible in the G-virulent trial where severity ranged from 7% to 50% on these hybrids. These hybrids probably carry the *Rp-G*, *Rp1-I*, or *Rp1-E* gene. The remaining 121 Rp-resistant hybrids were resistant in the avirulent and G-virulent trials, while rust severity on these hybrids ranged from 6% to 37% in the D-virulent trial. These hybrids probably carry the *Rp1-D* gene.

Among the 174 hybrids that were not Rp-resistant, rust severity ranged from 8% to 50%, 7% to 48%, and 11% to 58% in the avirulent, D-virulent,

and G-virulent trials, respectively. Ten hybrids were rated MR or better in all three trials including: Captain, GG 74, Incredible, Lancelot, Merlin, Miracle, PAC 612750, SEM 122, Sumptuous, and Synergy R. Eighteen hybrids with an average rust severity of 37% or higher were classified as MS to S in all three trials. Another 13 hybrids were classified MS to S in two of three trials.

Reactions to herbicides. Reactions to Accent and Capreno, two cytochrome P450-metabolized herbicides, were based on stunting (i.e., plant height expressed as a percentage of non-treated plots) and visual ratings of injury. Most hybrids (317) were classified tolerant (1) with no injury and little or no stunting. Eighty-one hybrids were classified as tolerant of one herbicide and moderately tolerant (3) of the other. Nine hybrids were severely injured or killed by both herbicides and were classified as sensitive (9), including: 177A, 3175, 0870 5770, Code 1038, DMC 20-38, GSS 5763, HMX 6386S, Merit, and UY 2587 OQ. Four of these nine hybrids are known to be homozygous for a mutant cytochrome P450 (CYP) allele that conditions sensitivity to several P450-metabolized, post-emergence herbicides. An additional 29 hybrids were classified as moderately sensitive (7) to moderately tolerant (3) to both herbicides. These hybrids probably are heterozygous for a mutant and functional CYP allele.

Based on previous research, 57 hybrids were known to be homozygous or heterozygous for CYP alleles that condition herbicide reactions. All four hybrids that were homozygous for the mutant cyp allele that conditions sensitivity were killed by Capreno or Accent (Table 4). Only two of the 34 hybrids that were homozygous for the functional CYP allele that conditions tolerance were mildly injured by Capreno. Of 19 hybrids that were heterozygous for mutant and functional CYP alleles, about half were mildly to moderately injured by Capreno (3 or 5) and a quarter were mildly to moderately injured by Accent (3 or 5).

Table 4. Reactions of hybrids with known CYP alleles to Capreno (tembotriione + thiencarbazone-methyl) and Accent (nicosulfuron)

		Number of hybrids per category								
		Capreno				Accent				
		1	3	5-7	9	1	3	5-7	9	
Homozygous sensitive	<i>cyp cyp</i>	0	0	0	4	0	0	0	4	
Heterozygous	<i>CYP cyp</i>	10	7	2	0	14	4	1	0	
Homozygous tolerant	<i>CYP CYP</i>	32	2	0	0	34	0	0	0	

Category: 1-tolerant, 3-moderately tolerant, 5-moderate, 9-sensitive

Table 5. Protocol for the 2010 University of Illinois sweet corn hybrid disease nursery

Field, trial, and planting date	Inoculated	Rated
641-49 (May 24)		
avirulent rust (2 reps)	June 7, 10, 15, 17, 22, 28, 30	June 28-29 (Rp), July 27-28
MDM	June 7, 10	June 16 (early), 30 (late)
M5S (May 24)		
NLB race 0	June 8, 9, 15, 18	July 29
G-rust (2 reps)	June 7, 9, 11, 15, 18, 21	June 29-30 (Rp), July 26-27
Cruse 1000W (May 26)		
D-rust	June 14, 17, 21, 23, 28, 30	June 30 (Rp), July 29
Stewart's wilt	June 14, 16	June 29
SLB	June 17, 21, 30	July 30
NLB race 1	June 14, 17, 21, 22, 29	August 2
Capreno (2 reps)	June 18	June 28-29
Accent (2 reps)	June 18	June 28-29
Cruse 1000W (June 4)		
Stewart's wilt	June 23, 25	July 6-7
MDM	June 21, 24	June 30 (early), July 7 (late)
NLB race 0	June 22, 23, 25, 29; July 2, 6, 13	August 8
D-rust	June 21, 23, 25, 28, 30; July 6, 12	August 6-7
SLB	June 30; July 6, 12	August 7
NLB race 1	June 22, 23, 25, 29; July 2, 6, 13	August 8-9

Table 6. Number of hybrids in each category from the 2010 University of Illinois sweet corn disease nursery

Trial	Rp	Resistant		MR 3	Moderate			MS 7	Susceptible	
		1	2		4	5	6		8	9
Common rust										
avirulent	263	3	12	16	28	46	36	17	8	8
D-virulent	143	5	4	16	36	119	68	38	6	3
G-virulent	200	2	17	32	18	80	39	25	12	10
NLB race 0										
Ht-resistant rxn		18	19	36	35	34	8	7	1	0
no Ht-resistant rxn		0	1	11	25	83	55	43	48	14
NLB race 1	20	23	38	43	149	62	64	22	17	
Stewart's wilt	5	30	52	106	129	67	29	10	7	
MDM	32	36	9	18	6	5	20	66	247	
SLB	11	27	61	50	155	50	40	34	8	
Capreno		339		80		8		0		9
Accent	380		42		3		2			9

Participating seed programs

AC	Abbott & Cobb	GG	Green Giant	MKS	Mikado Kyowa
Adv	Advanta/Pacific	HARC	Hawaiian Agr. Res.	PV	Pop Vriend
Cent	Centest	HM	Harris Moran	Rog	Rogers (Syngenta)
Cr	Crookham Co.	IFS	Illinois Foundation Seeds	Sem	Seminis (Monsanto)
DM	Del Monte	MM	Mesa Maize	SnRv	Snowy River

