Working out the Mechanisms of Host Plant Resistance in Sorghum and Forage Sorghum to the Sugarcane Aphid

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Cooperative work with:

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Sugarcane Aphid Task Force

Many others……Including Chromatin, Advanta U.S., Alta Monsanto, B&H Genetics, Pioneer, Warner Seeds, .

1. Hosts Range of the SCA.
2. Greenhouse screening, GB sources, industry sources.
3. Field evaluations for SCA resistance, TA&M breeders.

All aphids used were from an established colony collected from Matagorda Co. Texas (Bay City), by Clyde Crumley from grain sorghum, August 2013, used for all screening trials.

Hosts of the Sugarcane aphid in the U. S. ?????

Host	Cultivar
Forage sorghum	AF7301
Johnsongrass	Local (Stillwater)
Sugarcane	“Weslaco”
Proso Millet	Alan Mindemann
Field Corn	“B73”
Teff Grass	“Tiffany”
Winter Wheat	“Tam 101”
Rye	“Elbon”
Barley	“812”

Hosts of the Sugarcane aphid in the U. S. ?????

Host	Cultivar	Damage Rating (1-9)	Mean number of SCA /plant	Difference in Plant height (cm)
Forage sorghum	AF7301	8.0 ± 0.84	1150 ± 51	20.7 ± 2.97
Johnsongrass	Stillwater	6.3 ± 1.29	1229 ± 95	16.4 ± 6.81
Sugarcane	“Weslaco”	3.3 ± 1.39	115 ± 15	0.00
Proso Millet	Local	NS	NS	NS
Field Corn	“B73”	NS	NS	NS
Teff Grass	Tiffany	NS	NS	NS
Winter Wheat	Tam 101	NS	NS	NS
Rye	Elbon	NS	NS	NS
Barley	812	NS	NS	NS

Table 1. Mean[a] Leaf number, number of nymphs, alates and damage rating for sugarcane aphids on different millets after being infested with 10 aphids and counted after 26 days infesting. Millets were infested at the 3 leaf stage.

Millet entry	Millet type	Leaf number	Mean nymphs	Mean alates	Mean damage (1-9)
EXCEED bmr	Pearl	6.5 ± 0.3 bc	18.3 ± 6.7 b	6.0 ± 0.7 a	1.0 ± 0.0
LEAFY 22	Pearl	6.5 ± 0.3 bc	39.3 ± 7.6 a	7.8 ± 1.1 a	2.8 ± 0.8
LEAFY 60	Pearl	6.3 ± 0.3 c	32.3 ± 4.5 ab	6.0 ± 0.9 a	2.5 ± 0.6
TIFLEAF 3	Pearl	8.0 ± 0.0 a	31.0 ± 9.7 ab	7.8 ± 1.4 a	2.5 ± 0.3
PROSO	Proso	7.0 ± 0.0 b	1.3 ± 0.5 c	0.3 ± 0.3 b	1.0 ± 0.0
MILLET 32	Pearl	7.0 ± 0.0 b	23.3 ± 6.3 ab	5.3 ± 2.2 a	3.5 ± 0.3
PARAKEET	Proso	6.8 ± 0.1 bc	0.25 ± 0.3 c	0.0 ± 0.0	1.0 ± 0.0

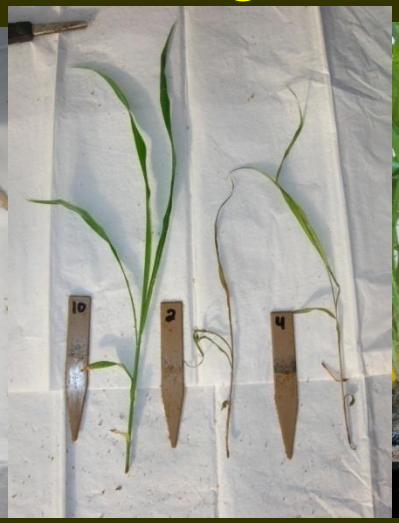
[a]Leaf number at time of evaluation; df = 6, 27, $F = 7.93$, P > F= 0.0001; Mean nymphs; df = 6, 27, $F = 7.93$, P > F= 0.0001; Mean alates; df = 6, 27, $F = 13.45$, P > F= 0.0001

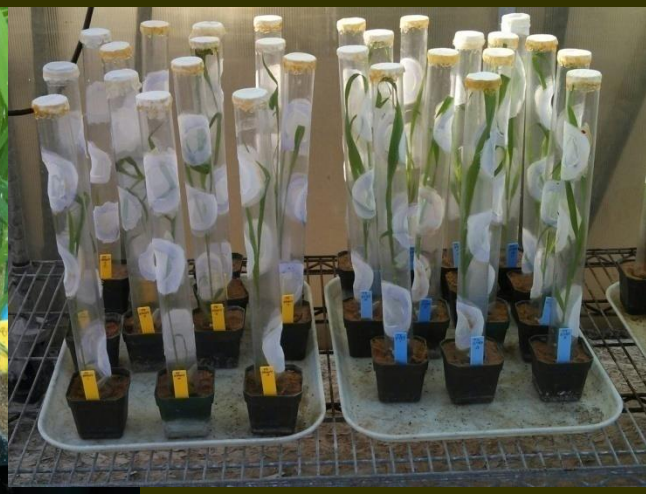
Mean damage (Webster 1992) 1= no damage, 9 =dead plant; df = 6, 27, $F = 6.42$, $P > F$= 0.0006

Sorghum host plant resistance – one of the best methods of preventing damage and controlling costs. What do we have from GB resistance???

HPR = antibiosis, antixenosis, tolerance

~~Chlorosis~~ Damage Ratings 1 – 9 damage scale



Free-choice test vs no-choice test, field evaluated

Ravenngrass or Sugarcane grass

Saccharum ravennae (L.) L. (Poaceae)

…… is a robust bunchgrass with culms up to 4 m tall, a native to northern Africa, temperate and tropical Asia, and southern Europe - Ravennagrass is commonly used in ornamental plantings in the US, where it has since escaped from cultivation and become naturalized in many areas. Besides its use as an ornamental, ravennagrass has been used for erosion control and livestock forage at young stages, genetic investigations as a gene source for plant breeding and as a bioenergy crop (Springer and Goldman, 2016).

Sorghum lines used to determine Greenbug differentials

Colony Selection	TX 7000	TX 2737	TX 2783	PI 550607
C	S	R	R	R
E	S	S	R	R
F			S	S
G	S	S	S	R
H				R
I	S	S	S	R
K	S	S	S	S

SCA used were from Matagora Co, TX Thanks to Clyde Crumley, United Ag Cooperative, Inc. Wharton TX

Biotype "E": TX 7000 and TX 2737 are susceptible, TX 2783 and PI 550607 are resistant

Biotype "I": TX 7000, TX 2737 and TX 2783 are susceptible. PI 550607 is resistant;

Biotype "K": PI 550607, TX 7000, TX 2737 and TX 2783 are all susceptible.

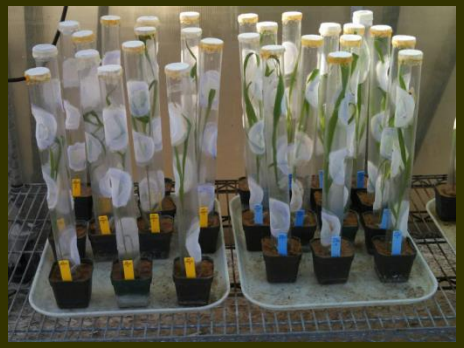
M 627 – Mycogen, now Dow Ag. Sci. Biotypes C, E, I and K greenbugs

PI 550610 – recently discovered to be a little better than 550607, by IRI studies.

PI 264453 – From Spain (Africa) 1960, resistant to GB C and E. Parent to many commercial lines

Evaluation #1 - host plants / resistance

Crop	Cultivar
Grain Sorghum	TX 7000
Grain Sorghum	TX 2737
Grain Sorghum	TX 2783
Grain Sorghum	PI 550607
Grain Sorghum	PI 550610 <
Grain Sorghum	M 627 <
Grain Sorghum	JS222 <
Grain Sorghum	PI 264453 <
Forage sorghum	AF7301 <
Johnsongrass	_ Very good
Sugarcane	<
Proso Millet	
Field Corn	B73
Teff Grass	
Winter Wheat	Tam 101
Rye	Elbon
Barley	812



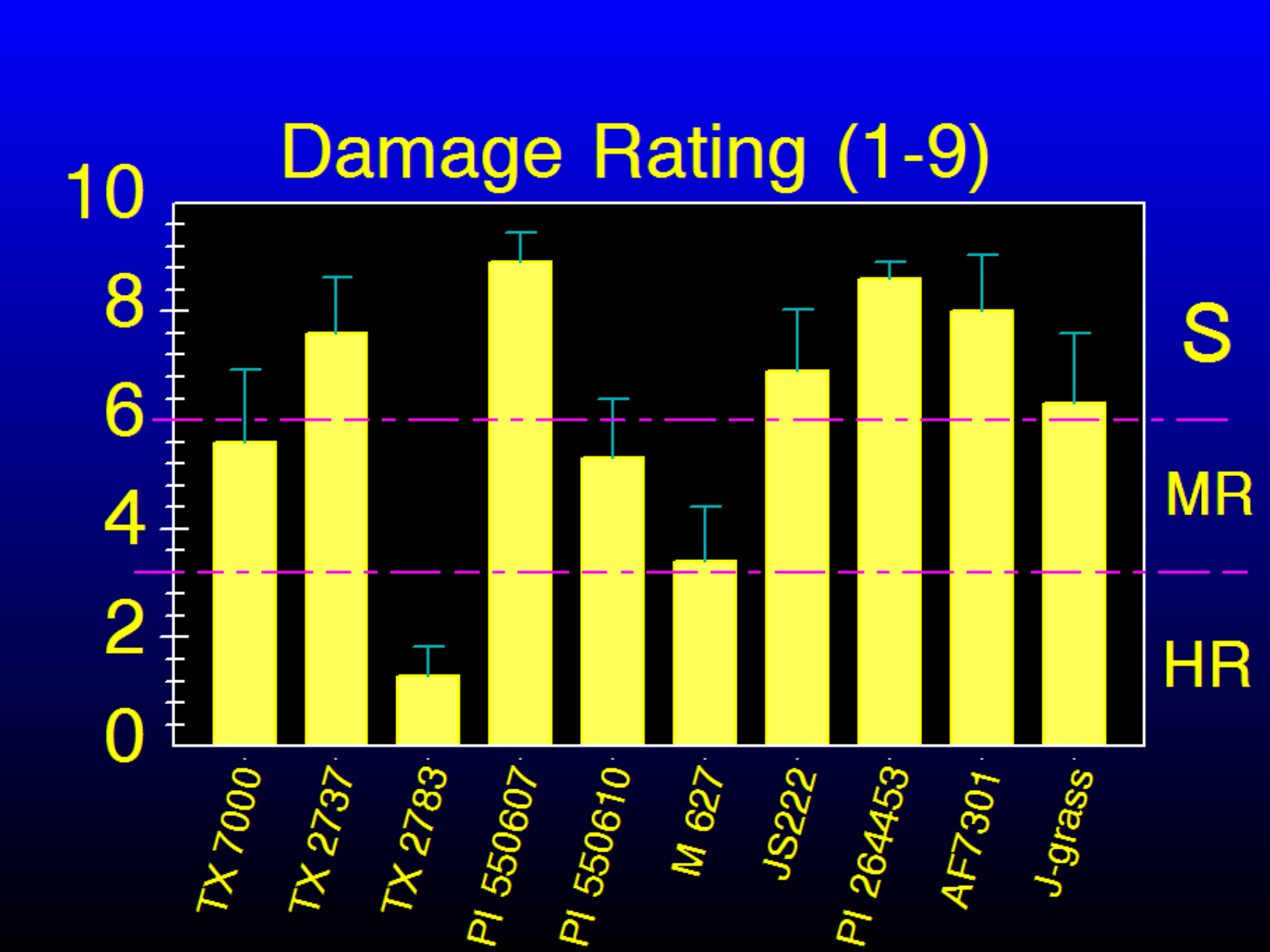
Infested October 28, 2013 / 10 aphids per plant,

when plants were 2-3 leaves.

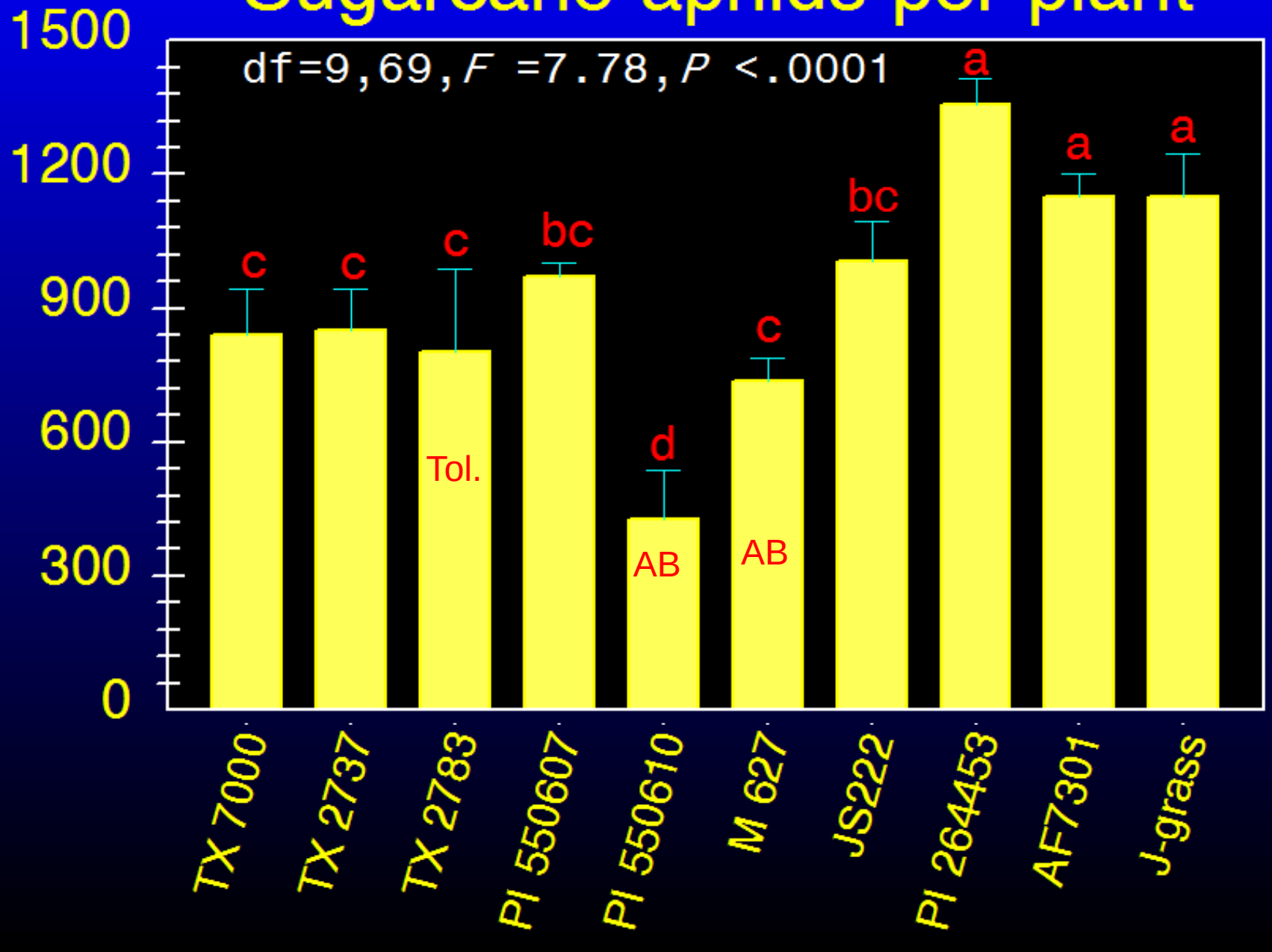
Evaluated 12 November, 2013 for:

Chlorosis / Damage rating (1 – 9)

Plant height, Leaf number (node number)

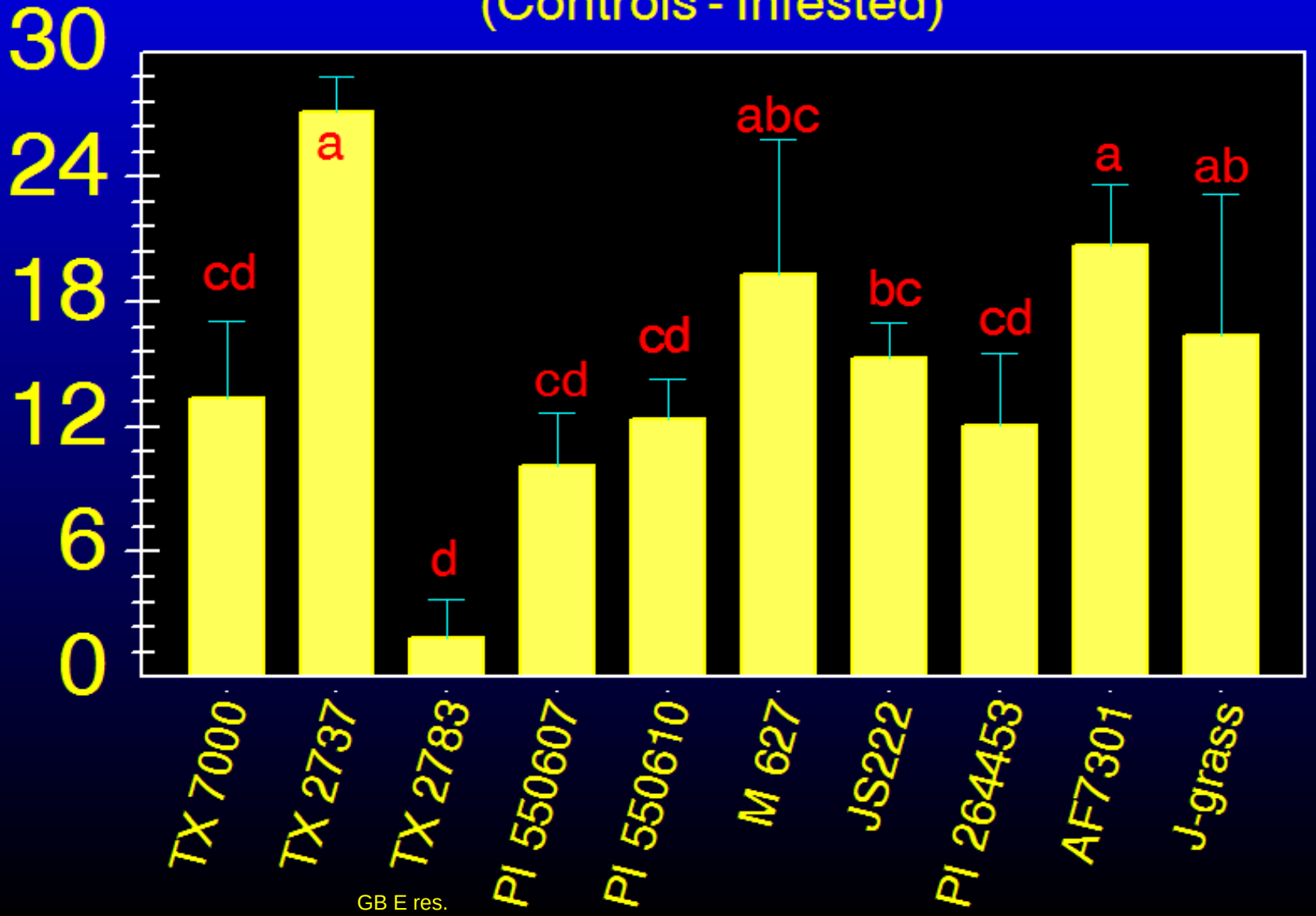

Damage Rating (1-9)
10
8
6
4
2
0
S
MR
HR
TX 7000
TX 2737
TX 2783
PI 550607
PI 550610
M 627
JS222
PI 264453
AF7301
J-grass

Sugarcane aphids per plant



Difference in plant height (cm)

(Controls - Infested)



GB E res.

Up to this point we have:

Looked at the hosts plants and discovered they are in the *sorghi* genus, johnsongrass, sugarcane, sugarcane grass

Discovered cross resistant sources of sorghum to GB and SCA

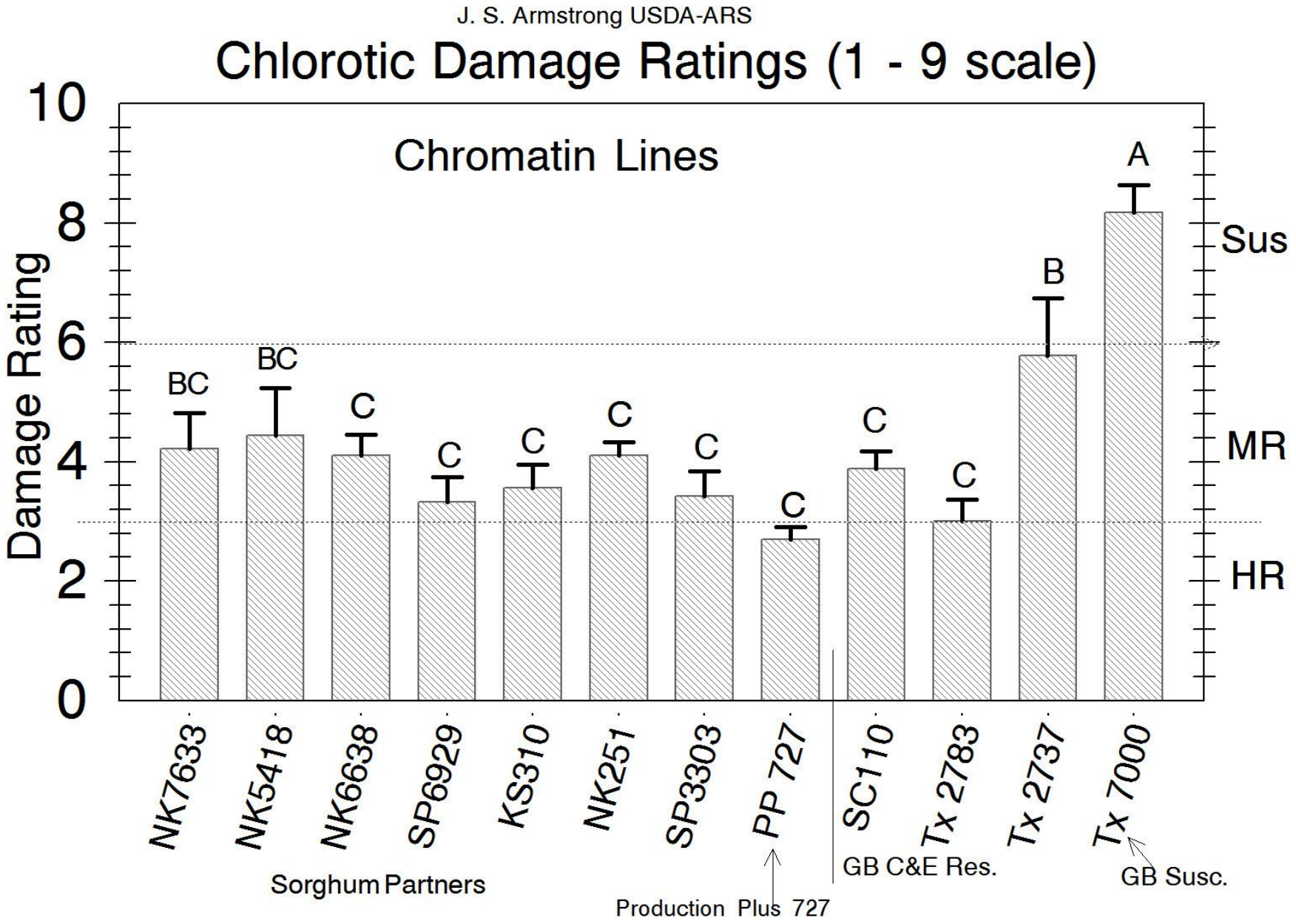
But wait – there's more!!!!

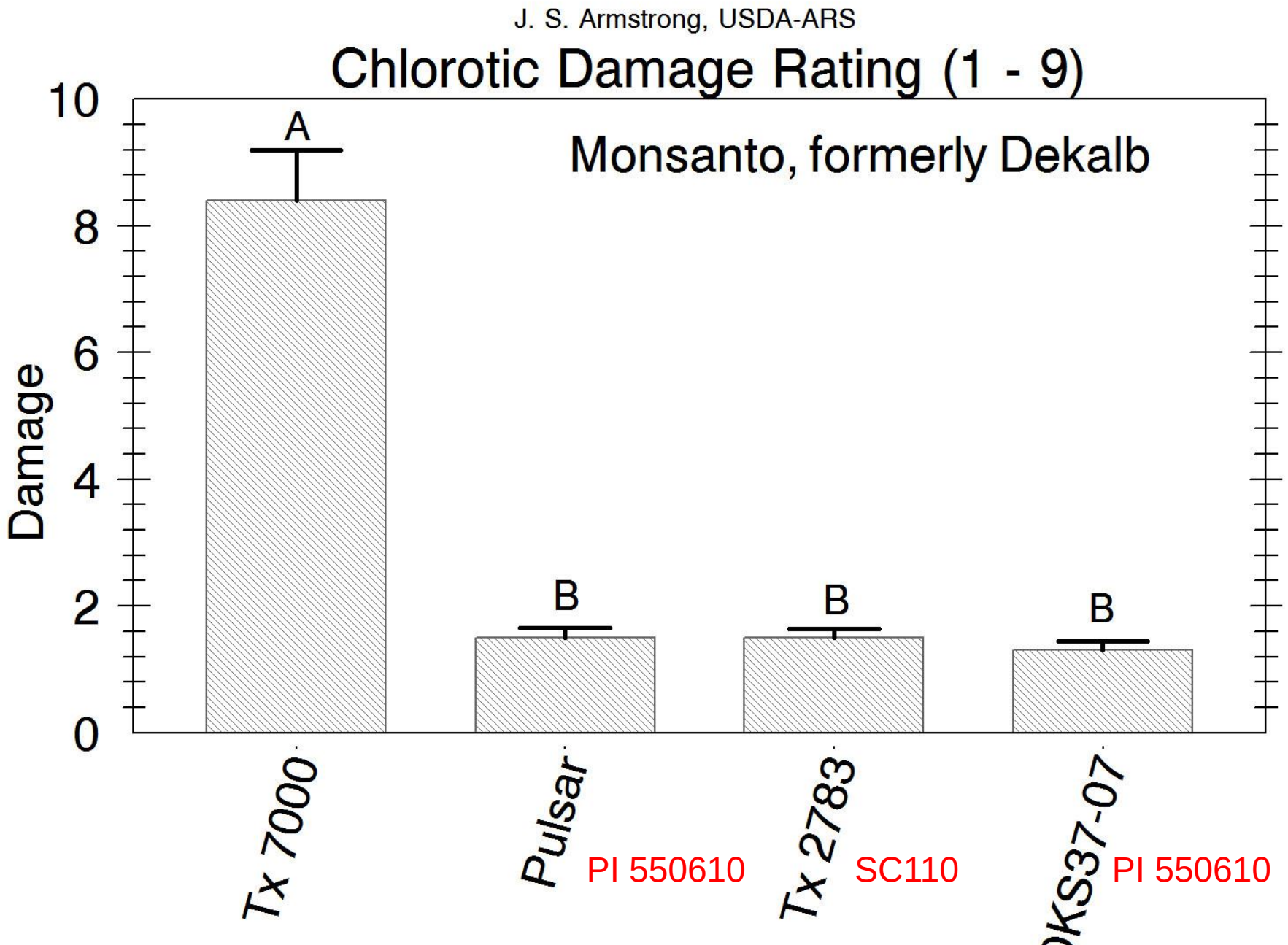
2014 &15 Replicated Free-choice Evaluations:

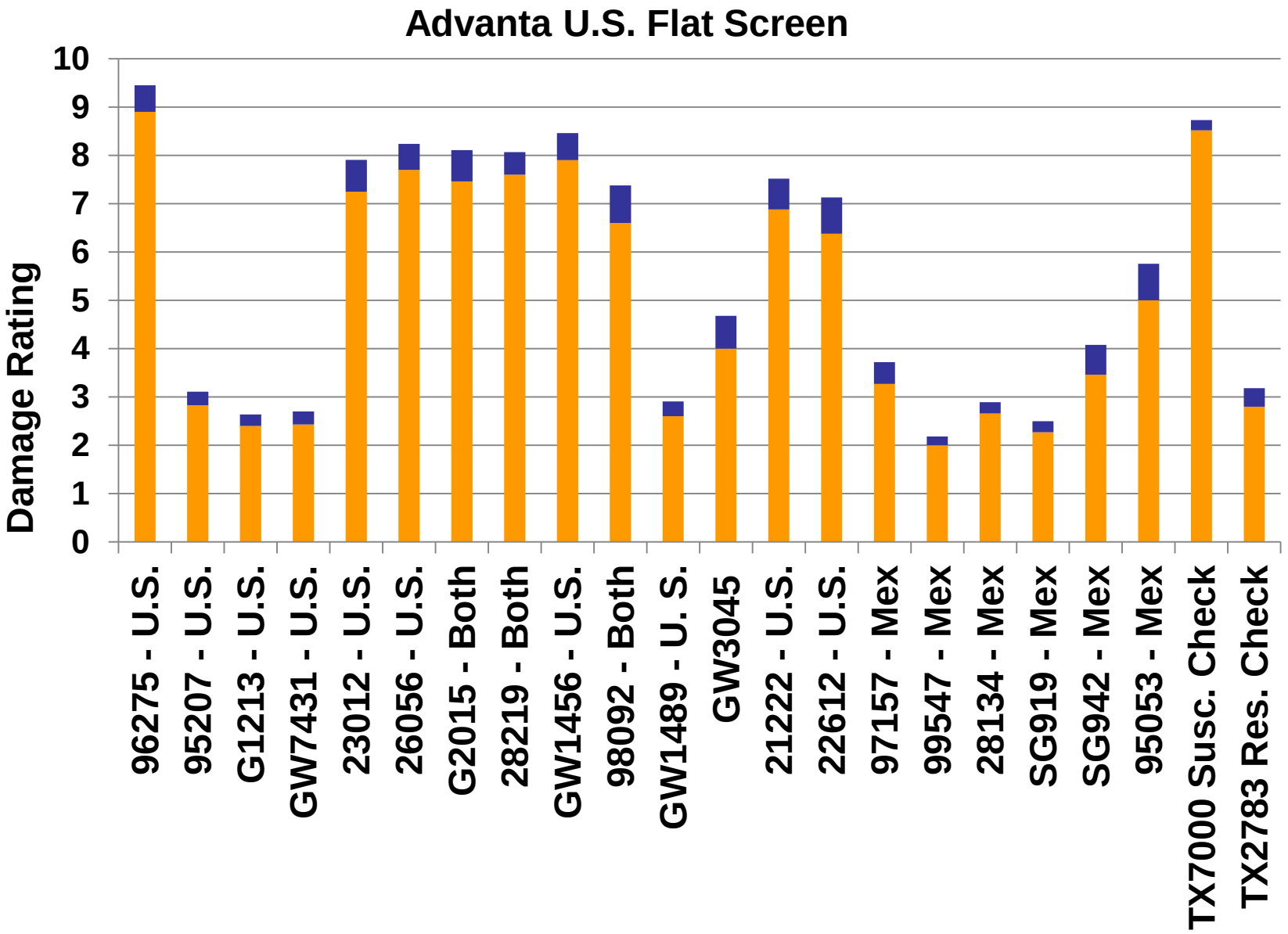
Monsanto (Dekalb), Chromatin, B&H Genetics,

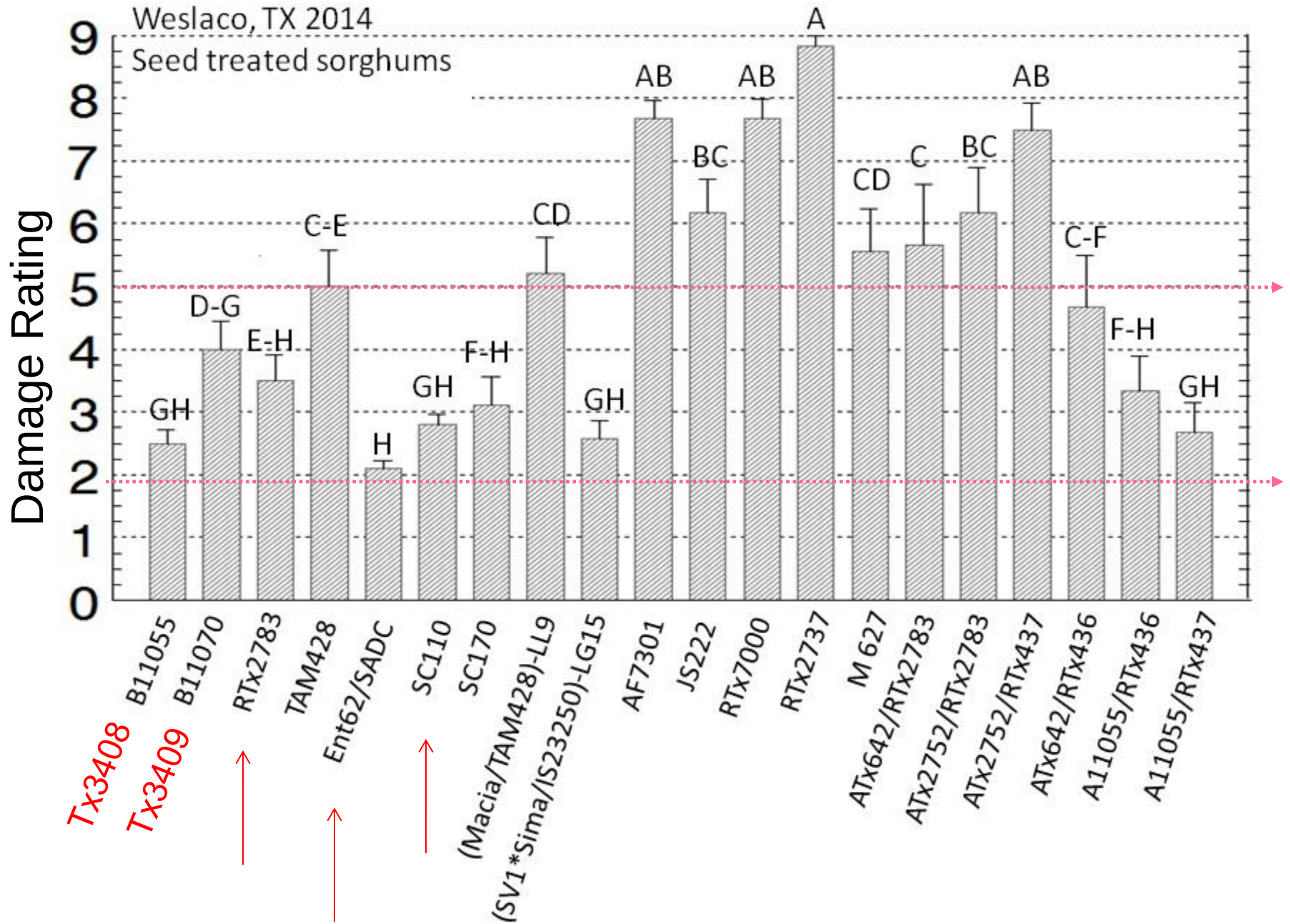
Dow/Mycogen (Agrigenetics), Adavanta US, Pioneer

Webster et al. 2001, 1–9 Damage rating scale


J. S. Armstrong USDA-ARS
Chlorotic Damage Ratings (1 - 9 scale)
Chromatin Lines
Damage Rating
10
8
6
4
2
0
Sus
MR
HR
BC
BC
C
C
C
C
C
C
C
C
B
A
NK7633
NK5418
NK6638
SP6929
KS310
NK251
SP3303
PP 727
SC110
Tx 2783
Tx 2737
Tx 7000
Sorghum Partners
Production Plus 727
GB C&E Res.
GB Susc.


J. S. Armstrong, USDA-ARS
Chlorotic Damage Rating (1 - 9)
Monsanto, formerly Dekalb
Damage
10
8
6
4
2
0
A
B
B
B
Tx 7000
Pulsar
Tx 2783
OKS37-07
PI 550610
SC110
PI 550610


Advanta U.S. Flat Screen
Damage Rating
10
9
8
7
6
5
4
3
2
1
0
96275 - U.S.
95207 - U.S.
G1213 - U.S.
GW7431 - U.S.
23012 - U.S.
26056 - U.S.
G2015 - Both
28219 - Both
GW1456 - U.S.
98092 - Both
GW1489 - U. S.
GW3045
21222 - U.S.
22612 - U.S.
97157 - Mex
99547 - Mex
28134 - Mex
SG919 - Mex
SG942 - Mex
95053 - Mex
TX7000 Susc. Check
TX2783 Res. Check


Weslaco, TX 2014
Seed treated sorghums
Damage Rating
0
1
2
3
4
5
6
7
8
9
GH
D-G
E-H
C-E
H
GH
F-H
CD
GH
AB
BC
AB
A
CD
C
BC
AB
C-F
F-H
GH
B11055
B11070
RTx2783
TAM428
Ent62/SADC
SC110
SC170
(Macia/TAM428)-LL9
(SV1*Sima/IS23250)-LG15
AF7301
JS222
RTx7000
RTx2737
M 627
ATx642/RTx2783
ATx2752/RTx2783
ATx2752/RTx437
ATx642/RTx436
A11055/RTx436
A11055/RTx437
Tx3408
Tx3409

Grain sorghum / forage sorghum resistance

“The genes are very similar”

And this is where we discover tolerance, antibiosis, and antixenosis are working together in some lines

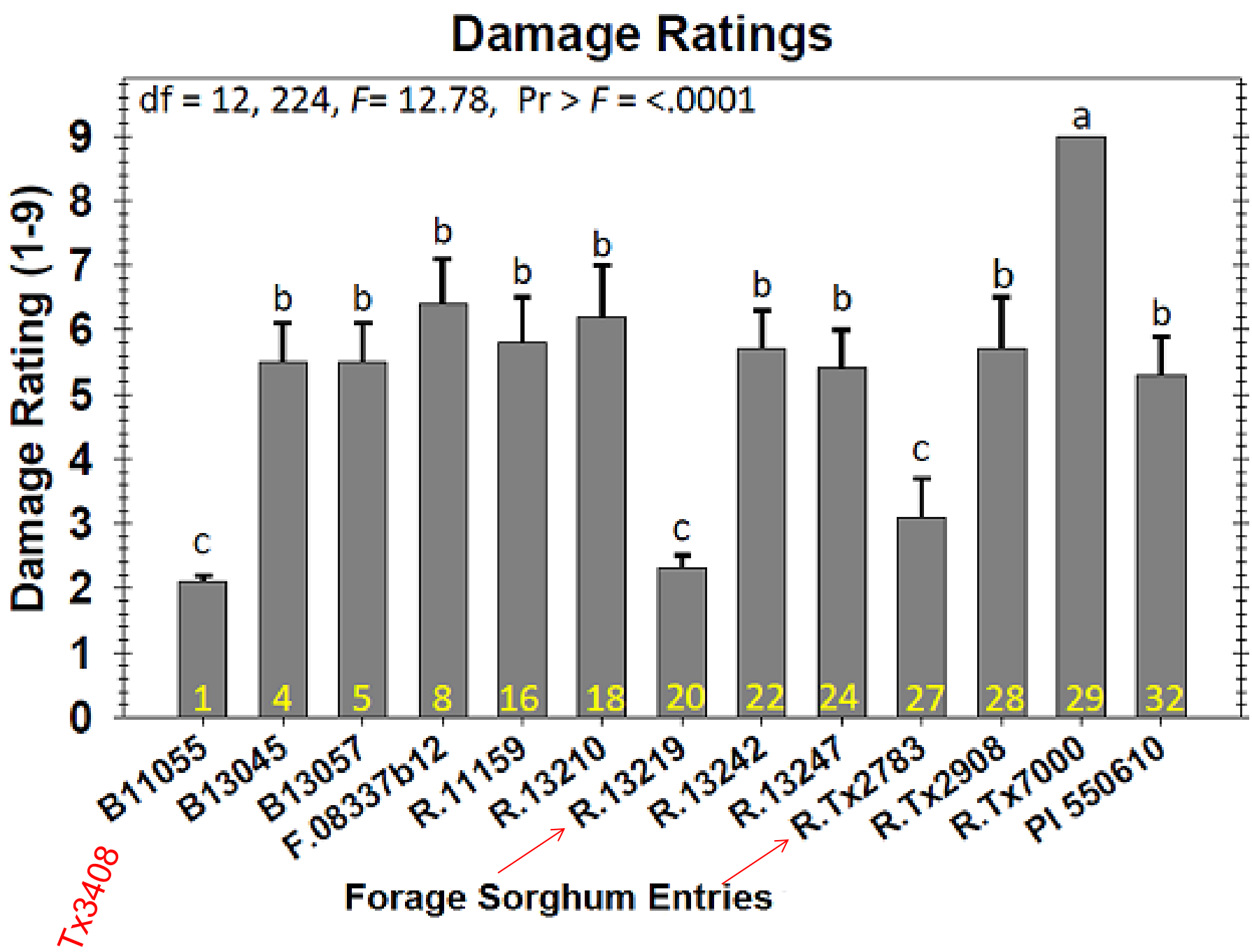

Damage Ratings
df = 12, 224, F= 12.78, Pr > F = <.0001
Damage Rating (1-9)
0
1
2
3
4
5
6
7
8
9
c
b
b
b
b
b
c
b
b
c
b
a
b
1
4
5
8
16
18
20
22
24
27
28
29
32
B11055
B13045
B13057
F.08337b12
R.11159
R.13210
R.13219
R.13242
R.13247
R.Tx2783
R.Tx2908
R.Tx7000
PI 550610
Tx3408
Forage Sorghum Entries

Table 3. Demographic statistics for M. sacchari (sugarcane aphid) on thirteen forage sorghum entries.

Cultivar	Entry	rm	λ	T (d)	DT (d)
B11055	1	0.21 ± 0.02 ef	1.23 ± 0.03 e	12.73 ± 0.51 ab	3.85 ± 0.51 bc
B13045	4	0.34 ± 0.03 b	1.41 ± 0.04 b	10.02 ± 0.26 d	2.21 ± 0.26 def
B13057	5	0.43 ± 0.04 a	1.55 ± 0.05 a	8.66 ± 0.36 e	1.85 ± 0.36 ef
F.08337b12	8	0.32 ± 0.03 bc	1.39 ± 0.03 bc	11.60 ± 0.17 b	2.25 ± 0.17 def
R.11159	16	0.36 ± 0.02 ab	1.44 ± 0.05 b	10.02 ± 0.10 d	1.96 ± 0.10 def
R.13210	18	0.35 ± 0.02 b	1.43 ± 0.05 b	10.29 ± 0.27 cd	2.19 ± 0.27 def
R.13219	20	0.20 ± 0.03 ef	1.22 ± 0.03 e	11.51 ± 11.5 bc	4.00 ± .054 ab
R.13242	22	0.30 ± 0.03 bcd	1.36 ± 0.04 bc	11.66 ± 0.24 b	2.47 ± 0.24 def
R.13247	24	0.29 ± 0.04 bcd	1.35 ± .05 bcd	9.87 ± 0.46 de	2.82 ± 0.46 cde
R.Tx2783	27	0.17 ± 0.02 f	1.19 ± 0.03 e	13.81 ± 0.64 a	5.02 ± 0.64 a
R.Tx2908	28	0.25 ± 0.04 cde	1.29 ± 0.05 cde	10.30 ± 0.64 cd	3.73 ± 0.64 bc
R.Tx7000	29	0.44 ± 0.02 a	1.55 ± 0.01 a	9.89 ± 0.12 de	1.59 ± 0.12 f
PI 550610	32	0.23 ± 0.01 def	1.25 ± 0.08 de	13.70 ± 0.10 a	3.06 ± 0.10 bcd

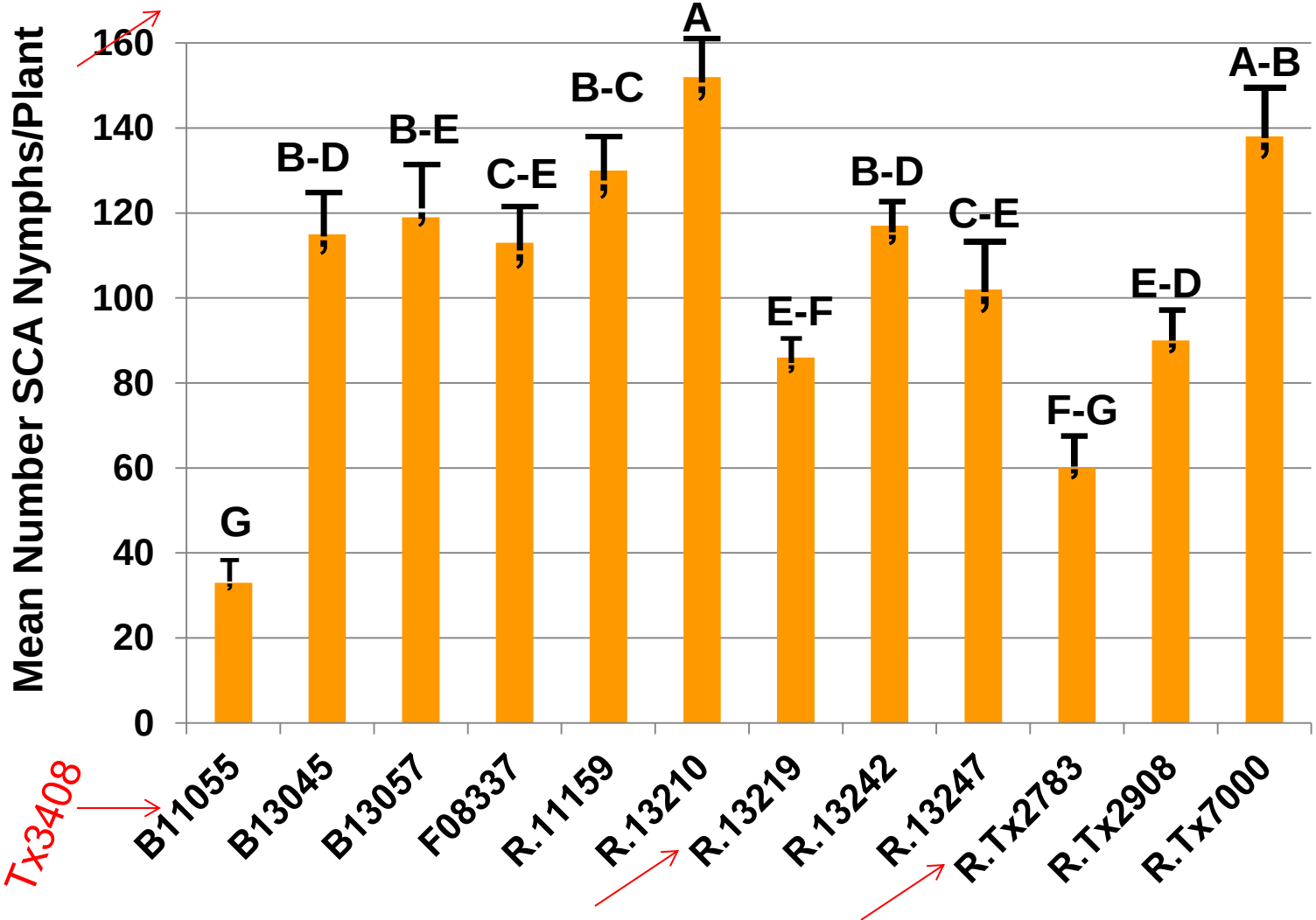
Column means followed by the same lowercase letters are not significantly different, $P > 0.05$; LSD.
rm = intrinsic rate of increase; df = 12, 128, F = 10.04; $P > F = < 0.0001$.
λ = finite daily rate of increase, df = 12, 128; $F = 10.06$; $P > F = < 0.0001$.
T = generation time in d; df =12, 128, $F = 11.53$; $P > F = < 0.0001$.
DT (d); df = 12, 128, $F = 6.83$, $P > F = < 0.0001$.

Table 2. Life table parameters for M. sacchari (sugarcane aphid) progeny produced from synchronous female cohorts and developmental statistics on thirteen forage sorghum entries.

Cultivar	Entry	Pre-reproductive Period (d)	Reproductive Period (d)	Fecundity (Md)	Nymphs/ ♀ / d	Female Longevity (d)
B11055	1	9.9 ± 0.4 a	14.0 ± 2.9 bc	16.6 ± 2.9 fg	1.0 ± 0.1 d	23.4 ± 3.1 bcd
B13045	4	7.4 ± 0.5 d	18.9 ± 2.5 b	37.1 ± 6.3cde	1.7 ± 0.2 bc	26.3 ± 2.8 bcd
B13057	5	6.4 ± 0.2 e	19.2 ± 2.7 b	56.5 ± 8.8 ab	2.3 ± 0.3 b	25.6 ± 2.5 bcd
F.08337b12	8	8.6 ± 0.5 bc	20.4 ± 2.5 b	42.3 ± 5.9 bc	1.8 ± 0.2 b	29.0 ± 2.5 ab
R.11159	16	7.5 ± 0.2 d	19.2 ± 1.9 b	40.0 ± 5.7 cd	1.8 ± 0.3 b	26.6 ± 1.9 bc
R.13210	18	7.6 ± 0.3 cd	19.1 ± 3.7 b	42.8 ± 8.1 bc	1.9 ± 0.3 b	27.4 ± 3.6 bc
R.13219	20	8.5 ± 0.5 bc	11.2 ± 2.1 c	10.4 ± 1.8 g	0.9 ± 1.2 d	13.7 ± 2.0 def
R.13242	22	8.6 ± 0.4 b	19.4 ± 2.0 b	35.1 ± 5.5 cde	1.7 ± 0.3 bc	28.0 ± 2.0 bc
R.13247	24	7.3 ± 0.3 de	12.1 ± 2.6 c	28.5 ± 8.0cdef	1.9 ± 0.2 b	19.3 ± 2.7 ef
R.Tx2783	27	10.2 ± 0.1 a	7.7 ± 1.9 c	11.3 ± 2.7 g	1.2 ± 0.1cd	17.9 ± 1.9 f
R.Tx2908	28	7.6 ± 0.3 dc	10.6 ± 2.6 c	23.9 ± 7.4 defg	1.7 ± 0.3bc	18.2 ± 2.6 f
R.Tx7000	29	7.3 ± 0.2 d	27.6 ± 0.8 a	61.3 ± 2.8 a	3.9 ± 0.1a	34.9 ± 2.7 a
PI 550610	32	10.1 ± 0.3 a	11.2 ± 2.1 c	23.8 ± 2.0efg	1.7 ± 0.2 bc	21.3 ± 1.9 cdef

Column means followed by the same lowercase letters are not significantly different, $P > 0.05$; LSD.
Pre-reproductive period (d) df = 12, 116, F = 11.54; $P >$ F = < 0.0001.
Reproductive period (d) = 12, 116; $F = 5.41$; $P > F =$ < 0.0001.
Fecundity (Md); df = 12, 116, $F = 7.72$; $P > F =$ < 0.0001.
Nymps/♀/d; = (Md/d), df = 12, 116, $F = 11.17$, $P > F =$ < 0.0001.
Female Longevity (d), df = 12, 116, $F = 4.24$; $P > F =$ <0.0001.

Non-preference / Antixenosis test
Texas A&M Breeders Lines



Google: "Sorghum Checkoff" and "pest management"

Grain Sorghum Hybrids with Some Tolerance to the Sugarcane Aphid

Several commercial hybrids are being sold that have shown some degree of tolerance to the sugarcane aphid. In most cases the hybrids have exhibited the ability to withstand higher infestation populations of aphids without affecting yield or the aphids have been shown to increase in number much slower than in susceptible hybrids.

Sound, integrated pest management strategies must still be utilized with these hybrids and the application of an insecticide may still be warranted if action thresholds are reached.

The list below has been put together after visiting with seed company representatives and reviewing various university data. Check with your seed company for other hybrids that they may consider as having some degree of tolerance to the sugarcane aphid.

Company/Brand	Hybrid*	Maturity
Pioneer	83P17	Med-Full
Pioneer	83P56	Med-Full
DEKALB	37-07	Med-Early
DEKALB	Pulsar	Med-Early
Sorghum Partners	SP 7715	Med-Full
Sorghum Partners	SP 78M30	Med-Full
Sorghum Partners	SP 73B12	Med-Full
Richardson	RS260E	Med-Full
Richardson	Sprint W FG	Med-Early
Richardson	Jowar I	Full
Richardson	Swift	V. Early
Alta	AG1201	Early
Alta	AG1301	Med-Early
Alta	AG1203	Med-Early
Mycogen	627	Med-Early
Mycogen	1G688	Medium
B-H Genetics	BH 4100	Medium
B-H Genetics	BH 3400	V Early
Warner Seed	W-844-E	Med-Full
Warner Seed	W-7051	Med-Full
Golden Acres	3960B	Med

**All of these hybrids may need to be treated with an insecticide if the action threshold is reached.*

Summary:

SCA host range is within the Sorghum (*bicolor, halepense*) and *Saccharum officinarum genotypes.*

TX 2783 from SC110 shows tolerance and AB, and is the basis for resistance. Antibiosis is within PI 550610 (i.e. DKS 37-07)

Several other commercial lines from the TX 2783 background have high tolerance and AB (Monsanto, Chromatin, Alta (Adavanta US), B&H Genetics, Warner,).

B. Rooney, G. Peterson, L. Mbulwe, & S. Armstrong - released 2 parental lines Tx3408 Tx3409 for breeding for SCA resistance, this is all good news for sorghum breeding programs.

B. Rooney, Armstrong, L. Mbulwe, Will release 2 parental lines that have excellent resistance in forage sorghum.

Thanks Very Much!

Bill Rooney, Texas A & M

Raul Villanueva, Daniella Sekula-Ortiz, Texas AgriLife

The Weslaco and Corpus Christi, TX Experiment Stations.

Industry –

Chromatin, Larry Lambright, Sorghum Partners Rick Kochenower
B&H Genetics, Travis Janak
Advanta US, Travis Kidd, Ricardo Marquez
Monsanto, Mike Lenz, Ryan Bading
Pioneer, Roger Monk
Warner Seeds – Sanjeev Yalla

Dr. Scott Armstrong,
USDA-ARS

Dr. Rick Grantham
OSU Entomology and
Plant Pathology