BT RESISTANCE AND IMPLICATIONS FOR FUTURE PEST MANAGEMENT STRATEGIES

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PAST AND CURRENT BT COTTON TECHNOLOGIES

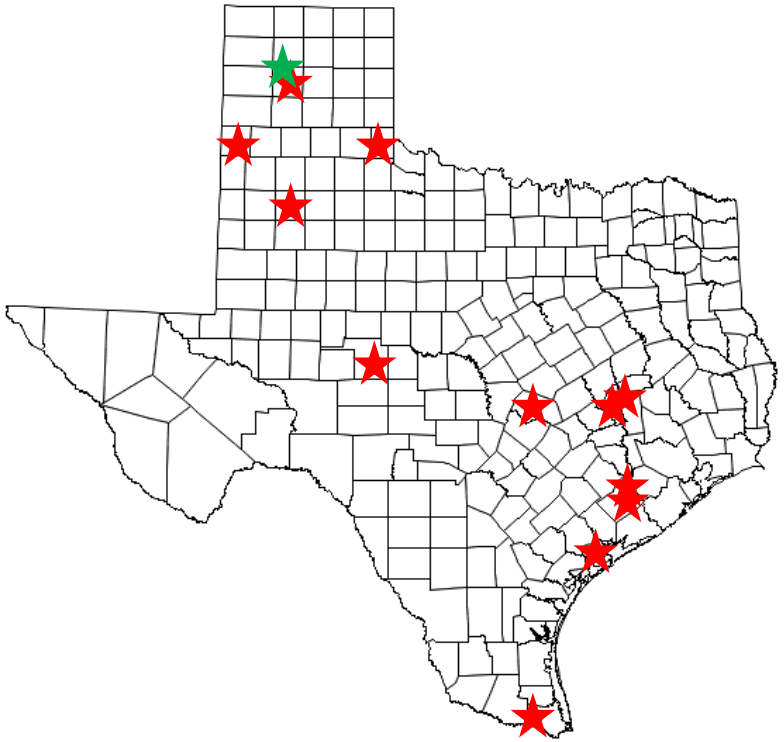
Company	1st generation (single gene)	2nd generation (dual gene)	3rd generation (multi-gene)	3rd generation (2017)
Bayer	Bollgard (Cry1Ac)	Bollgard 2 (Cry1Ac+Cry2Ab)		Bollgard 3 (Cry1Ac+Cry2Ab+Vip3A)
Corteva		WideStrike (Cry1Ac+Cry1F)	WideStrike 3 (Cry1Ac+Cry1F+Vip3A)	
BASF		TwinLink (Cry1Ab+Cry2Ae)		TwinLink Plus (Cry1Ab+Cry2Ae+Vip3A)
Homogeny across crops				
Crop	**Cry1A**	**Cry1F**	**Cry2**	**Vip3A**
Cotton	Cry1Ac, Cry1Ab	Cry1F	Cry2Ab, Cry2Ae	Vip3A
Corn	Cry1Ab	Cry1F	Cry2Ab2	Vip3A
	Cry1A.105 (Cry1Ab, Cry1Ac, Cry1F)			
Both crops	**Cry1As, Cry1F, Cry2As and Vip3A**			

SURVEY BIOASSAY PROCEDURE

- Bollworms/corn earworm collected from the field as larvae
- Overnight delivery to lab in College Station
- Reared to F1 or F2 generation and then bioassays
- Tested for response to Cry1Ac, Cry2Ab2, Cry1F and Vip3A
- Diet overlay bioassays
  - Test 6-8 Bt concentrations and a control
  - Used 16-32 neonate larvae, replicated 4 times for each concentration; allowed to feed for 7 days
- Record number alive/dead, instar and weight of survivors
- Compare field populations to a standard laboratory strain (Benzon)
  - Dead = Actual dead larvae + 1st instar larvae
  - Dose response bioassay: Probit analysis for LC50 and their 95% CL.
  - Resistance ratio = LC50 of a field population / LC50 of the susceptible strain.

TEXAS 2018 - CRY1AC

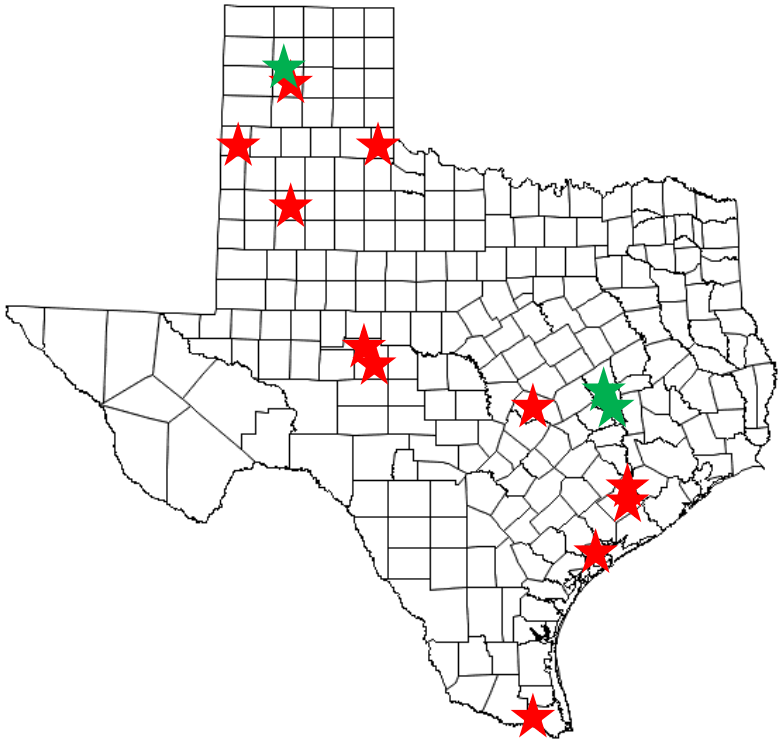
Insect strain	N[a]	LC_{50} (95% CL) ($\mu g/cm^2$)[b]	Slope ± SE	X^2	df	Resistance ratio[c]
CBW-BZ-SS-TAMU	958	0.10 (0.08, 0.11)	1.55 ± 0.09	28.4	26	1.0
CBW-TX-SS-TAMU	576	0.11 (0.08, 0.14)	1.39 ± 0.11	31.6	30	1.1
CBW-EC-TX-BG2	576	1.25 (0.76, 2.09)	1.33 ± 0.17	62.6	30	12.5 *
CBW-WH-TX-BG2	576	> 31.60	/	/	/	> 316.0 *
CBW-WE-TX-BG2	576	23.21 (11.78, 60.50)	0.59 ± 0.07	20.2	30	232.1 *
CBW-CS-TX-Bt corn	576	13.26 (8.34, 24.81)	1.19 ± 0.16	22.9	30	132.6 *
CBW-MU-TX-VT2P	576	16.41 (7.87, 50.04)	0.77 ± 0.11	42.3	30	164.1 *
CBW-Thrall-TX-SMT	576	22.91 (10.60, 73.70)	0.64 ± 0.09	40.8	30	229.1 *
CBW-Wall-TX-VT3P	576	14.80 (8.46, 32.67)	0.98 ± 0.13	52.6	30	148.0 *
CBW-AM-TX-NBt corn	576	10.70 (8.55, 13.63)	1.94 ± 0.20	24.0	30	107.0 *
CBW-LB-TX-NBt corn	576	8.15 (3.59, 28.21)	0.71 ± 0.12	103.8	30	81.5 *
CBW-LI-TX-NBt corn	576	> 31.60	/	/	/	> 316.0 *
CBW-PLV-TX-GS	576	10.66 (5.33, 29.81)	1.02 ± 0.18	46.3	30	106.6 *
CBW-BZ-SS-UWG	724	0.14 (0.10-0.19)	1.62 ± 0.12	9.56	7	1.0
College St-TX-NBt corn	281	15.2 (6.02-68.4)	0.53 ± 0.26	1.56	6	108.6 *
Amarillo-TX-NBt corn	442	0.14 (0.02-0.48)	0.73 ± 0.07	25.8	6	1.0



92.9% with RRs > 10X

TEXAS 2018 – CRY2AB2

Insect strain	N[a]	LC_{50} (95% CL) (µg/cm^2)[b]	Slope ± SE	X^2	df	Resistance ratio[c]
CBW-BZ-SS-TAMU	960	0.20 (0.17, 0.24)	1.61 ± 0.09	30.7	26	1.0
CBW-TX-SS-TAMU	448	0.69 (0.51, 0.95)	1.89 ± 0.22	32.2	22	3.4
CBW-EC-TX-BG2	448	4.94 (2.69, 10.68)	1.12 ± 0.19	53.4	22	24.7 *
CBW-WH-TX-BG2	448	5.63 (2.66, 21.46)	1.06 ± 0.22	40.3	22	28.2 *
CBW-WE-TX-BG2	448	> 10.00	/	/	/	> 50.0 *
CBW-CS-TX-Bt corn	448	1.50 (0.85, 2.58)	1.16 ± 0.17	74.7	22	7.5
CBW-MU-TX-VT2P	448	5.42 (3.64, 8.60)	1.14 ± 0.13	39.2	22	27.1 *
CBW-Thrall-TX-SMT	448	2.66 (2.06, 3.46)	1.43 ± 0.12	30.3	22	13.3 *
CBW-Wall-TX-VT3P	448	4.99 (1.05, 203.08)	0.59 ± 0.21	175.8	22	25.0 *
CBW-AM-TX-NBt corn	448	6.67 (3.85, 15.24)	0.98 ± 0.14	26.2	22	33.4 *
CBW-LB-TX-NBt corn	448	2.49 (1.19, 7.84)	0.77 ± 0.15	63.1	22	12.5 *
CBW-LI-TX-NBt corn	448	9.02 (4.81, 23.46)	0.71 ± 0.09	32.1	22	45.1 *
CBW-PLV-TX-GS	448	2.22 (1.78, 2.76)	1.93 ± 0.16	22.6	22	11.1 *
CBW-BZ-SS-UWG	300	0.20 (0.15-0.26)	2.25 ± 0.28	4.86	6	1.0
College St-TX-NBt corn	404	0.72 (0.28-1.89)	0.80 ± 0.08	15.9	6	3.60
Amarillo-TX-NBt corn	126	0.18 (0.01-0.66)	0.64 ± 0.14	5.56	6	0.90
San Angelo-TX-NBt corn	79	>31.6	/	/	/	> 158.0 *



71.4% with RRs > 10X

Population	Insect	N	LC_{50} (95% CI) (µg/cm²)	Slope ± SE	X^2	df	Resistance ratio
CBW-TX-SS	SS	512	0.70 (0.51, 0.67)	1.53 ± 0.15	40.2	26	-
CBW-G13-Cry2Ab2-RR	RR	512	286.35 (65.44, 5243)	0.41 ± 0.07	32.6	26	409.1*
F1a: RR♂*SS♀	F1a	512	14.96 (6.06, 105.08)	1.26± 0.37	43.3	26	21.4*
F1b: RR♀*SS♂	F1b	512	15.73 (8.88, 37.33)	1.18 ± 0.20	33.7	26	22.5*
Pooled F1	F1	1024	15.37 (9.48, 30.19)	1.20 ± 0.18	79.6	54	22.0*
F2a: F1a*F1a	F2a	512	43.33 (19.45, 151.42)	0.57 ± 0.08	27.4	26	61.9*
F2b: F1b*F1b	F2b	512	26.91 (17.40, 49.45)	1.08 ± 0.13	20.5	26	38.4*
Pooled F2	F2	1024	36.49 (20.99, 78.37)	0.73 ± 0.07	67.8	54	52.1*
BCS1: F1a♂*SS♀	BCS1	512	7.71 (6.39, 9.37)	2.56 ± 0.26	22.6	26	11.0*
BCS2: F1a♀*SS♂	BCS2	512	5.55 (2.58, 16.73)	1.02 ± 0.20	118.0	26	7.9
BCS3: F1b♂*SS♀	BCS3	512	6.32 (5.00, 8.15)	1.71 ± 0.16	27.4	26	9.0
BCS4: F1b♀*SS♂	BCS4	448	9.03 (4.65, 23.20)	1.64 ± 0.39	43.6	22	12.9*
BCR1: F1a♂*RR♀	BCR1	512	17.92 (15.37, 20.71)	4.93 ± 0.63	22.0	26	25.6*
BCR2: F1a♀*RR♂	BCR2	512	9.81 (7.94, 11.51)	4.19 ± 0.82	21.5	26	14.0*
BCR3: F1b♂*RR♀	BCR3	512	17.78 (15.32, 20.53)	4.88 ± 0.61	26.1	26	25.4*
BCR4: F1b♀*RR♂	BCR4	512	134.76 (29.44, 288792)	0.89 ± 0.31	33.3	26	192.5*

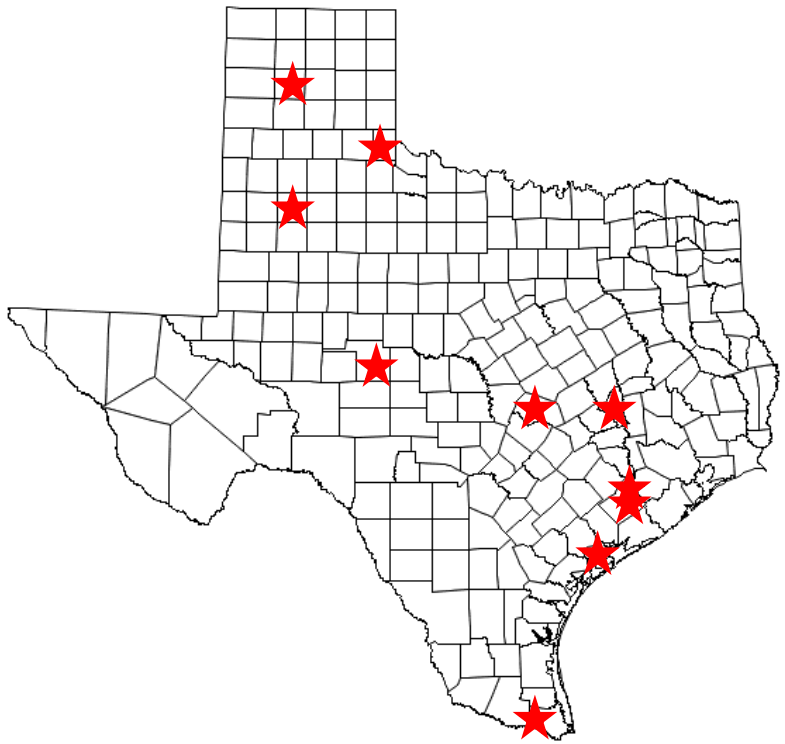
- Relative to the susceptible Benzon strain, the CBW-G13-Cry2Ab2-RR is highly resistant to Cry2Ab2
- Resistance appears to be controlled by a single or several closely linked genes
- Resistance appears to be incompletely dominant
- There appears to be some influence on progeny resistance level depending on if the gene is carried by the male or female
- Appears more maternally than paternally controlled

FOCUS ON A CRY2AB2 RESISTANT STRAIN

Produced from an F2 screen for *H. zea* collected from grain sorghum in College Station, TX

TEXAS 2018 - CRY1F

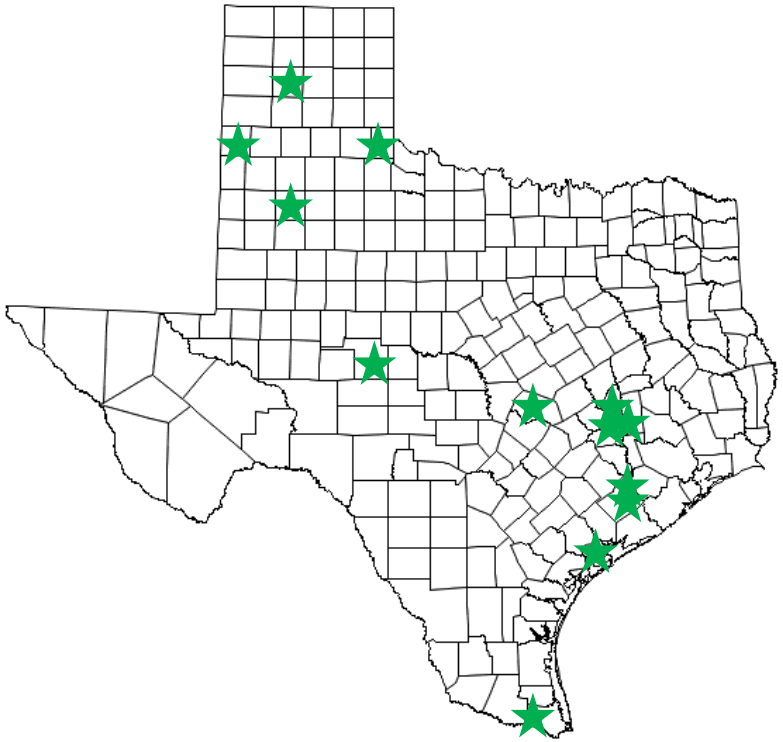
Insect strain	N[a]	LC_{50} (95% CL) ($\mu g/cm^2$)[b]	Slope ± SE	X^2	df	Resistance ratio[c]
CBW-BZ-SS-TAMU	512	0.73 (0.55, 0.97)	1.68 ± 0.15	28.9	26	1.0
CBW-EC-TX-BG2	512	>8.00	/	/	/	> 10.9*
CBW-WH-TX-BG2	512	>8.00	/	/	/	> 10.9*
CBW-WE-TX-BG2	512	>8.00	/	/	/	> 10.9*
CBW-CS-TX-Bt corn	512	>8.00	/	/	/	> 10.9*
CBW-Thrall-TX-SMT	512	>8.00	/	/	/	> 10.9*
CBW-Wall-TX-VT3P	512	>8.00	/	/	/	> 10.9*
CBW-AM-TX-NBt corn	512	>8.00	/	/	/	> 10.9*
CBW-LB-TX-NBt corn	512	>8.00	/	/	/	> 10.9*
CBW-LI-TX-NBt corn	512	>8.00	/	/	/	> 10.9*
CBW-PLV-TX-GS	512	>8.00	/	/	/	> 10.9*



100% with RRs > 10X

TEXAS 2018 – VIP3A

Insect strain	N[a]	LC_{50} (95% CL) (µg/cm²)[b]	Slope ± SE	X^2	df	Resistance ratio[c]
CBW-BZ-SS-TAMU	448	0.20 (0.16, 0.26)	1.48 ± 0.12	21.8	22	1.0
CBW-TX-SS-TAMU	448	0.16 (0.11, 0.25)	2.19 ± 0.36	28.0	22	-1.3
CBW-EC-TX-BG2	448	0.05 (0.04, 0.06)	2.76 ± 0.28	15.5	22	-4.0
CBW-WH-TX-BG2	448	0.04 (0.03, 0.05)	2.81 ± 0.29	18.2	22	-5.0
CBW-CS-TX-WS	448	0.37 (0.20, 0.71)	3.28 ± 0.97	26.8	22	1.9
CBW-WE-TX-BG2	448	0.03 (0.03, 0.04)	2.53 ± 0.27	6.8	22	-6.7
CBW-CS-TX-Bt corn	448	0.04 (0.03, 0.05)	2.81 ± 0.29	18.2	22	-5.0
CBW-MU-TX-VT2P	448	0.03 (0.02, 0.04)	1.83 ± 0.19	16.9	22	-6.7
CBW-Thrall-TX-SMT	448	0.08 (0.07, 0.10)	2.11 ± 0.19	13.2	22	-2.5
CBW-Wall-TX-VT3P	448	0.16 (0.12, 0.22)	2.28 ± 0.29	22.0	22	-1.3
CBW-CS-TX-Leptra corn	448	0.84 (0.69, 0.97)	4.93 ± 1.01	19.0	22	4.2
CBW-AM-TX-NBt corn	448	0.15 (0.13, 0.18)	2.82 ± 0.28	17.2	22	-1.3
CBW-LB-TX-NBt corn	448	0.17 (0.15, 0.20)	4.22 ± 0.50	2.2	22	-1.2
CBW-LI-TX-NBt corn	448	0.10 (0.08, 0.12)	2.50 ± 0.23	22.9	22	-2.0
CBW-PLV-TX-GS	448	0.09 (0.07, 0.11)	2.82 ± 0.28	16.0	22	-2.2



0% with RRs > 10X

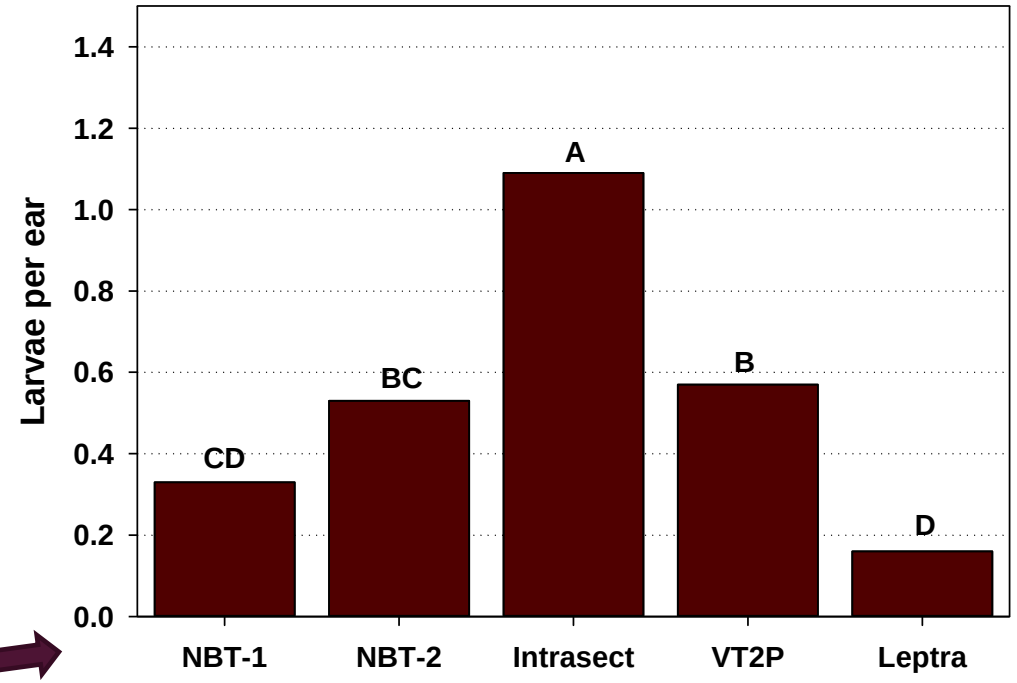
BT RESISTANCE SURVEY SUMMARY MID-SOUTH AND TEXAS

Percentage of populations expressing RR exceeding 10X					
2016[1]		2017		2018	
Cry1Ac	40%	Cry1Ac	100%	Cry1Ac	90.09%
Cry2Ab2	80%	Cry2Ab2	76.92%	Cry2Ab2	67.65%
Cry1F	ND	Cry1F[2]	28.5-100%	Cry1F	100%
Vip3A	0%	Vip3A	0%	Vip3A	0%

[1]Small sample size from the Mid-South; Bad Cry1F toxin
[2]RRs were >5.4 or >10.9, depending on highest concentration tested. Data suggests "true" RRs likely all exceeded 10X for all populations

PRELIMINARY DATA 2019 – RESISTANCE RATIOS

Insect strain	Cry1Ac	Cry2Ab	Vip3A39
CBW-AR-LE-VT2P	>31.60	22.10	2.44
CBW-AR-TR-VT2P	>31.60	40.30	0.94
CBW-LA-AA-VT2P	89.70	75.75	1.44
CBW-MS-SE-Leptra	23.70	10.25	13.81
CBW-MS-SE-VT2P	>31.60	192.75	0.50
CBW-MS-SK-VT2P	>31.60	100.50	1.00
CBW-TN-JN-BG2	>31.60	238.45	2.00
CBW-TX-HB-VT2P	60.10	15.70	1.88
CBW-TX-JN-BG2	>31.60	>50.00	1.25
CBW-TX-LK-NBt corn	>31.60	36.65	1.75
CBW-TX-NA-BG2	>31.60	95.90	0.50
CBW-TX-SK-Leptra	5.70	11.45	4.13
CBW-TX-SK-BG3	--	10.9	3.19
CBW-TX-WH-NBt corn	>31.60	97.70	1.50
Percentage	92.3%	100%	7.1%



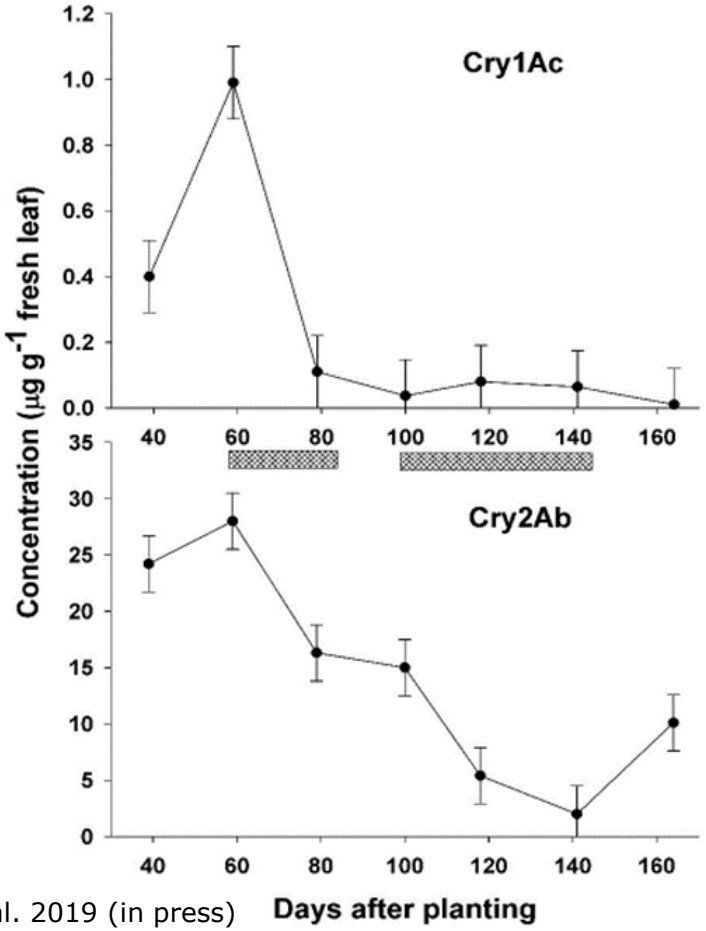
PRELIMINARY RESULTS FROM F2 SCREENS FOR BT RESISTANT ALLELES

F_2 families generated using light trap method from Snook, TX		
Bt toxin (discriminating dose)	Total F2 families tested	% H. zea F_2 families surviving the discriminatory dose (5 survivors with at least 1 larvae ≥ 3rd instar)
Cry1Ac (10 µg/cm2)	87	95.40
Cry2Ab2 (10 µg/cm2)	100	33.00
Vip3A (3 µg/cm2)	107	0.93
F_2 families generated from crosses with SS colony and feral collected in Alexandria, L.A. (VT2P)		
Bt toxin	Total F2 families tested	% H. zea F_2 families surviving the discriminatory dose (5 survivors with at least 1 larvae ≥ 3rd instar)
Cry1Ac (10 µg/cm2)	7	100.00
Cry2Ab2 (10 µg/cm2)	7	42.86
Vip3A (3 µg/cm2)	7	0.00
F_2 families generated from crosses with SS colony and feral collected in Stoneville, M.S. (VT2P)		
Bt toxin	Total F2 families tested	% H. zea F_2 families surviving the discriminatory dose (5 survivors with at least 1 larvae ≥ 3rd instar)
Cry1Ac (10 µg/cm2)	5	100.00
Cry2Ab2 (10 µg/cm2)	5	60.00
Vip3A (3 µg/cm2)	5	0.00

FIELD PERFORMANCE

EFFICACY OF BT COTTON TECHNOLOGIES AND VALUE OF TREATING WITH INSECTICIDE

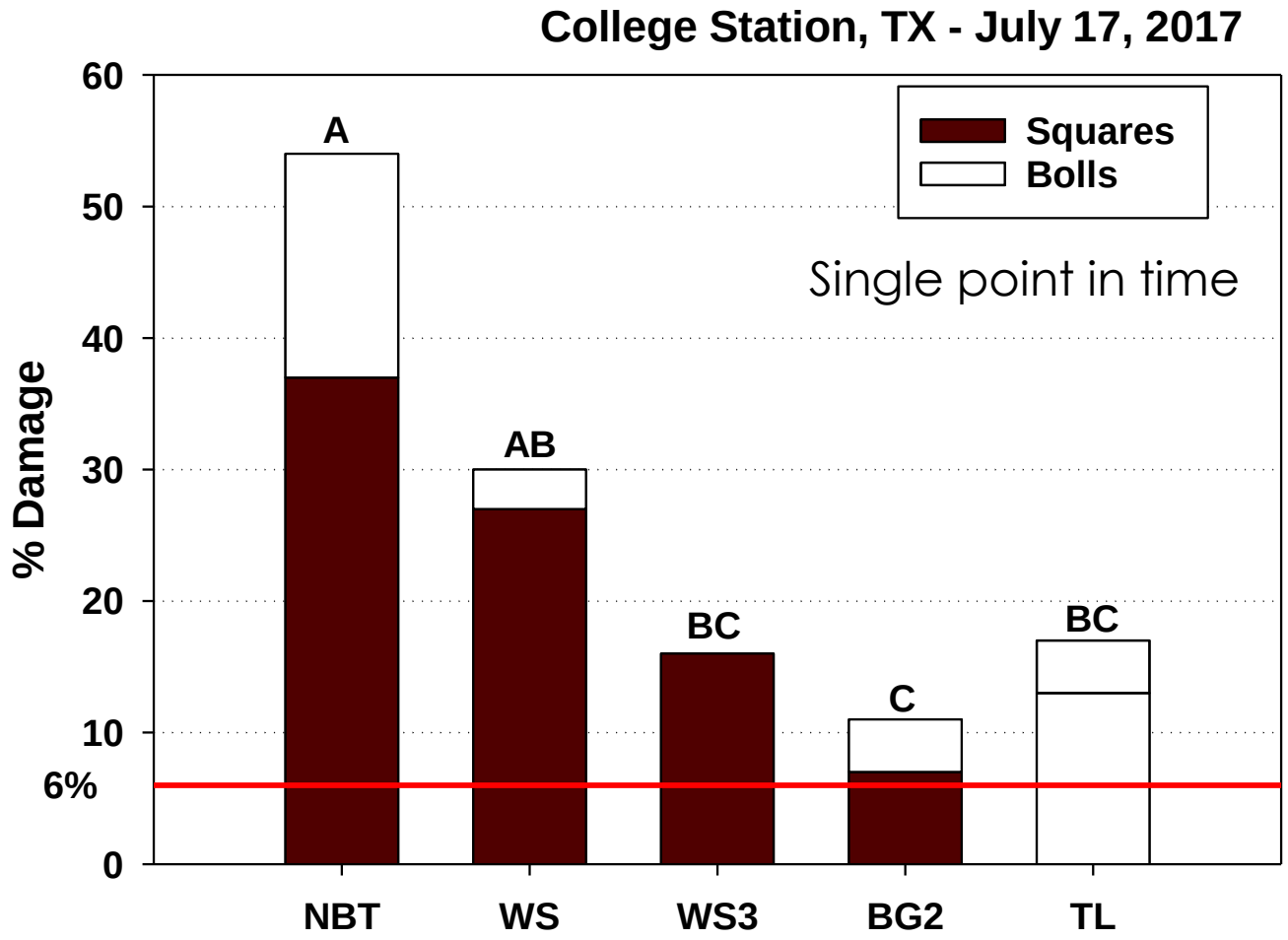
DECLINE IN BT EXPRESSION IN BG2



Carriere et al. 2019 (in press)

- Expression of Cry2Ab is about 4X that of Cry1Ac
- Seasonal
  - By 80 days (bloom) Cry1Ac and Cry2Ab2 expression declines
  - However, once expression declines, during bloom when its most needed, resistant bollworms are likely to survive
- Environmental stresses also affect Bt expression
- Varietal variation in Bt expression
- Different plant tissues express Bt at different levels
- Resistant strains of bollworms may still succumb to high expressing young plants
- Bollworms "seek out" lower expressing plant tissues
- We do not have data on Vip3A
- Pest pressure

BOLLWORM INJURY TO BT COTTON – COLLEGE STATION, TX



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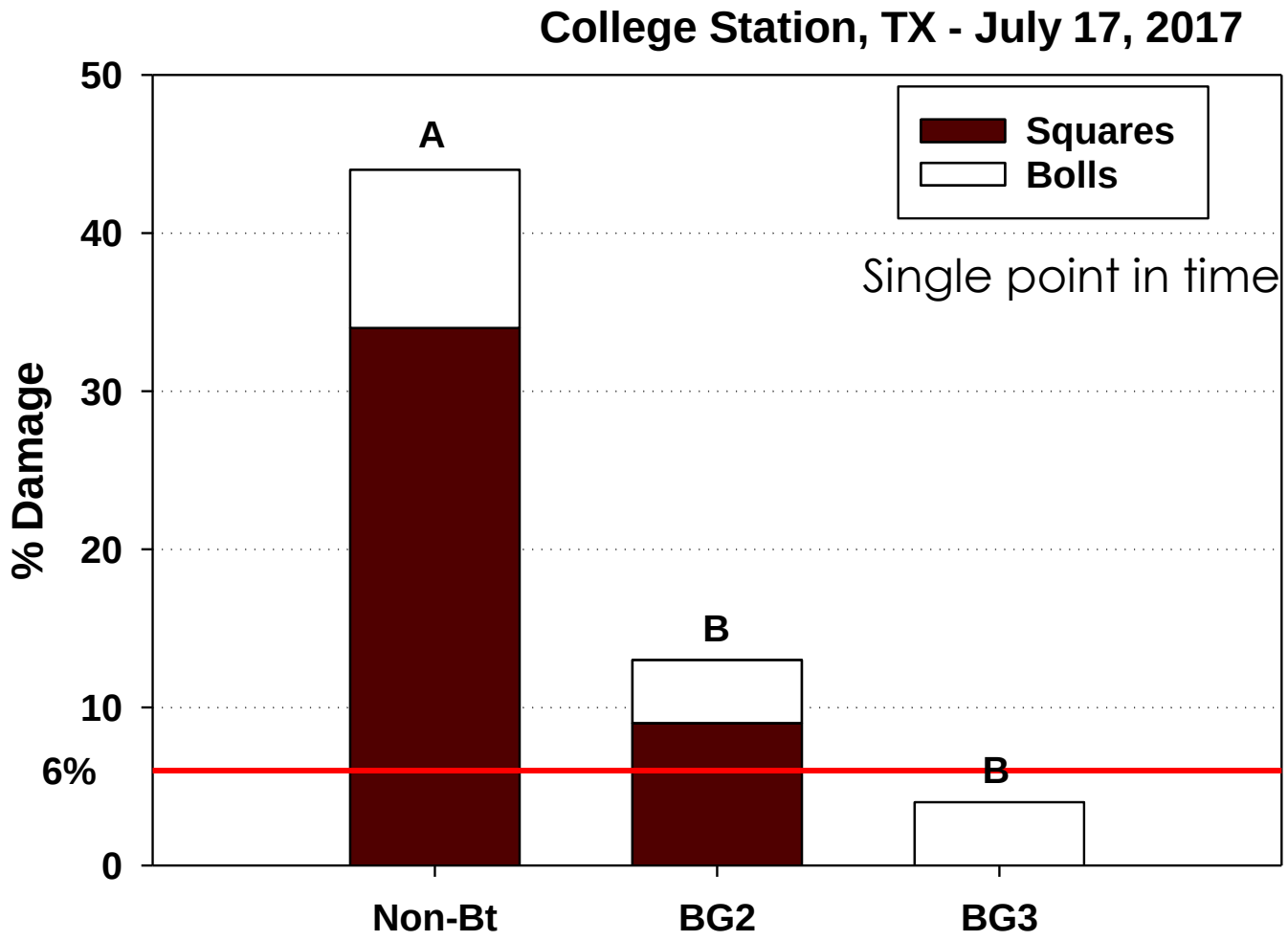
PERFORMANCE OF BOLLGARD 3 – COLLEGE STATION, TX



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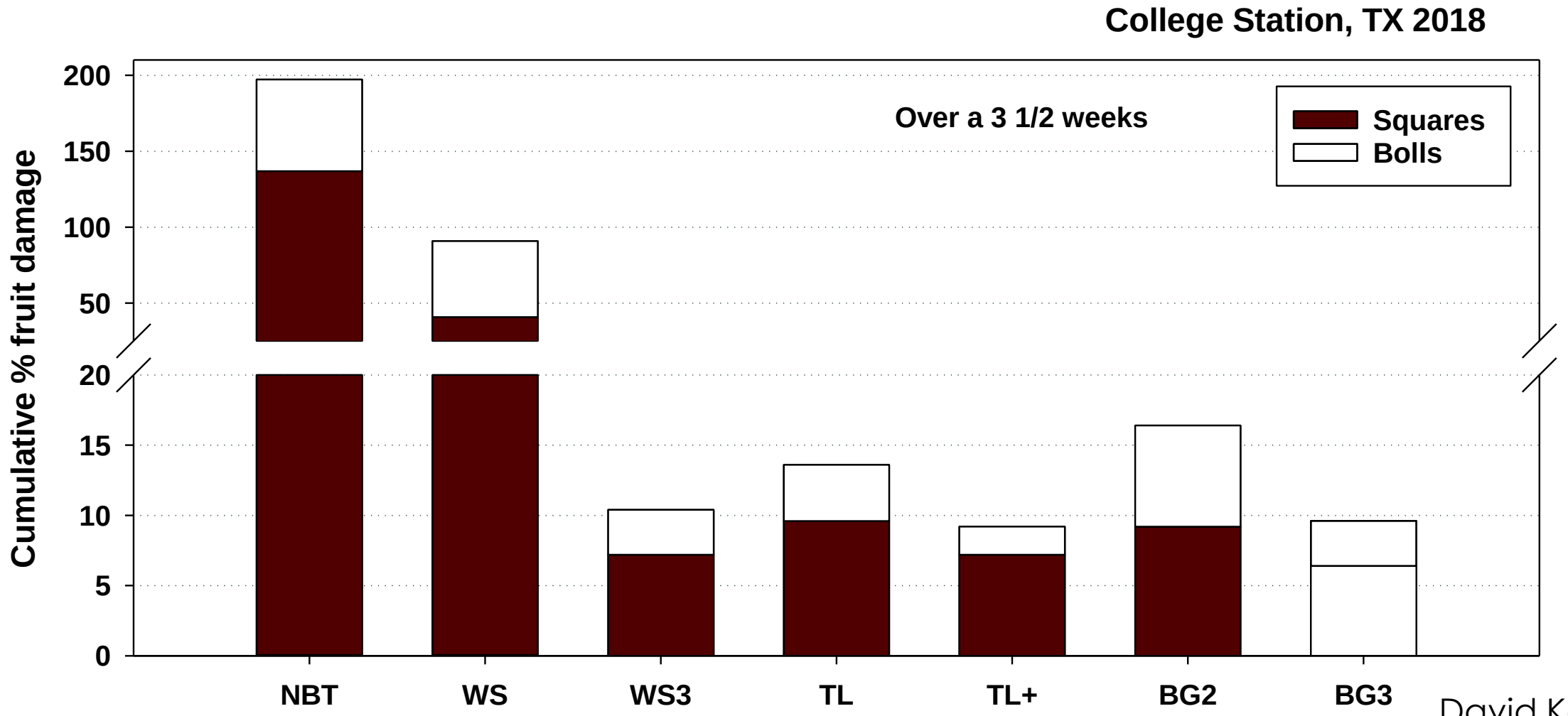
SEASONAL FRUIT DAMAGE – TEXAS 2018



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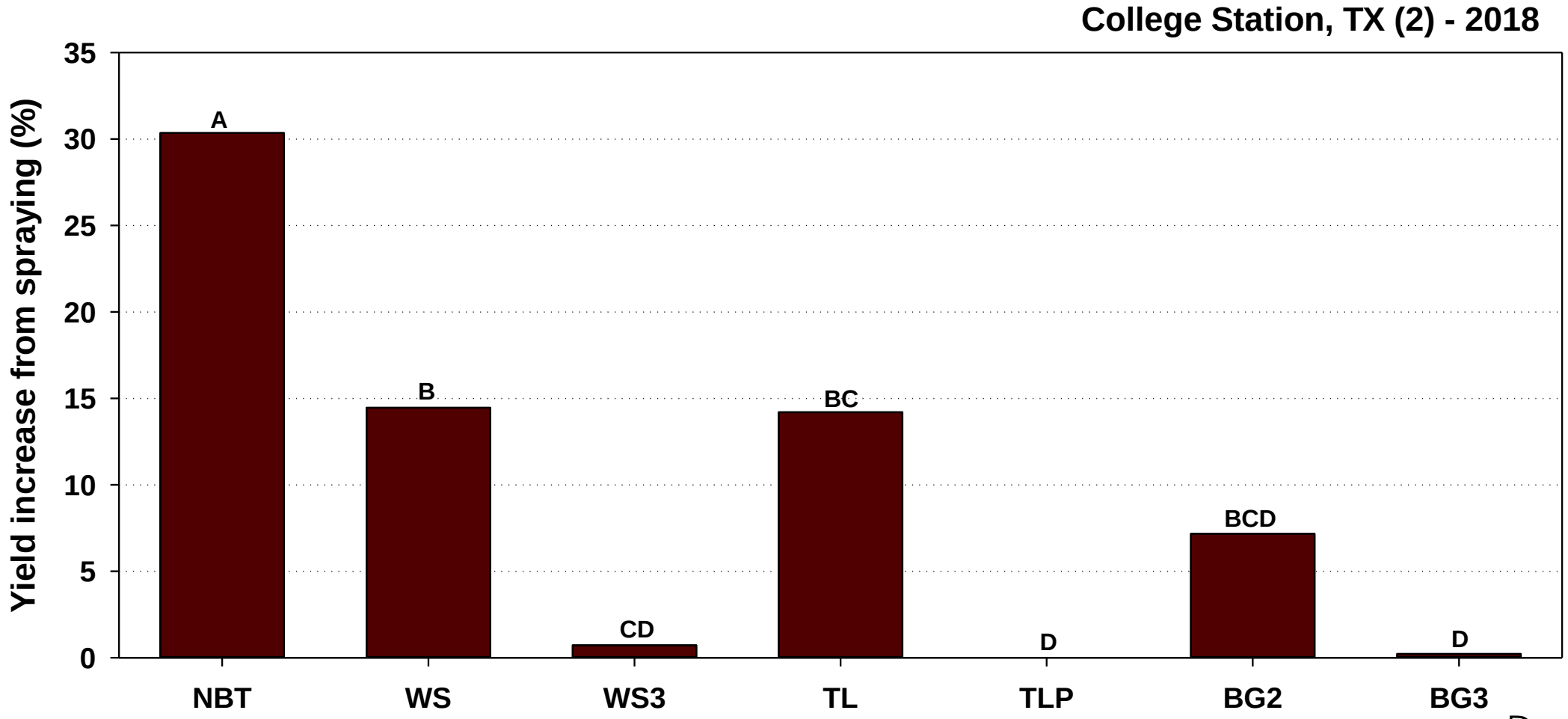
BENEFIT FROM PREVATHON TREATMENT – TEXAS 2018



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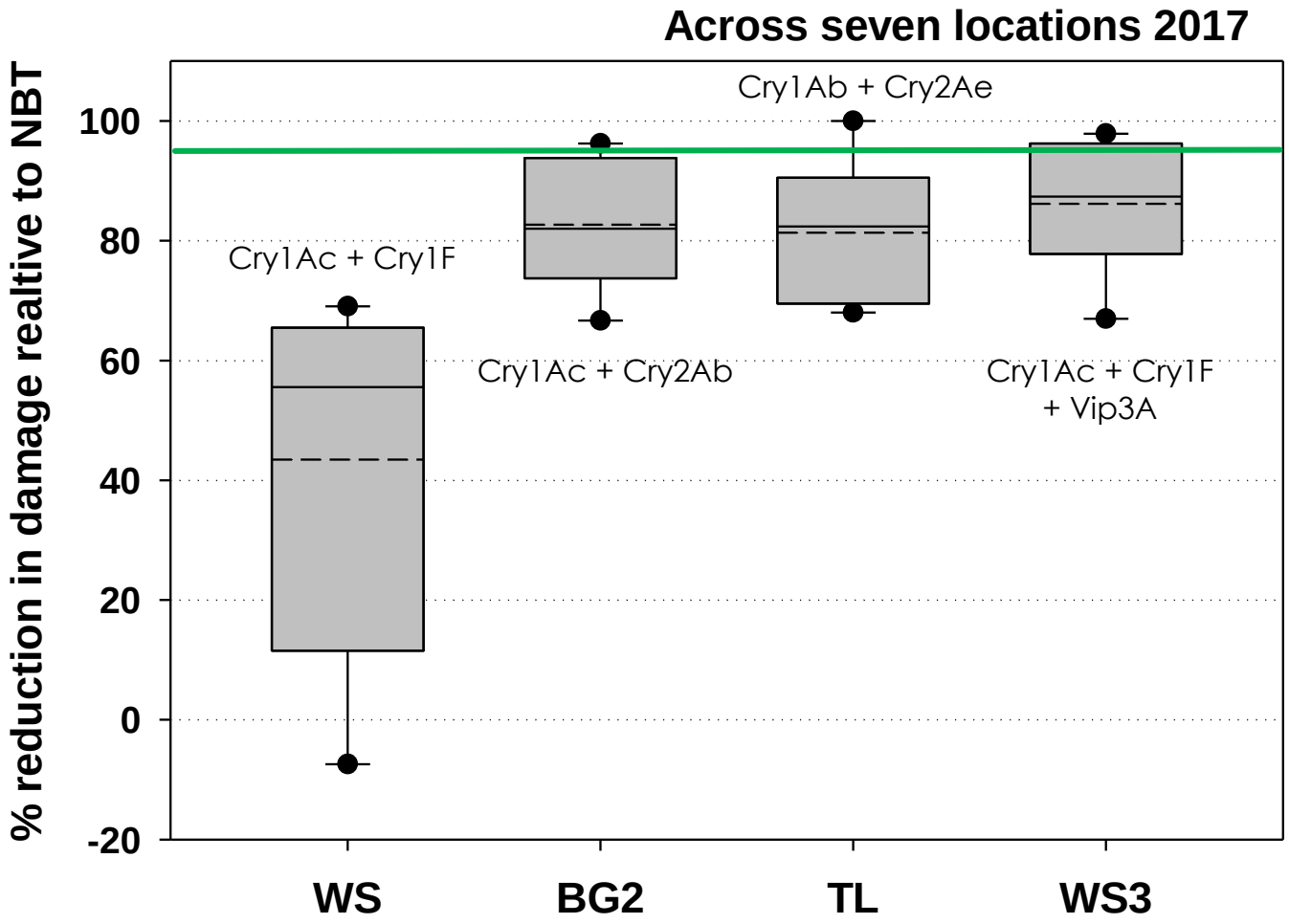
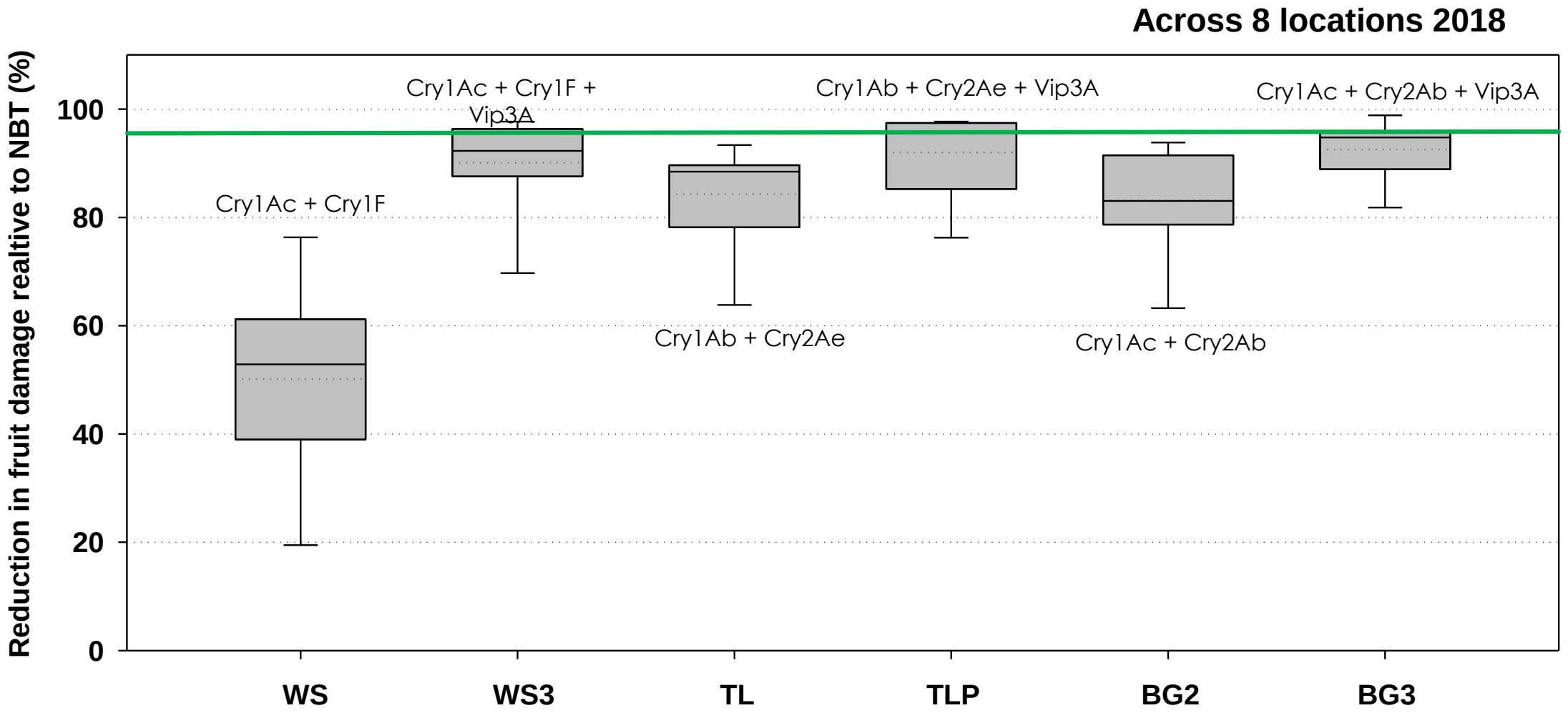
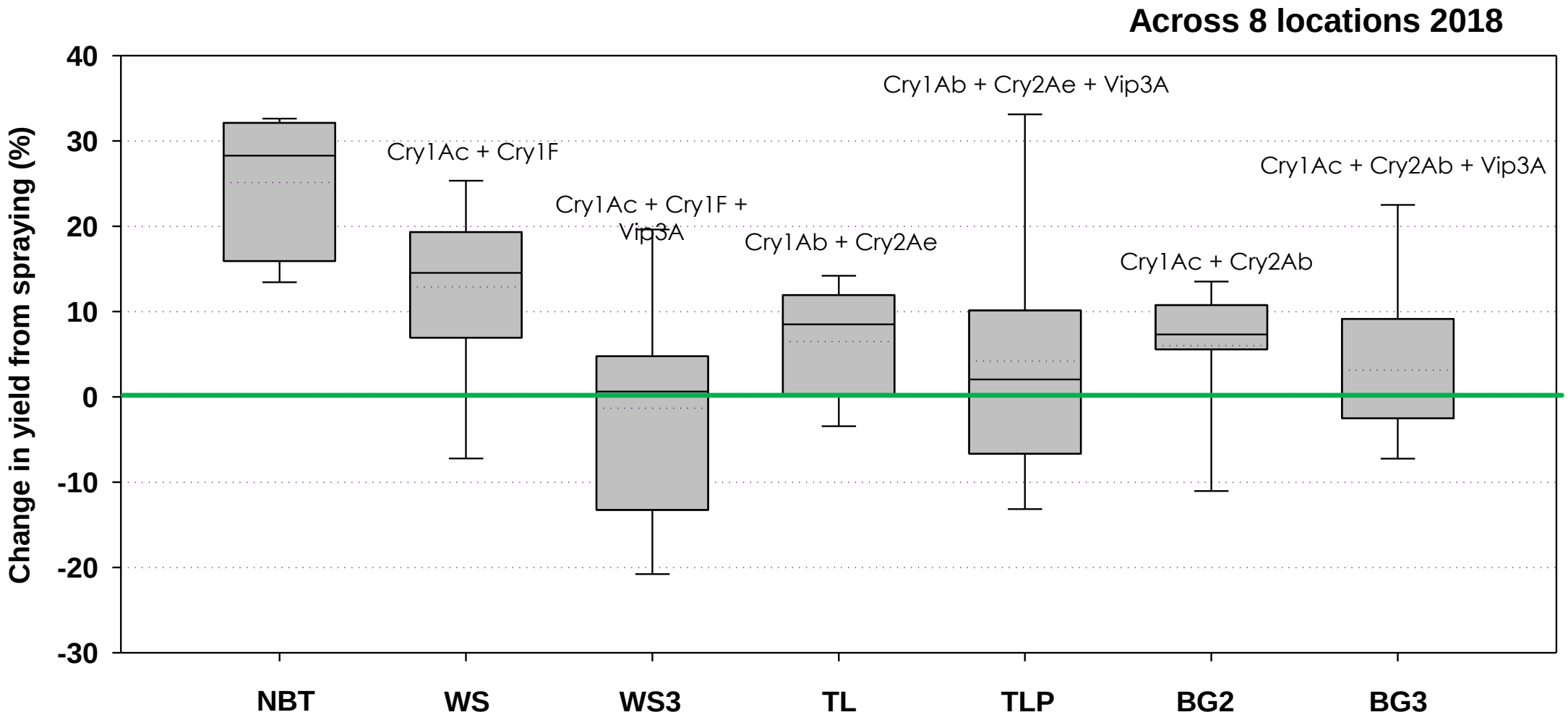
REDUCTION IN TOTAL FRUIT INJURY RELATIVE TO NON-BT - 2017



SEASONAL FRUIT DAMAGE – ALL LOCATIONS 2018



BENEFIT FROM PREVATHON TREATMENT – ALL LOCATIONS 2018






- Failures in Vip cotton are the exception, not the rule
- Most of the time occurs under very high pressure
  - Trap crop scenarios
- Bloom and bloom tags

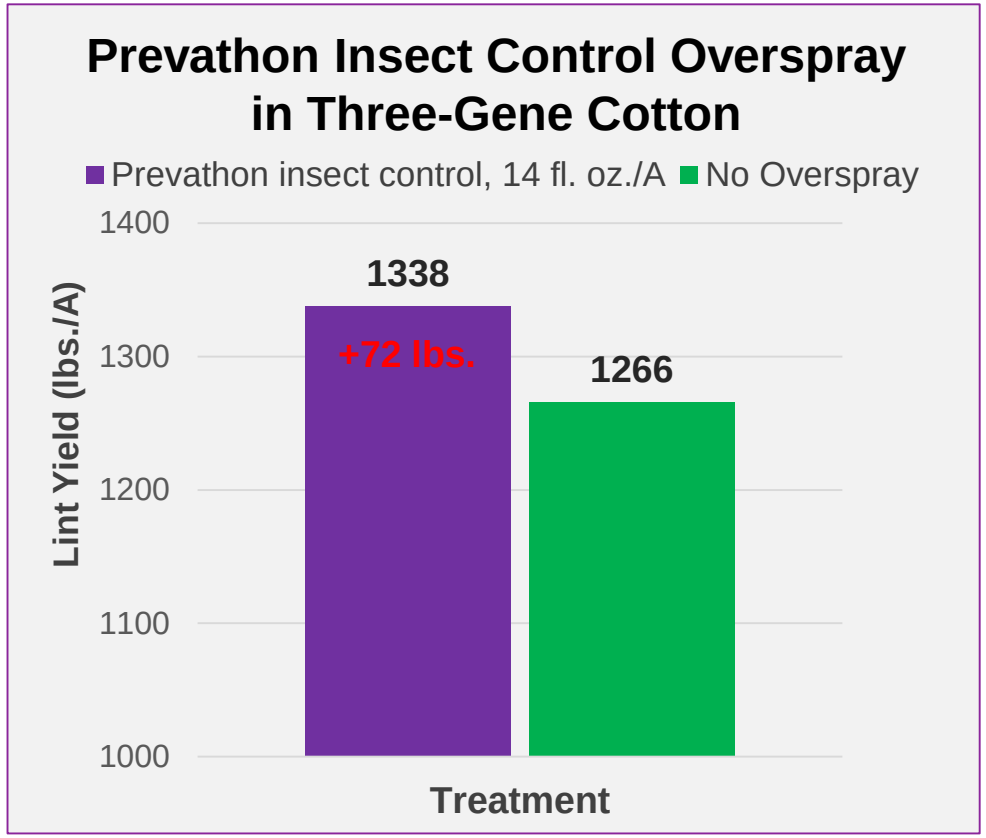
- Most common are incidences where there is unacceptable injury (20-30%) but very little worm survival
- The reason for survival to large worms is not known
- May result from low Vip expression, resistance or both

INCIDENCES OF BOLLWORM INJURY IN TRIPLE GENE COTTON

RESISTANCE RATIOS: CRY2AB2 = 10.9, VIP3A39 = 3.19

PREVATHON® INSECT CONTROL DEMONSTRATION: TRIPLE GENE COTTON

Smith and Sons Farms – Driscoll, TX 2019



Farmer/Cooperator: Smith and Sons Farms, Driscoll, TX
Consultant: Justin Chopelas, Mathis, TX

Trial Information

Variety: Phytogen® 580 W3FE
Planting Date: March 9, 2019
Application Date: June 19, 2019
GPA: 12
Treatment: Prevathon® insect control at 14 fl. oz./A
Insect pest: Cotton bollworm
Insect population: 100% of plants with bollworm eggs
Harvested: 8/12/19
Sample Size: One acre

Left photo: Dr. David Kerns, Texas A&M AgriLife Extension
Right photo: Justin Chopelas

CURRENT FIELD PERFORMANCE OF BT COTTON TECHNOLOGIES IN THE MID-SOUTH AND TEXAS

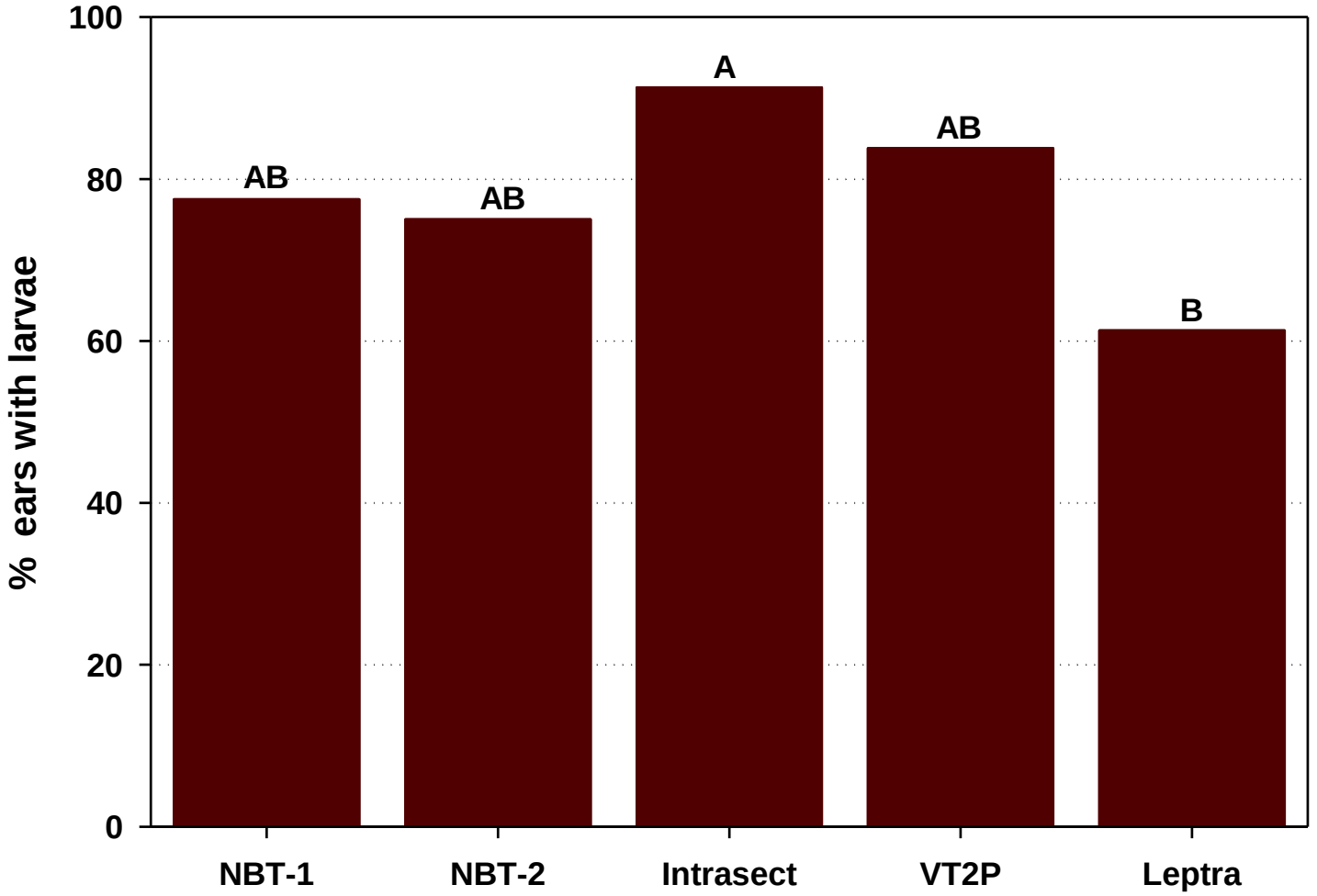
Target Pest	WideStrike Cry1F, Cry1A	Bollgard 2 or TwinLink Cry1A, Cry2A	WideStrike 3 Cry1F, Cry1A, Vip3A	Bollgard 3 or TwinLink Plus Cry1A, Cry2A, Vip3A
Tobacco Budworm*	Excellent	Excellent	Excellent	Excellent
Pink Bollworm	Excellent	Excellent	Excellent	Excellent
Bollworm	Fair	Good	Very Good	Very Good
Fall Armyworm	Very Good	Good	Excellent	Excellent
Beet Armyworm	Very Good	Very Good	Excellent	Excellent

* Tobacco budworm and pink bollworm were the primary target of the original Bt cotton technology (Bollgard, Cry1Ac)

Excellent (spraying not needed), Very Good (spraying is only rarely needed), Fair to Good (spraying is commonly needed at least during some times of the season or when pest pressure is high)

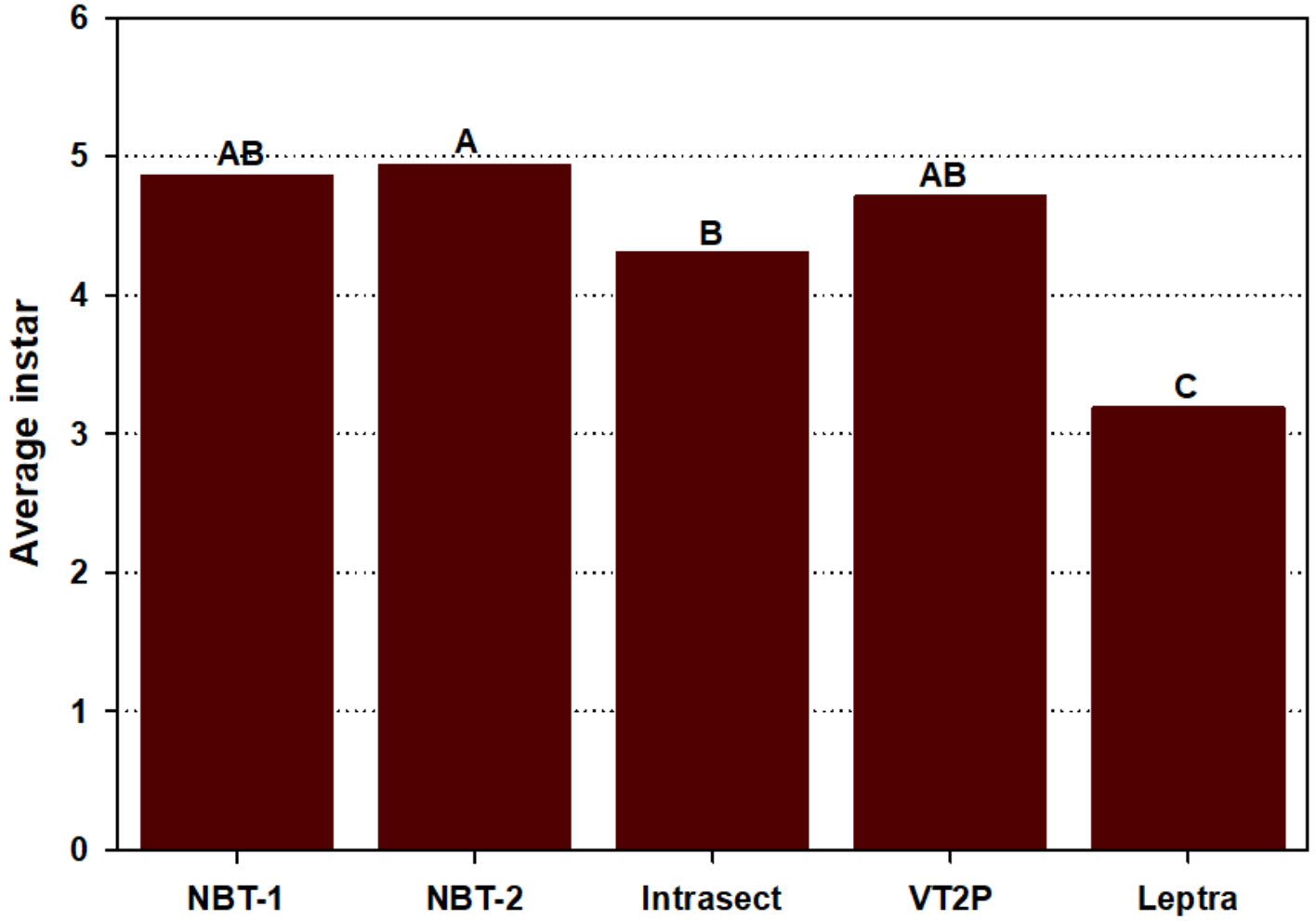
BT CORN TRAIT PERFORMANCE

FIELD PERFORMANCE OF *H. ZEA* ON DIFFERENT CORN TECHNOLOGIES



Technology	Bt traits
NBT-1&2	None
Intrasect	Cry1Ab+Cry1F
VT2P	Cry1A.105+Cry2Ab2 2
Leptra	Cry1Ab+Cry1F+Vip3 3A

FIELD PERFORMANCE OF *H. ZEA* ON DIFFERENT CORN TECHNOLOGIES



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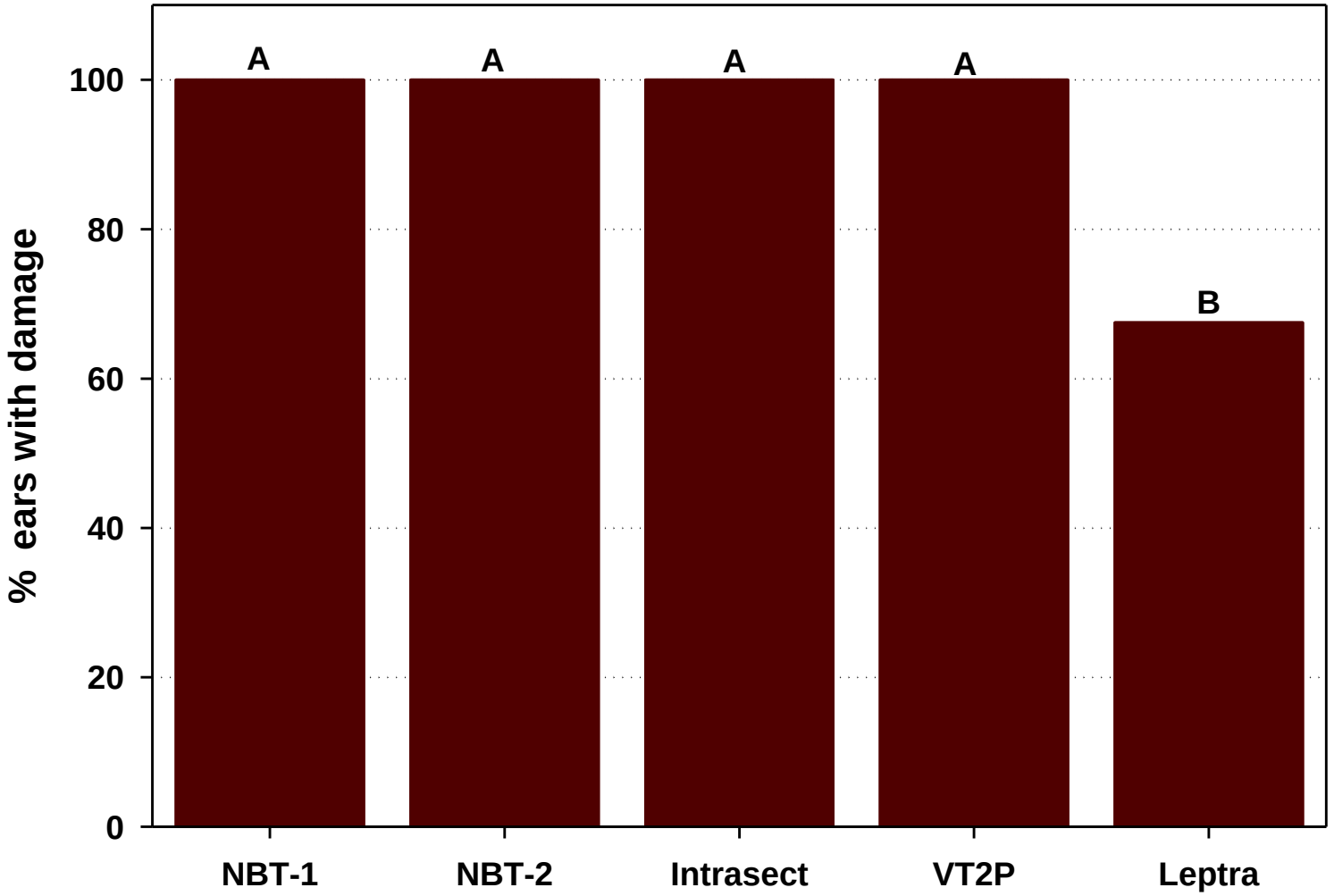

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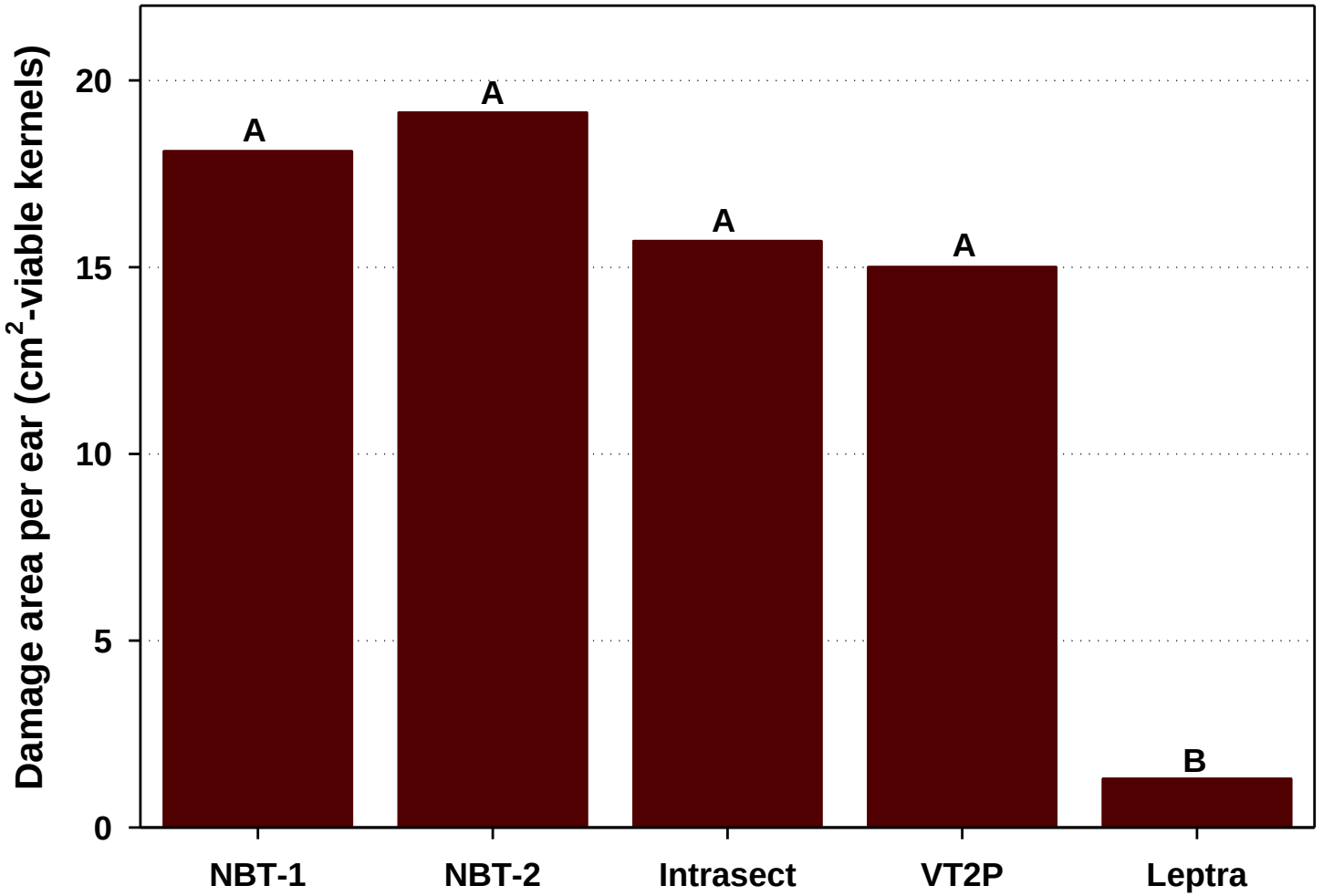

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PROTEIN BIOASSAY-OVERLAY

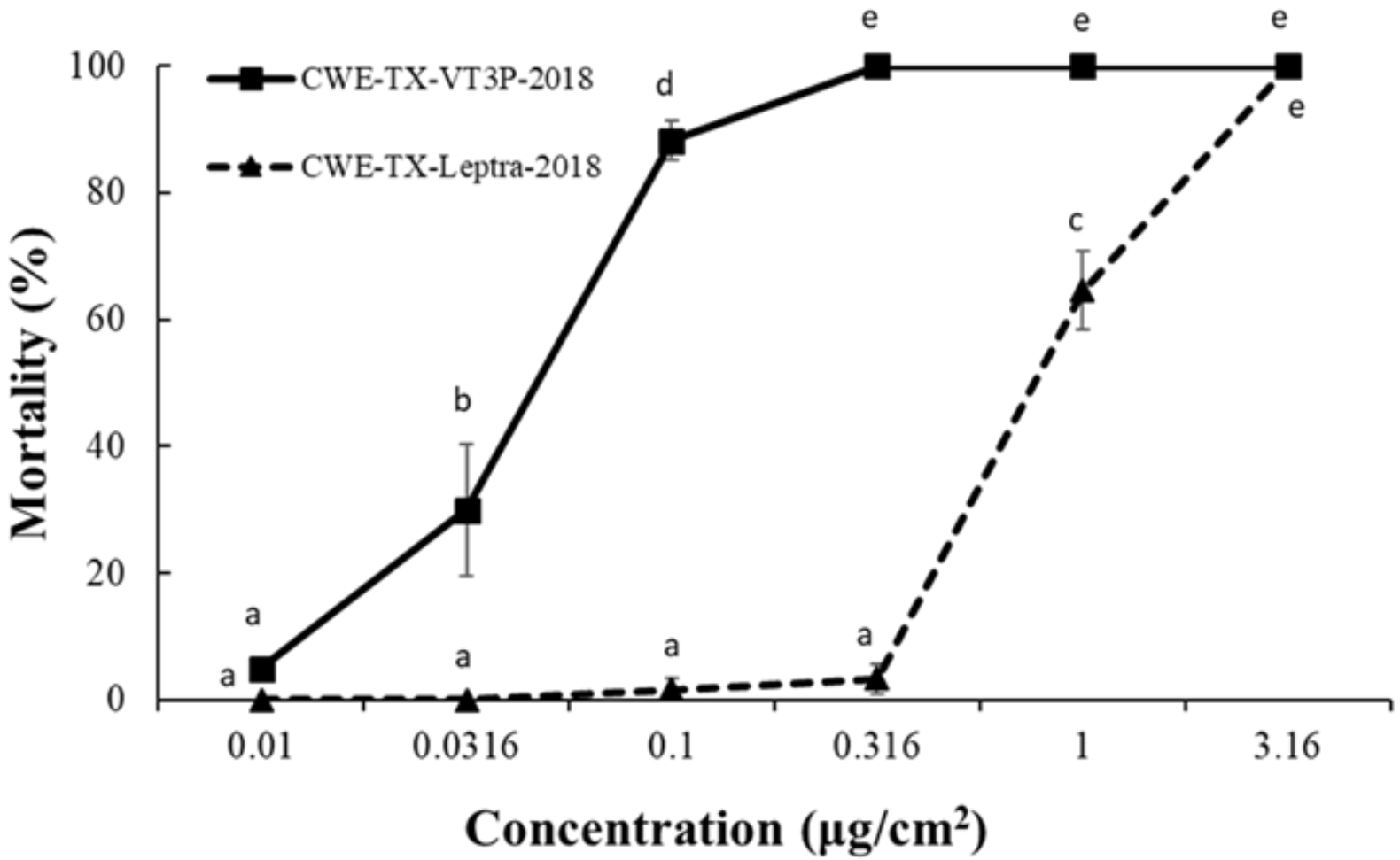
Insects: 1) CEW-TX-Leptra-2018, collected from Leptra (Cry1Ab+Cry1F+Vip3A)

2) CEW-TX-VT3P-2018, collected from VT3P (Cry1F+Cry1A.105+Cry2Ab2)

Diet bioassays:

- 128-CD- International trays
- Vip3A1 protein provided by BASF
- 7-8 concentrations and a control
- 1 neonate/cell; 4 replications;16 insects/rep.
- 28 °C, ~50% RH and photoperiod of 16:8(L:D)h.
- Larval instar & mortality were recorded after 7d.

MORTALITY


CWE-TX-VT3P-2018
CWE-TX-Leptra-2018
Mortality (%)
100
80
60
40
20
0
0.01
0.0316
0.1
0.316
1
3.16
Concentration (µg/cm²)
a
a
b
d
e
e
e
a
a
a
c
e

LC_{50}S / RESISTANCE RATIOS

Insect population*	N#	LC_{50} (95% CI) ($\mu g/cm^2$) §	Slope ± SE	X^2	df	Resistance ratio£
CEW-TX-VT3P-2018	448	0.041 (0.035, 0.050)	2.87 ± 0.30	18.9	22	1.0
CEW-TX-Leptra-2018	448	0.838 (0.686, 0.966)	4.93 ± 1.02	19.0	22	20.4

COTTON LEAF BIOASSAY

Cotton varieties: Widestrike 3 (WS3), expressing Cry1F+Cry1Ac+Vip3A protein and non-Bt.

Insects: 1) CEW-TX-Leptra-2018, collected from Leptra (Cry1Ab+Cry1F+Vip3A)

2) CEW-TX-SS, lab susceptible strain

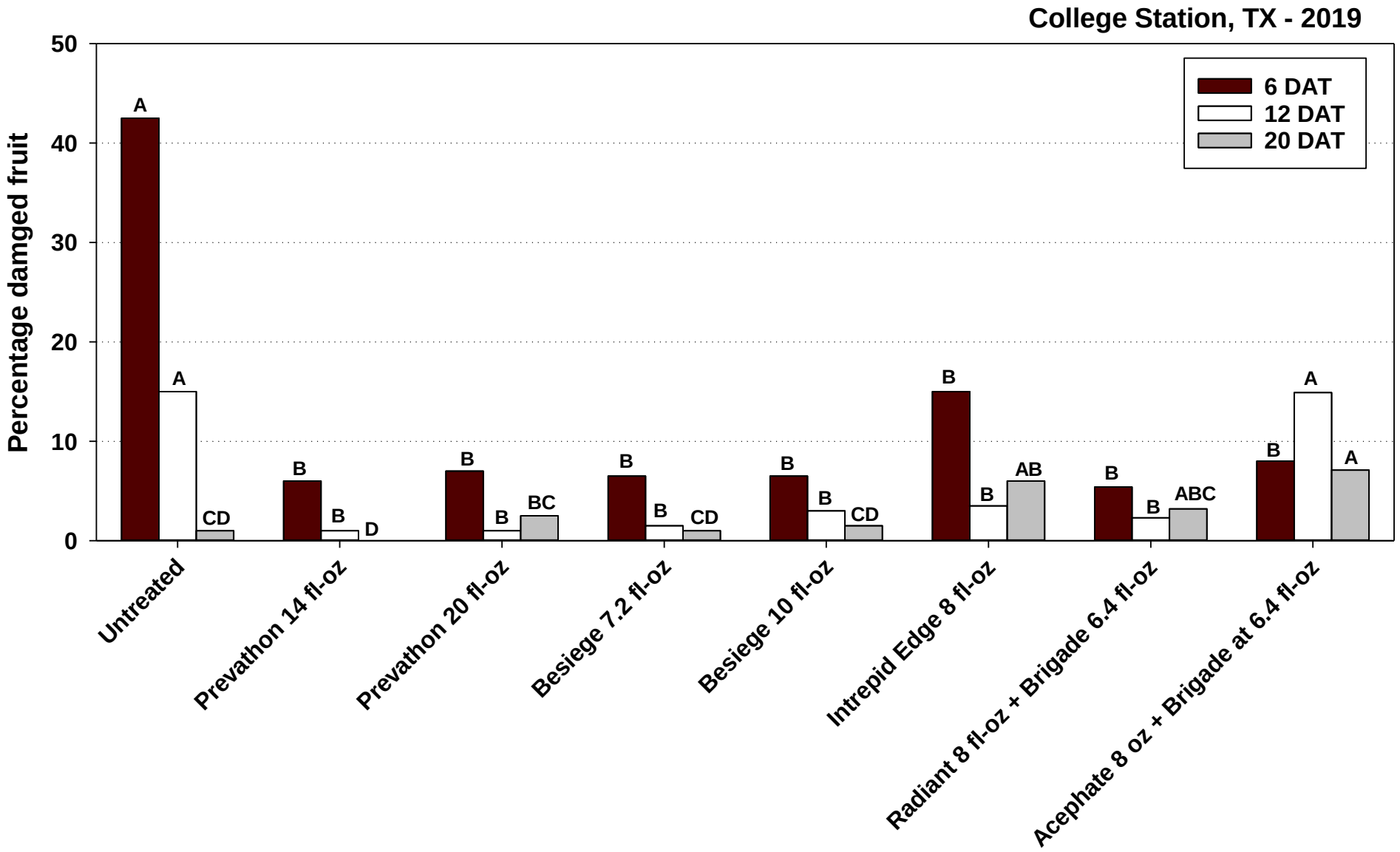
Leaf tissue bioassays:

- Cotton planted in the field
- Cotton leaves excised at the 7-8 nodes growth stage
- Expression/non-expression of the Cry and Vip3A proteins using stripes
- Leaves were placed in Petri Dishes lined with moistened filter paper
- 5 neonate/dish; 4 replications; 30 insects/rep.
- 28 °C, ~50% RH and photoperiod of 16:8(L:D)h.
- Larval instar & survivorship were recorded after 7d.

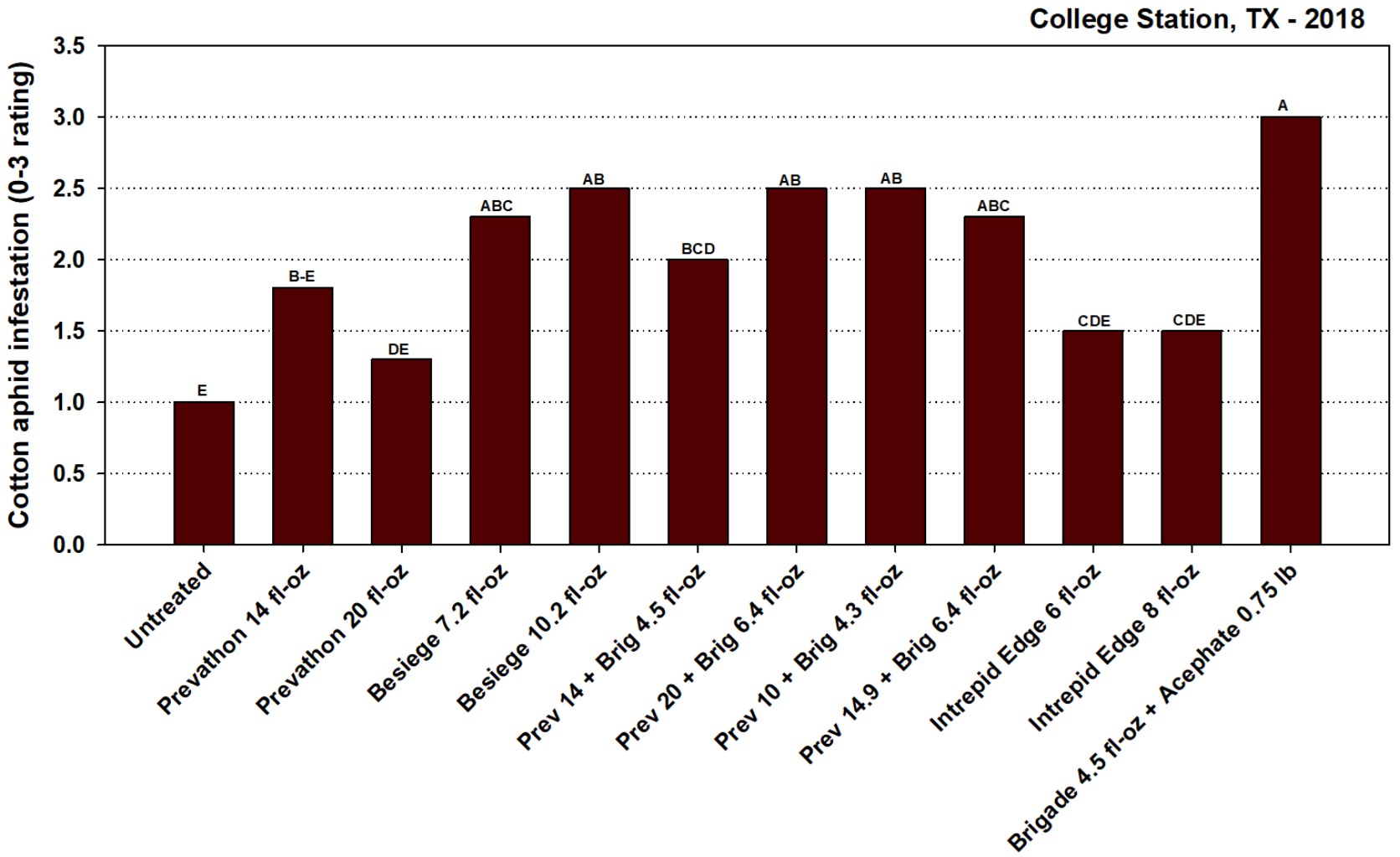
COTTON LEAF ASSAY RESULTS

Cotton variety	Insect	Survivorship (%)	Average instar
Non-Bt	CEW-TX-Leptra-2018	78.3 ± 2.9 c	3.39 ± 0.01 c
	CBW-TX-SS	82.5 ± 3.2 c	3.45 ± 0.05 c
WideStrike 3	CEW-TX-Leptra-2018	41.7 ± 7.5 b	2.68 ± 0.03 b
	CBW-TX-SS	3.3 ± 1.4 a	2.00 ± 0.00 a

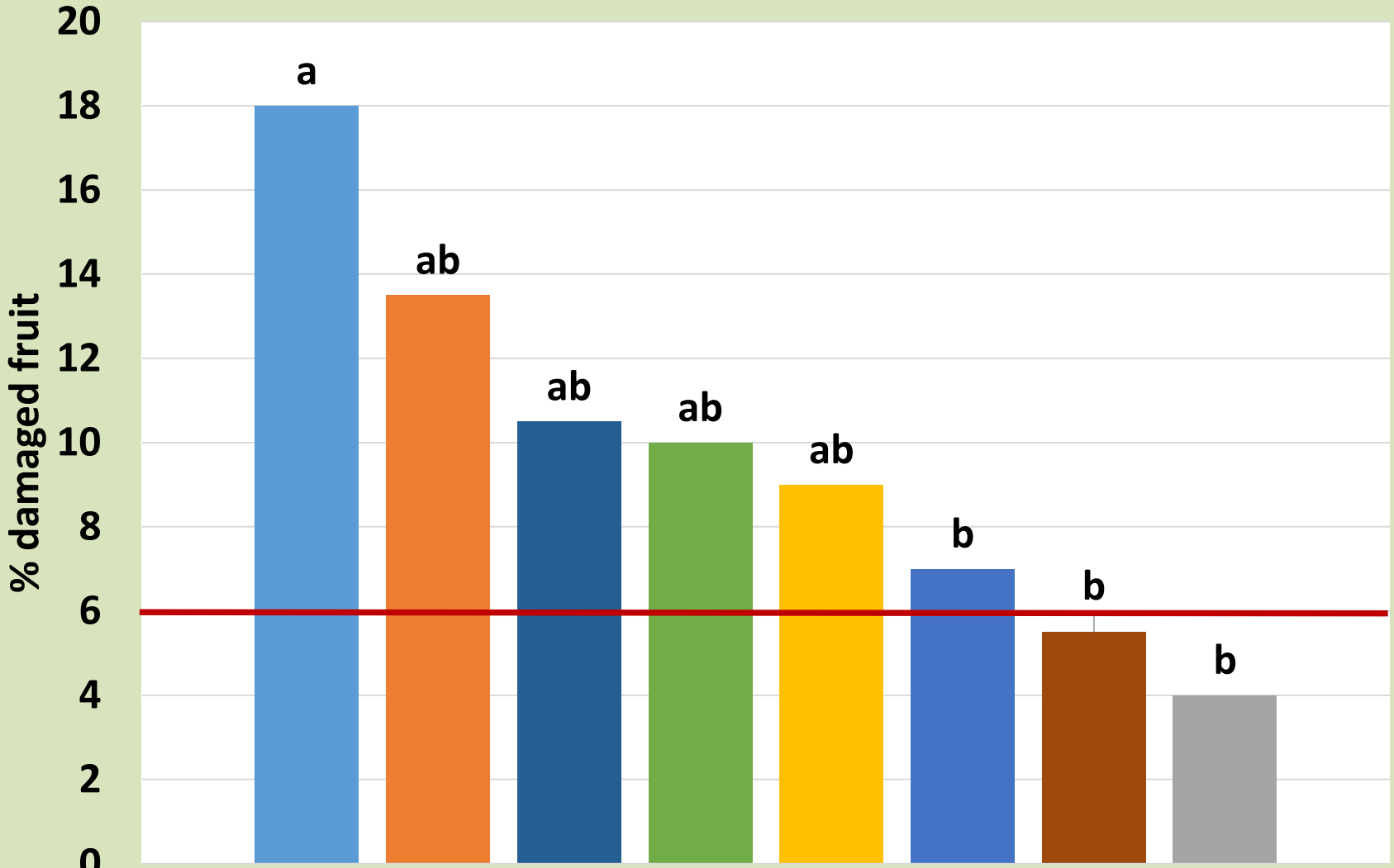
INSECTICIDE EFFICACY


College Station, TX - 2019
Percentage damged fruit
50
40
30
20
10
0
6 DAT
12 DAT
20 DAT
A
A
CD
B
B
D
B
B
BC
B
B
CD
B
B
CD
B
B
AB
B
B
ABC
B
A
A
Untreated
Prevathon 14 fl-oz
Prevathon 20 fl-oz
Besiege 7.2 fl-oz
Besiege 10 fl-oz
Intrepid Edge 8 fl-oz
Radiant 8 fl-oz + Brigade 6.4 fl-oz
Acephate 8 oz + Brigade at 6.4 fl-oz

IMPACT ON APHIDS - 2018



Regional Conventional Foliar Efficacy Trial, 2018
Drew County AR



Courtesy Gus Lorenz, Univ. Arkansas

TEXAS TREATMENT RECOMMENDATIONS

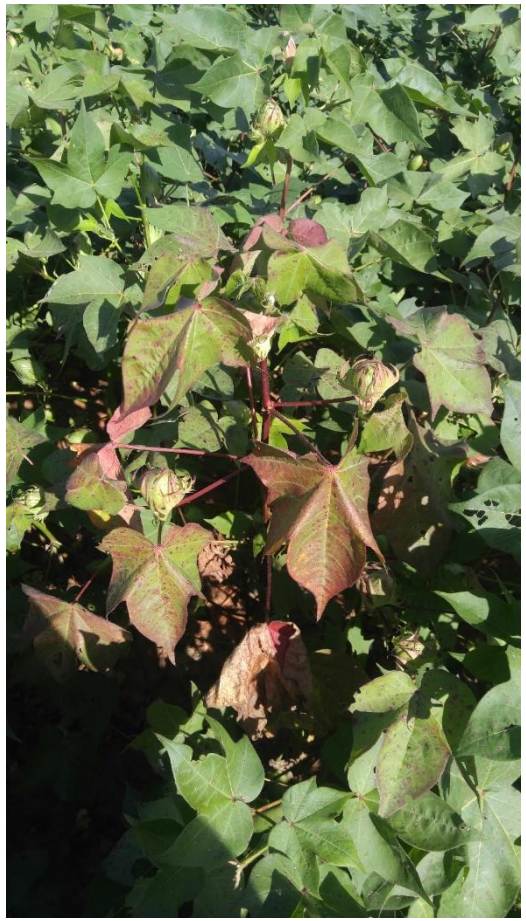
- Areas with history of Bt failures or where reports of failures are occurring
  - Dual-gene cotton (WS, TL, BG2)
    - Treat based on a 20% egg lay
      - 20% of plants found with at least 1 egg
  - Vip cotton (WS3, TL+, BG3)
    - Treat based on 6% damaged squares and/or bolls with larvae present
- Areas where Bt failures have not manifest
  - Treat based on 6% damaged squares and/or bolls with larvae present
- Use pyrethroids with caution
  - Resistance was detected throughout much of the state in 2018
- Prevathon and Besiege
  - Where residual control is needed
    - Rule of thumb each ounce of Prevathon or one-half ounce of Besiege will provide that length of control in days
    - Use Prevathon 18-20 fl-oz, Besiege at 9-10 fl-oz
  - Where residual control is not needed
    - Can get by with Prevathon 14 fl-oz, Besiege at 7-8 fl-oz
  - Timing is more important than rate

COTTON LEAF ROLL DWARF VIRUS

- Has been a problem in South American cotton
- Showed up in the SE U.S. last year
- Found it in the Brazos River Bottom this year
- Vectored by cotton aphid
- Best managed with resistant varieties
- Managing aphids can help prevent in-field spread of infection

BRAZOS RIVER BOTTOM 2019

Symptomology – Red petioles & leaves



Courtesy Dr. Alana Jacobson

Symptomology – Downward curling

09/06/2018

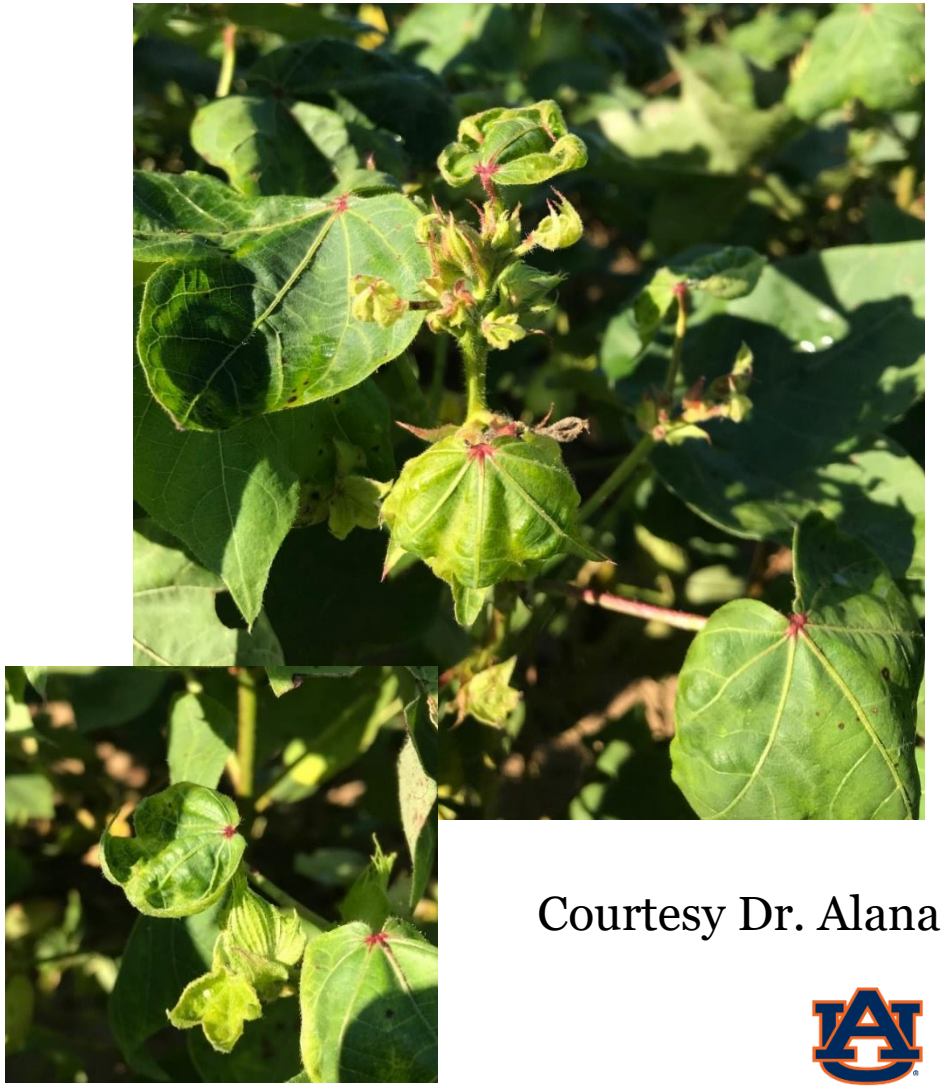
07/17/2018

Courtesy Dr. Alana Jacobson

October 2018

Symptomology – Upward curling

8/16/2018



Courtesy Dr. Alana Jacobson

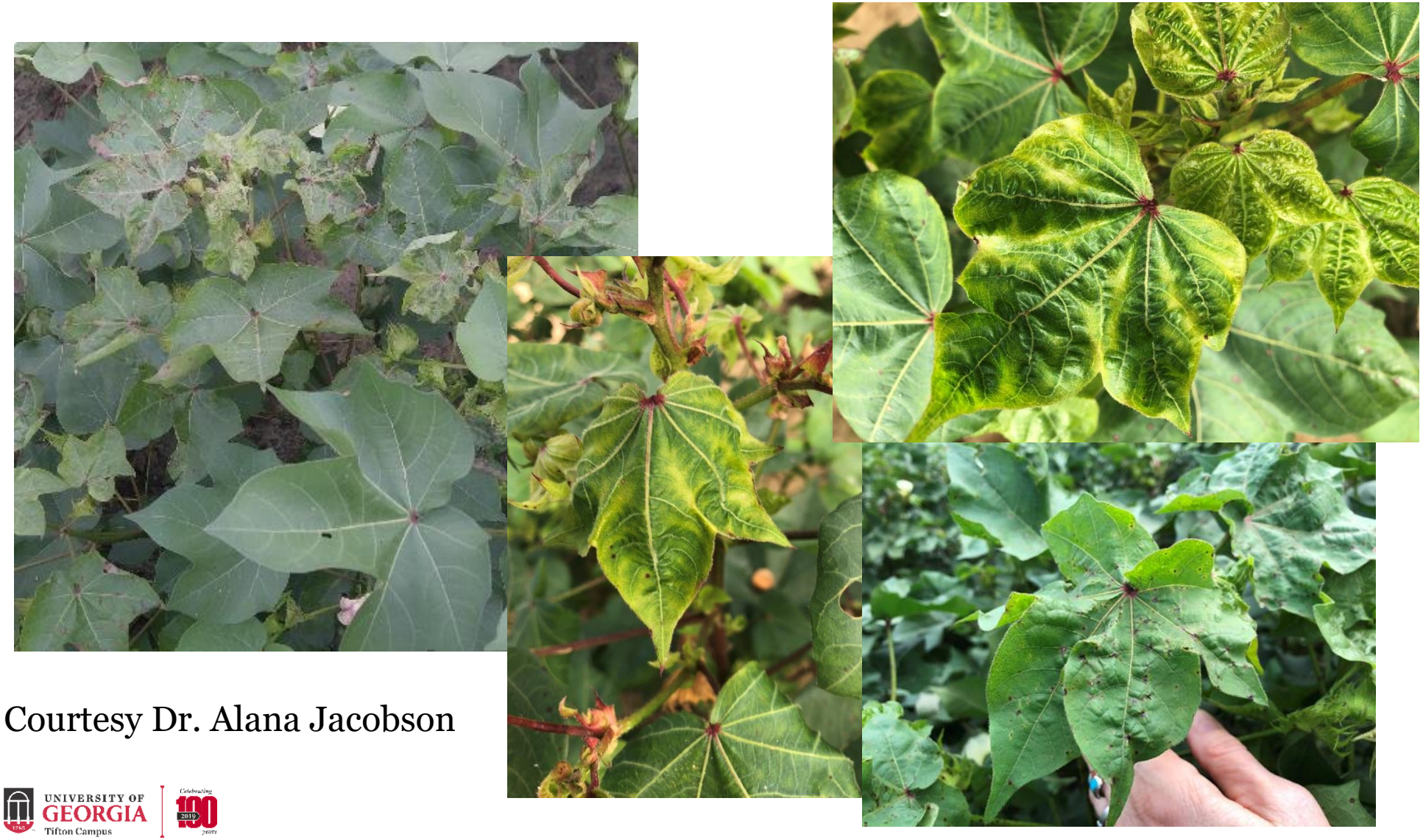
Symptomology – Leaf Distortions

09/06/2018

Courtesy Dr. Alana Jacobson

October 2018

Symptomology – Leaf Crinkling



Courtesy Dr. Alana Jacobson

Symptomology – Dwarfed plants

8/21/2018

Courtesy Dr. Alana Jacobson

Symptomology – Shortened internodes

Courtesy Dr. Alana Jacobson

October 2018

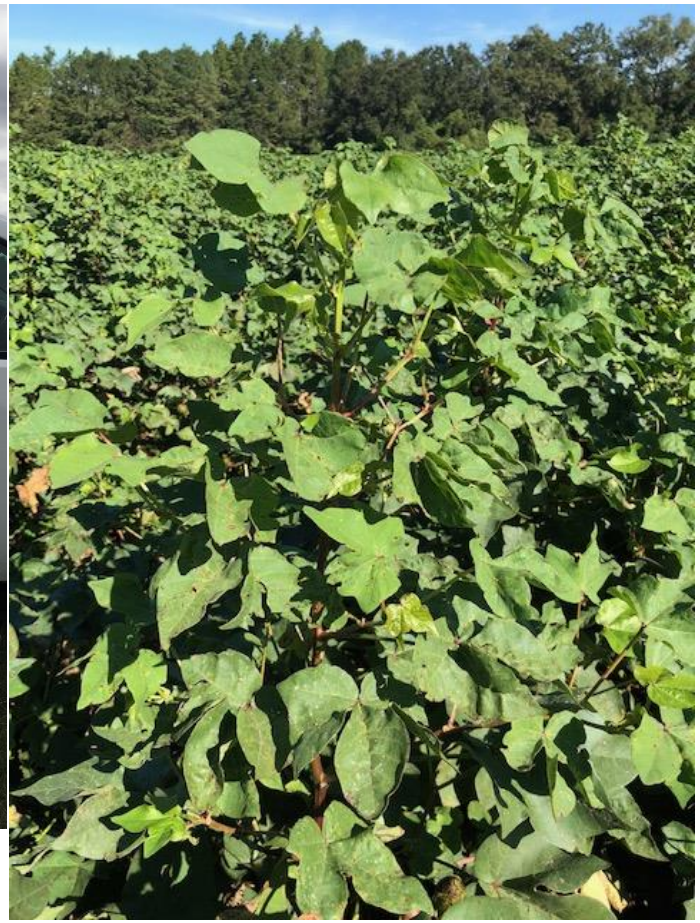
Symptomology – Shortened Internodes, abnormal top growth

Courtesy Dr. Alana Jacobson

October 2018

Symptomology & Yield Loss – Boll drop

Pic: Mark Freeman



Courtesy Dr. Alana Jacobson

QUESTIONS?

Thanks to:

- Bayer, Corteva and Syngenta for suppling Bt toxins and partial funding
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- Texas Corn Producer Board for partial funding
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United States Department of Agriculture
National Institute of Food and Agriculture