Bt Corn Performance Against Corn Earworm

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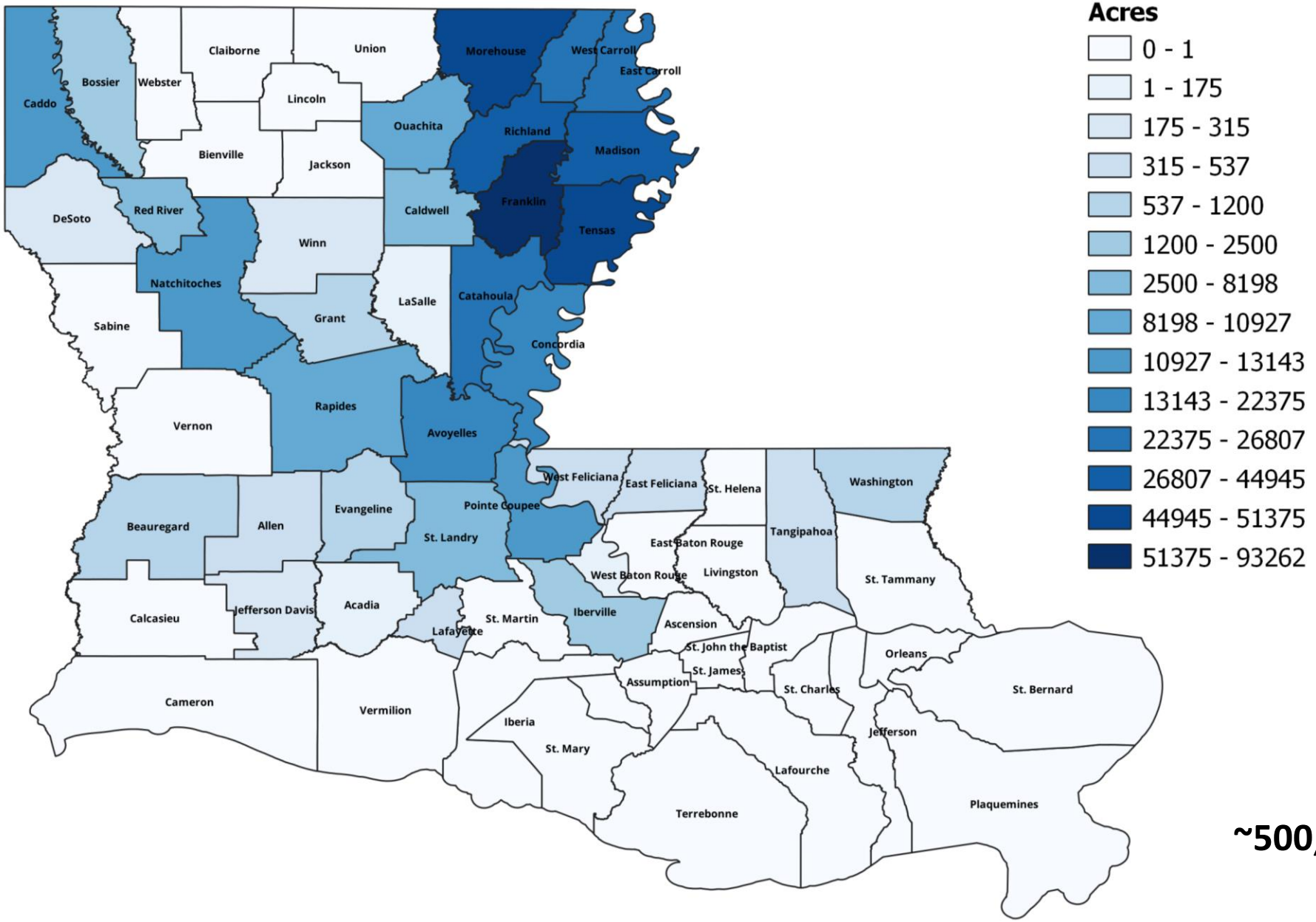
2020 Corn Acreage



~500,000 acres yearly

Chinch bug

Cutworms

Sugarcane beetle

Insect Pests of Corn

Wireworms

Fall armyworm – sporadic infestations

Main Pest of corn in Louisiana is corn earworm (aka bollworm, soybean podworm, sorghum headworm)

Corn is nursery crop for corn earworm

Corn Earworm Damage

- Feeding occurs at the tip of the ear
- Yield losses occur when 30-40 kernels are damaged

Ongoing Research

PLANTING DATE

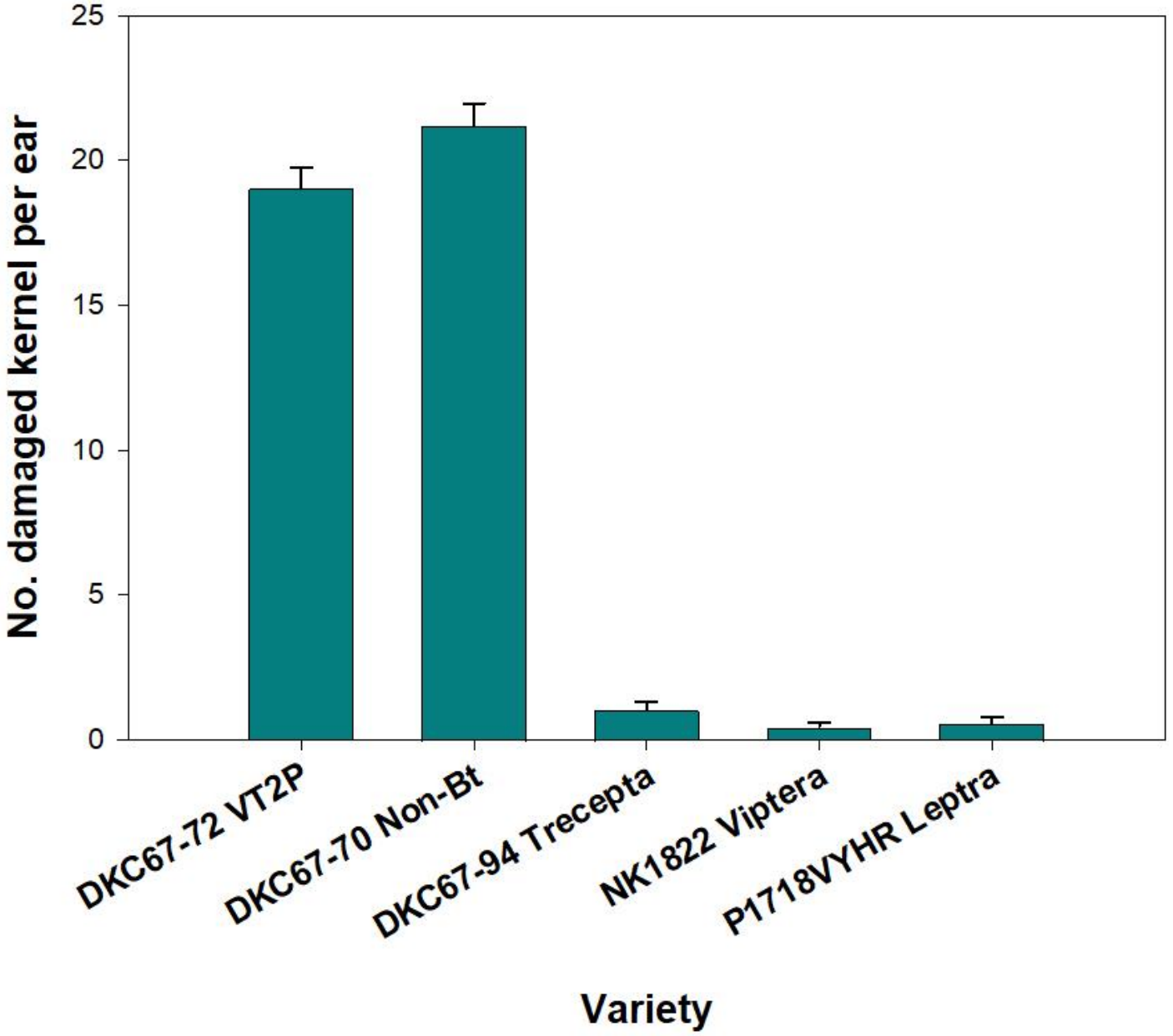
MULTIPLE VARIETY AT 3 LOCATIONS

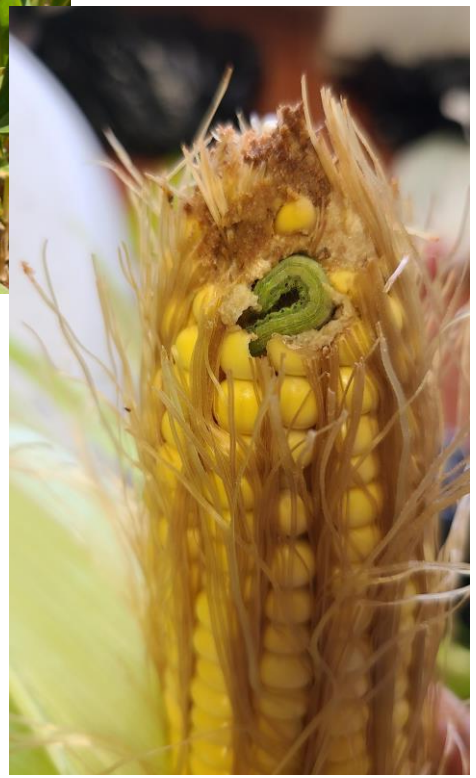
RESISTANCE MONITORING

Planting Date Study

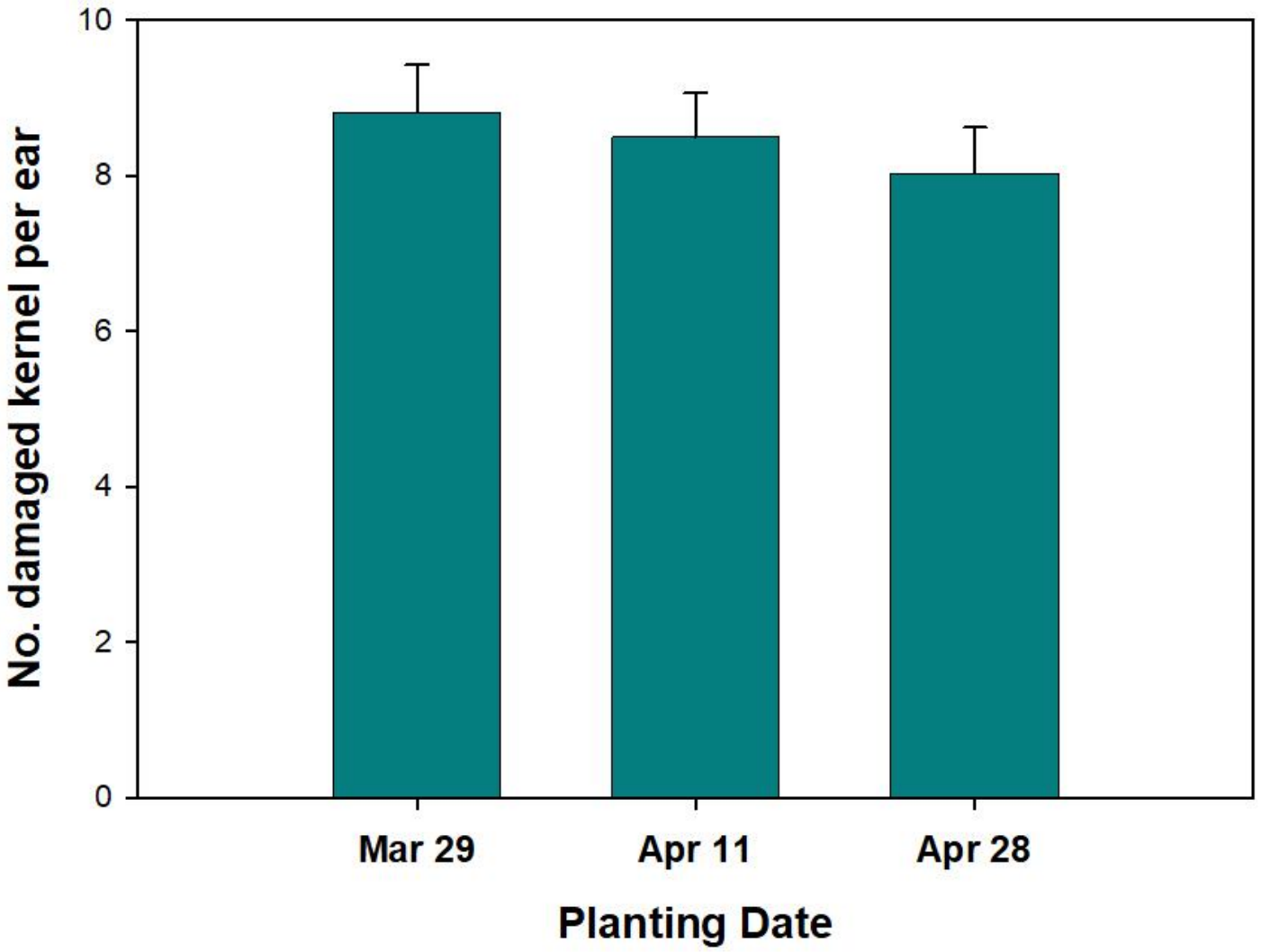
- Three planting Dates – March 29, April 11, and April 28
- Six Varieties – DKC67-70 (Non-Bt), DKC67-72 (VT2P), DKC67-94 (Trecepta), NK1822 (Viptera), P178VYHR (Leptra)
- Data Collected: CEW collection, Kernel Damage, and Yield

Kernel Damage (2022)

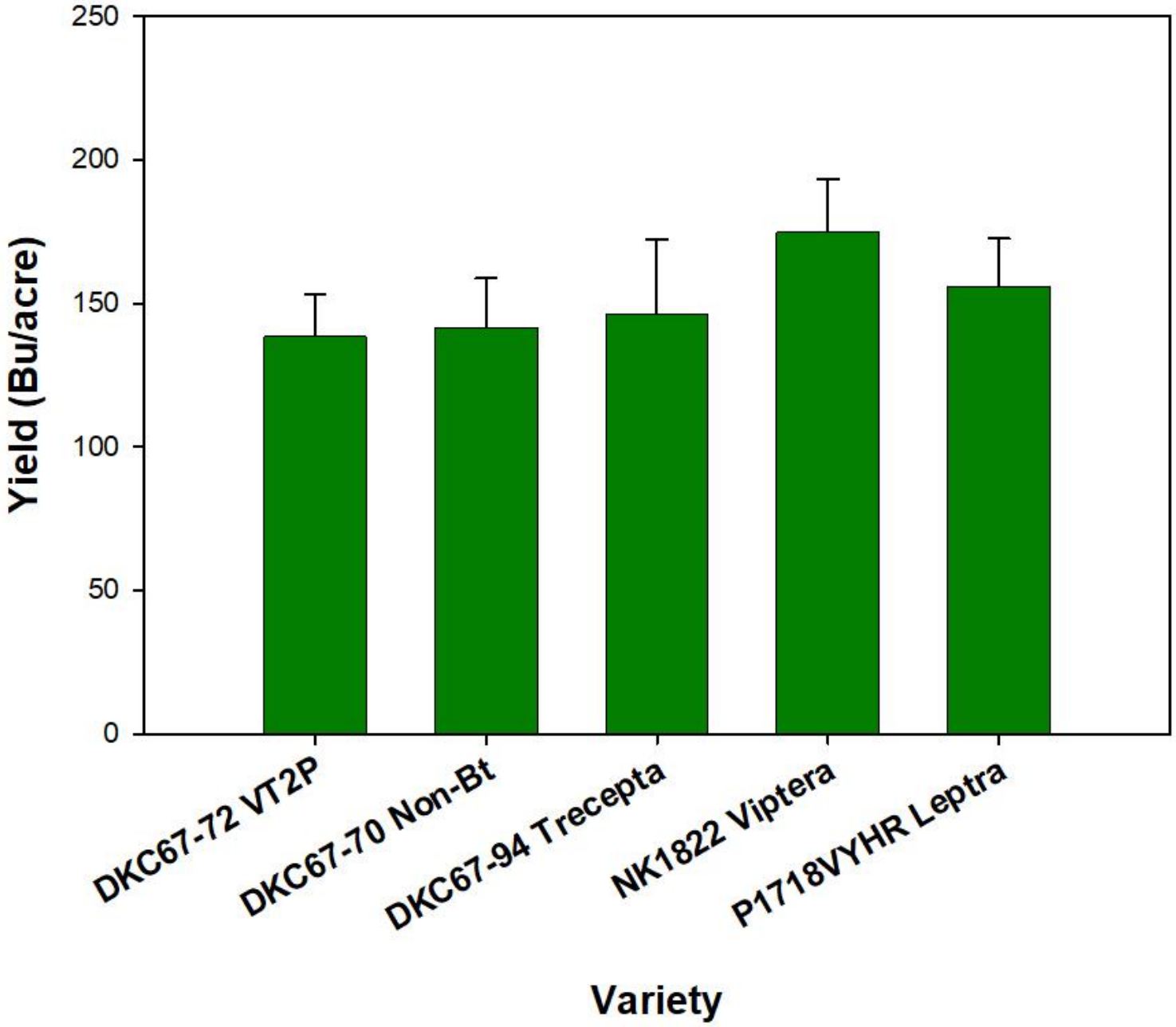




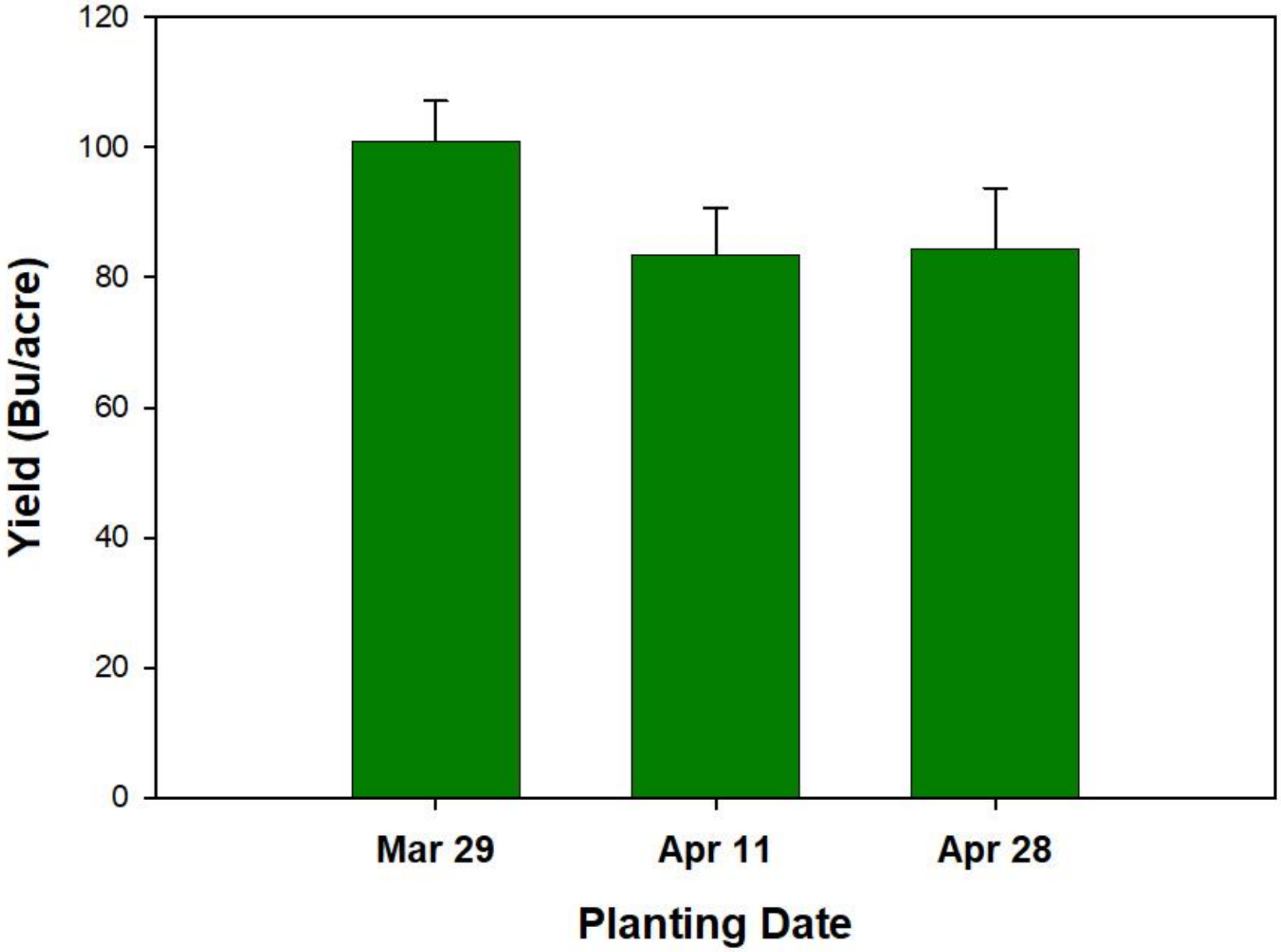
Kernel Damage (2022)

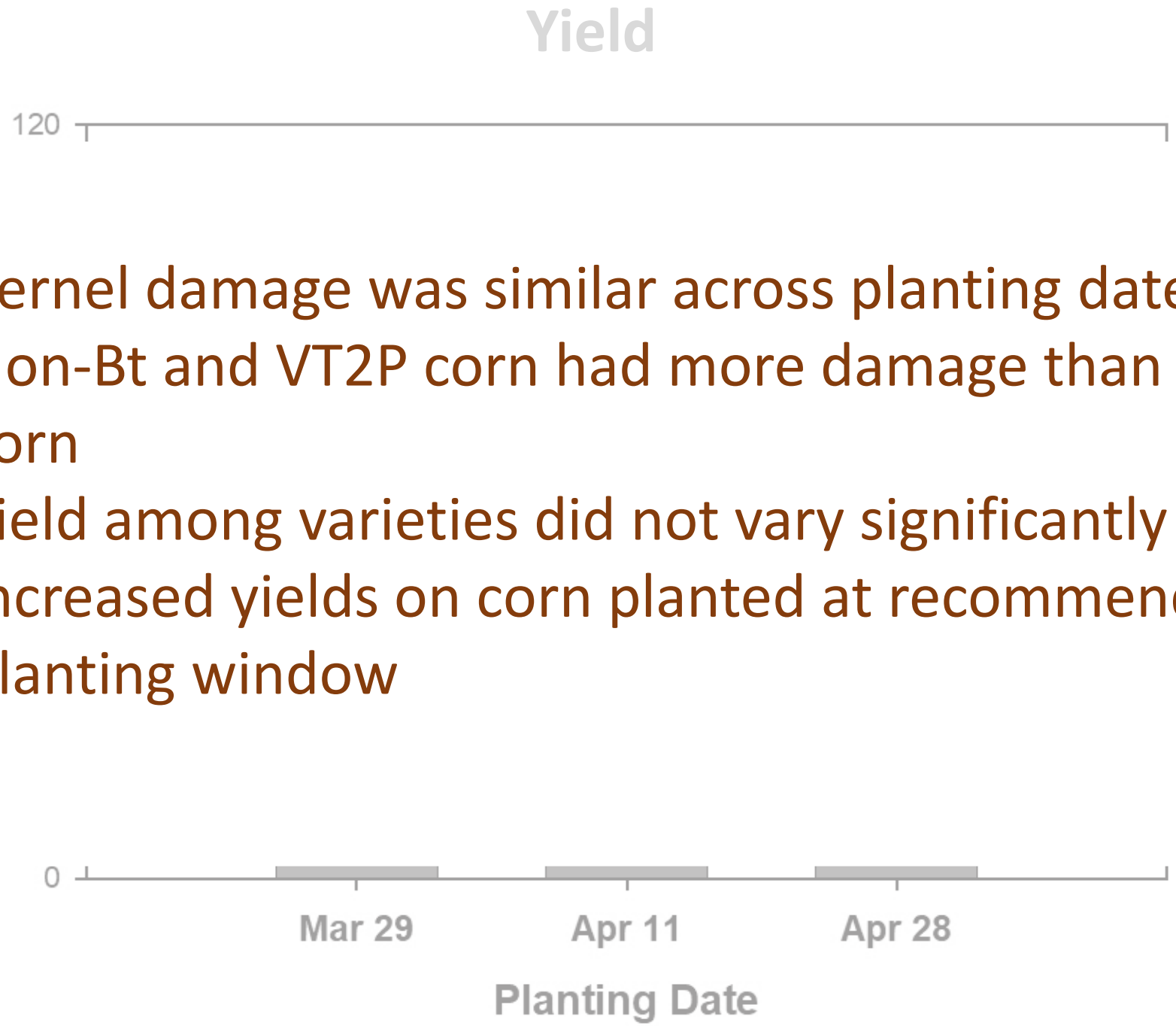


Yield (2022)


250
200
150
100
50
0
Yield (Bu/acre)
DKC67-72 VT2P
DKC67-70 Non-Bt
DKC67-94 Trecepta
NK1822 Viptera
P1718VYHR Leptra
Variety

Yield (2022)


120
100
80
60
40
20
0
Yield (Bu/acre)
Mar 29
Apr 11
Apr 28
Planting Date



- Kernel damage was similar across planting dates
- Non-Bt and VT2P corn had more damage than Vip corn
- Yield among varieties did not vary significantly
- Increased yields on corn planted at recommended planting window

Ongoing Research

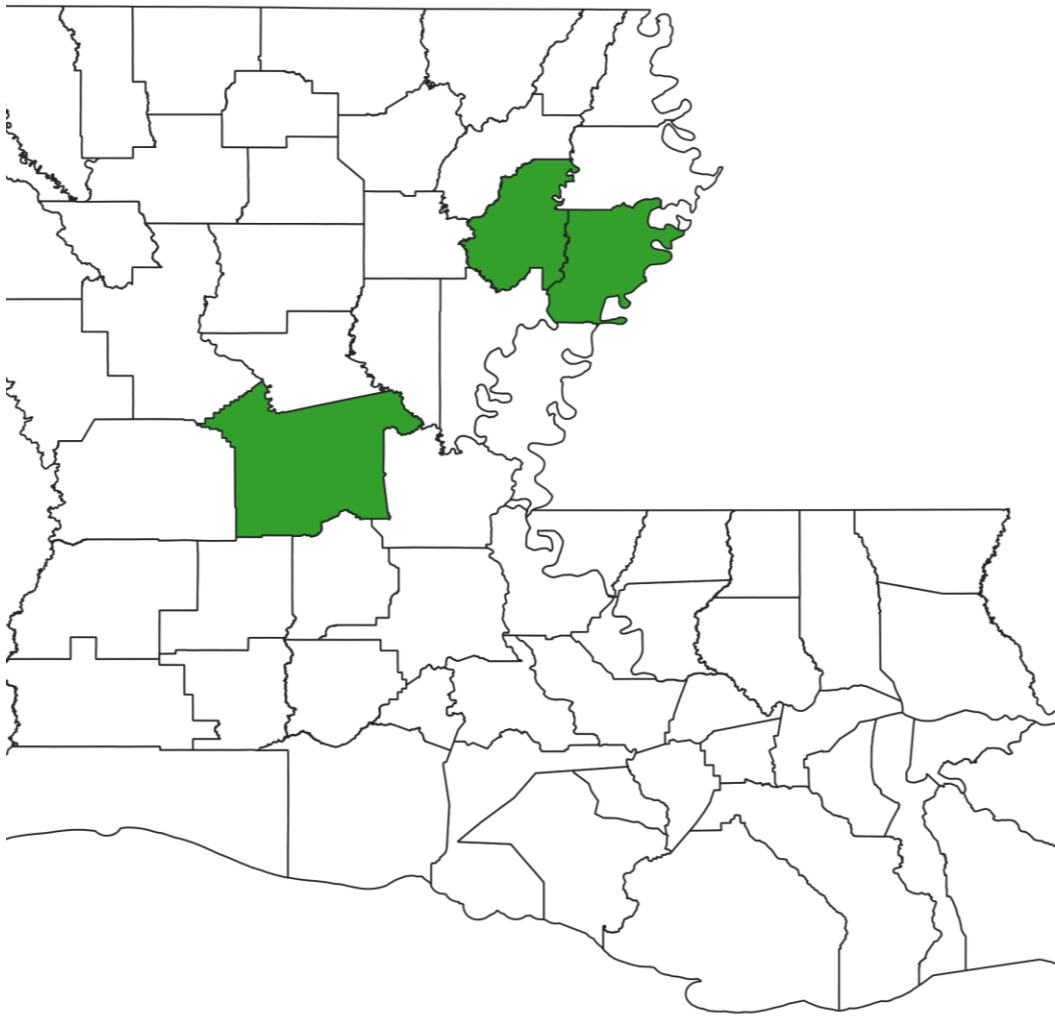
PLANTING DATE

MULTIPLE VARIETY AT 3 LOCATIONS

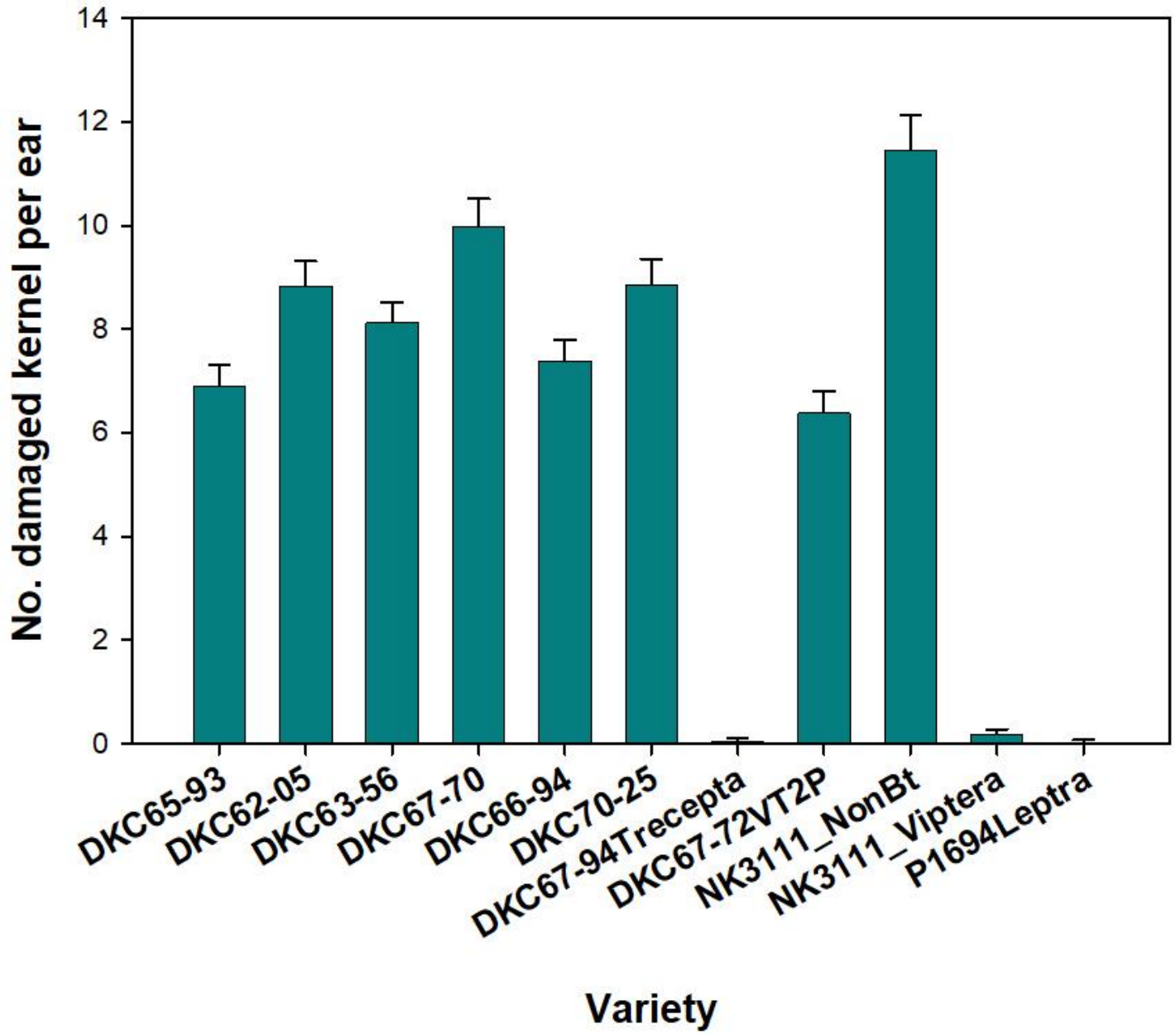
RESISTANCE MONITORING

Multiple Variety and Location Trials

- Three locations – LSU AgCenter Research Stations in Alexandria, Winnsboro, and St. Joseph (trials conducted with Dr. Towles)
- 11 varieties- Non-Bt, VT2P, and Vip
- Data Collected: CEW collection, Kernel Damage, and Yield



Kernel Damage (2022)



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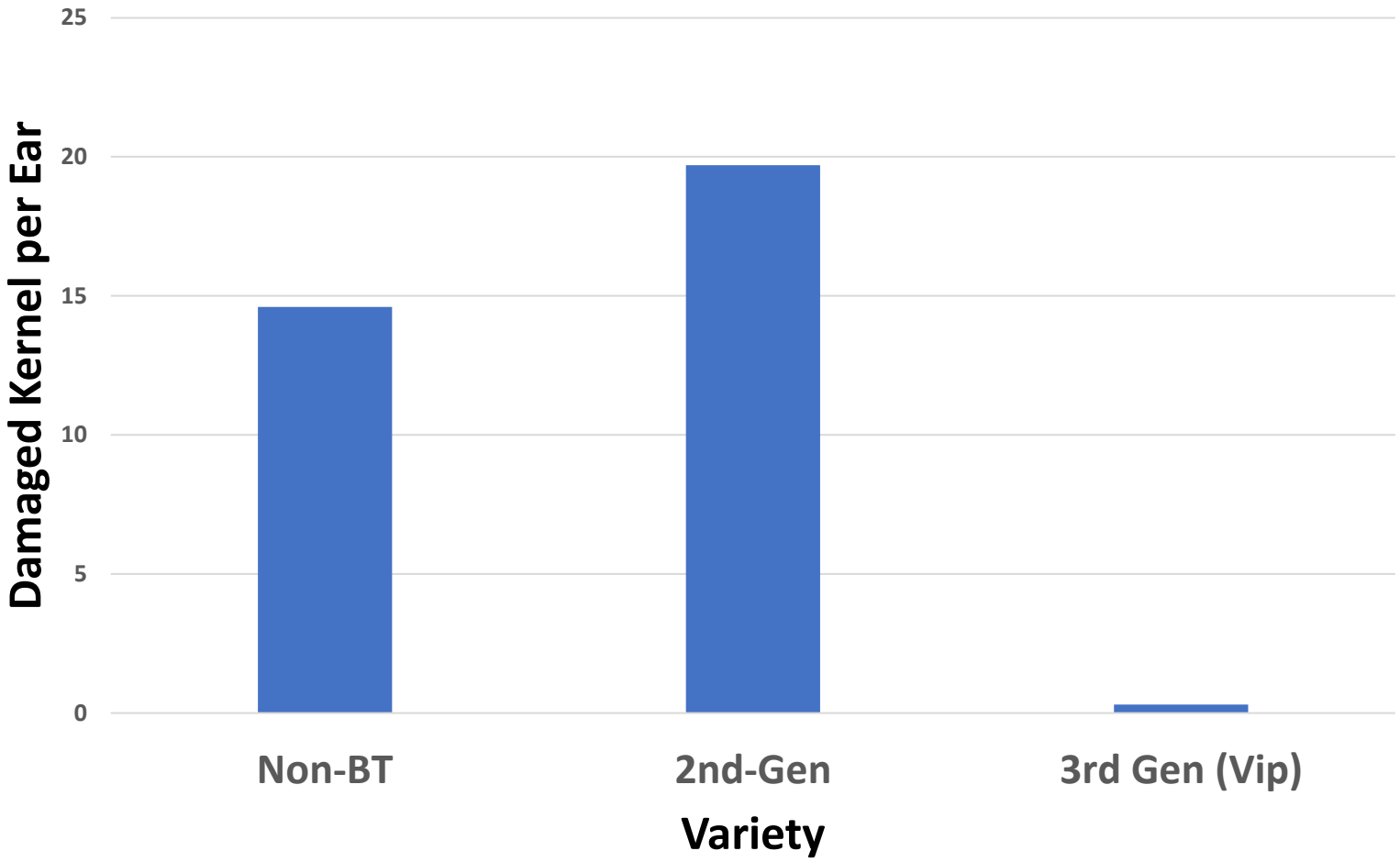
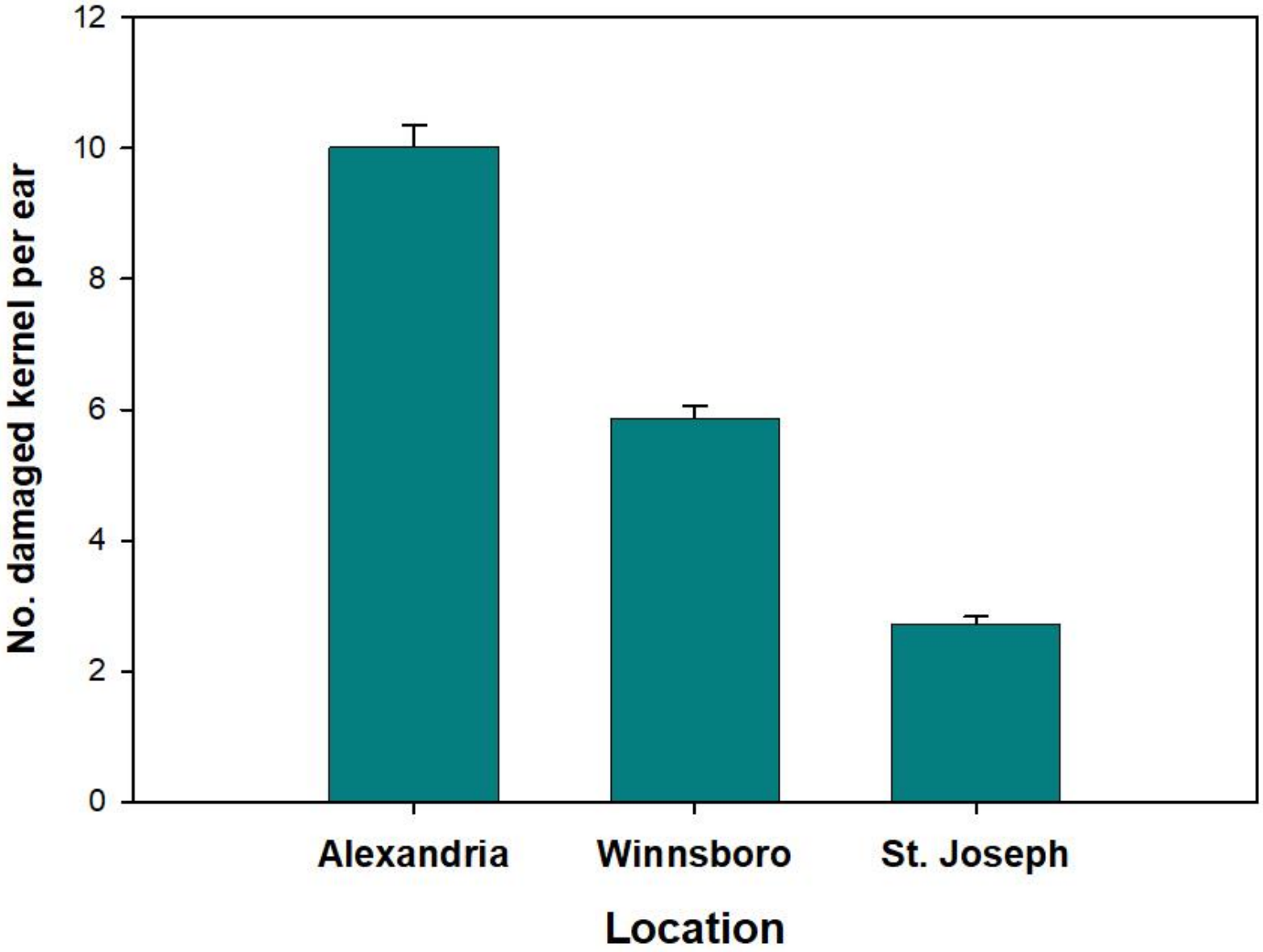
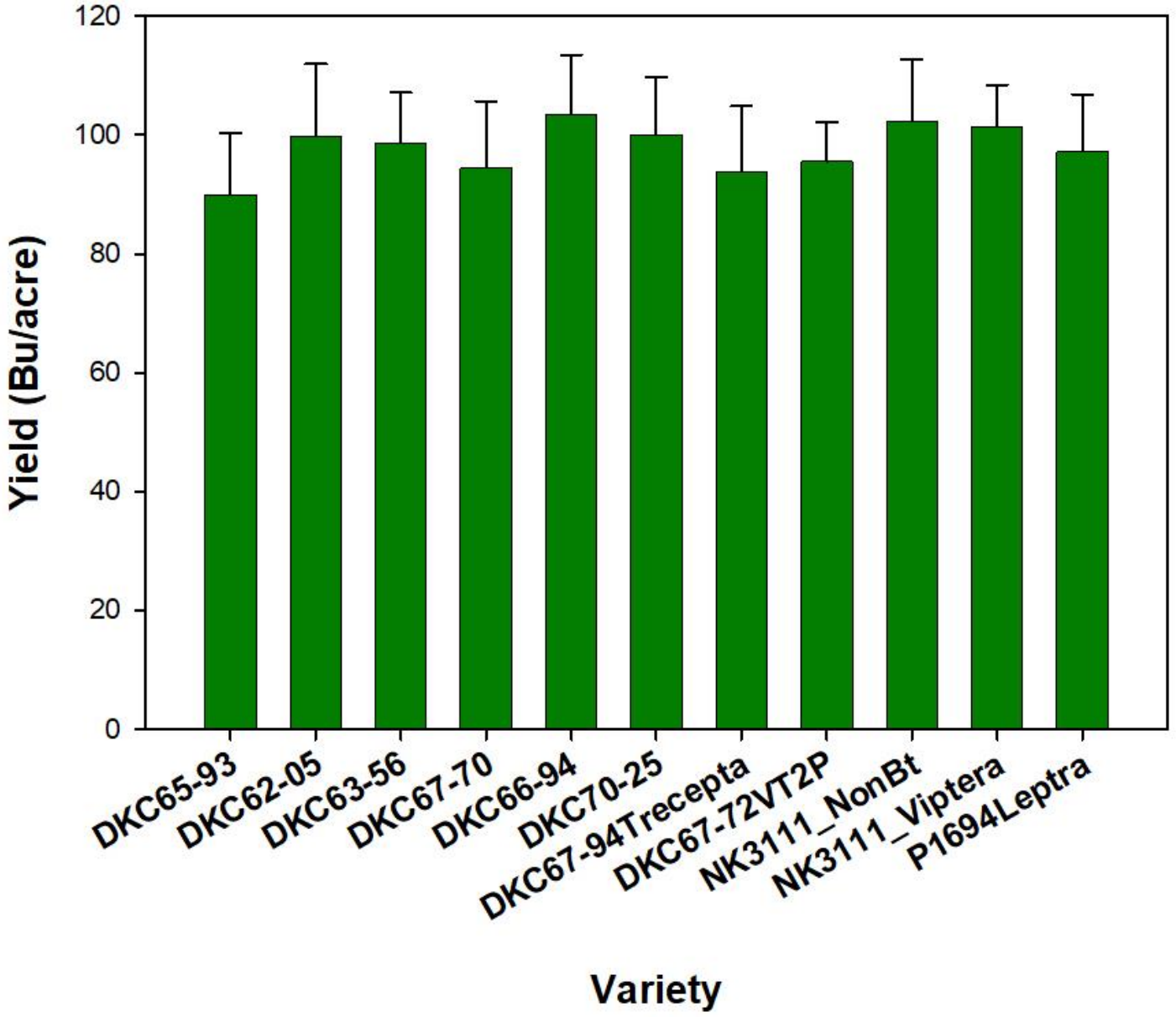


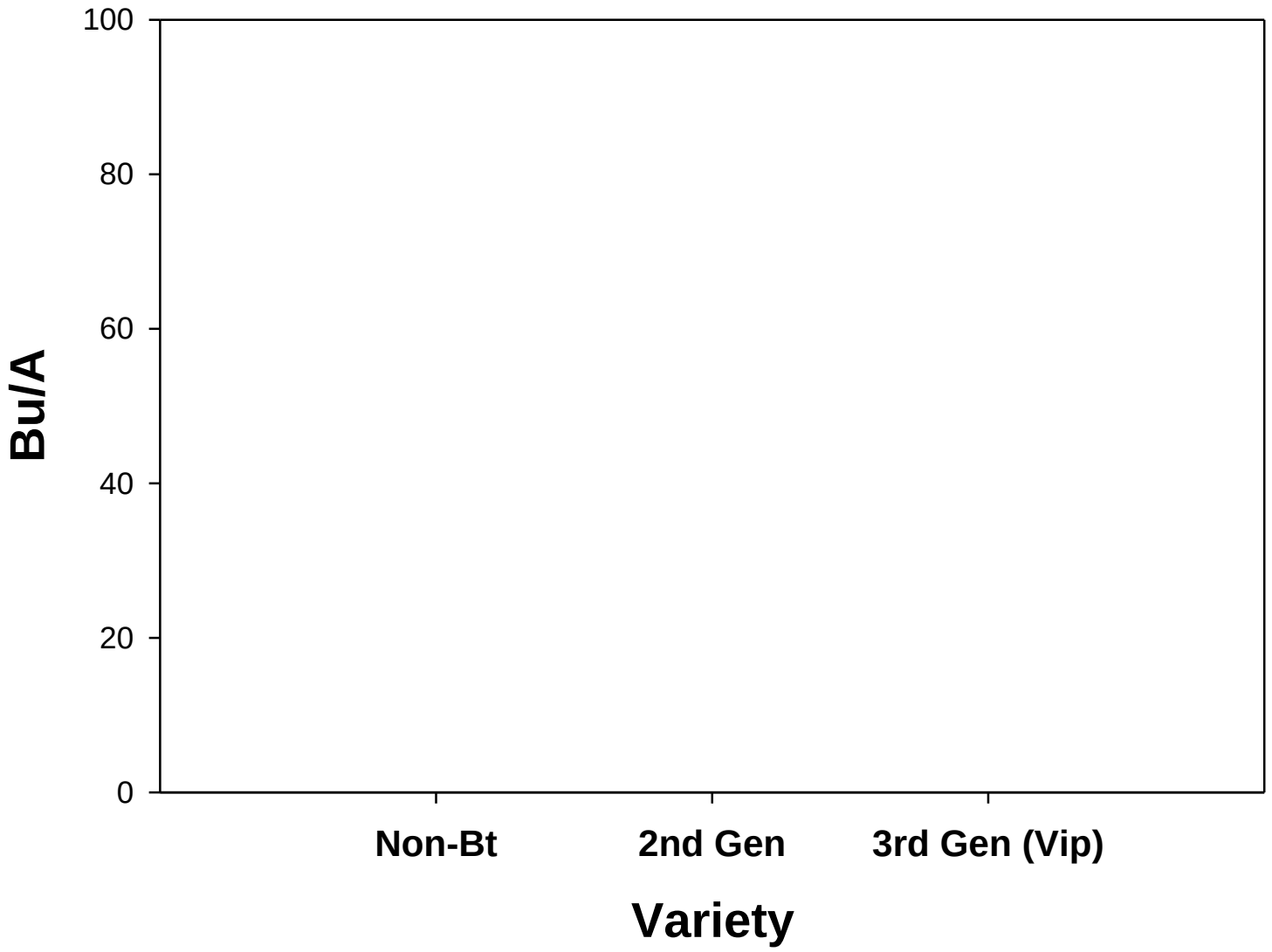
Kernel Damage (2022)



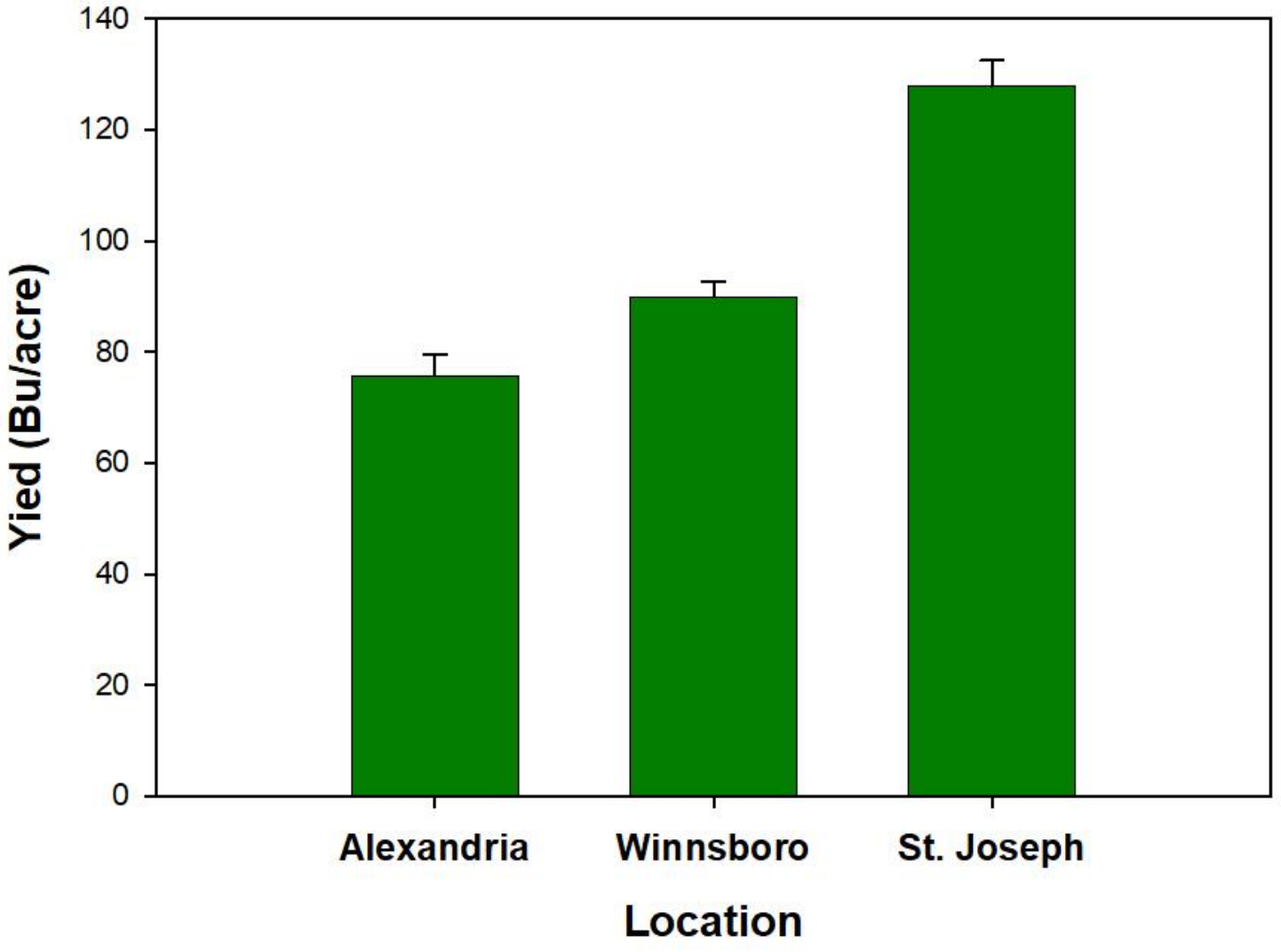
Yield (2022)


120
100
80
60
40
20
0
Yield (Bu/acre)
DKC65-93
DKC62-05
DKC63-56
DKC67-70
DKC66-94
DKC70-25
DKC67-94Trecepta
DKC67-72VT2P
NK3111_NonBt
NK3111_Viptera
P1694Leptra
Variety

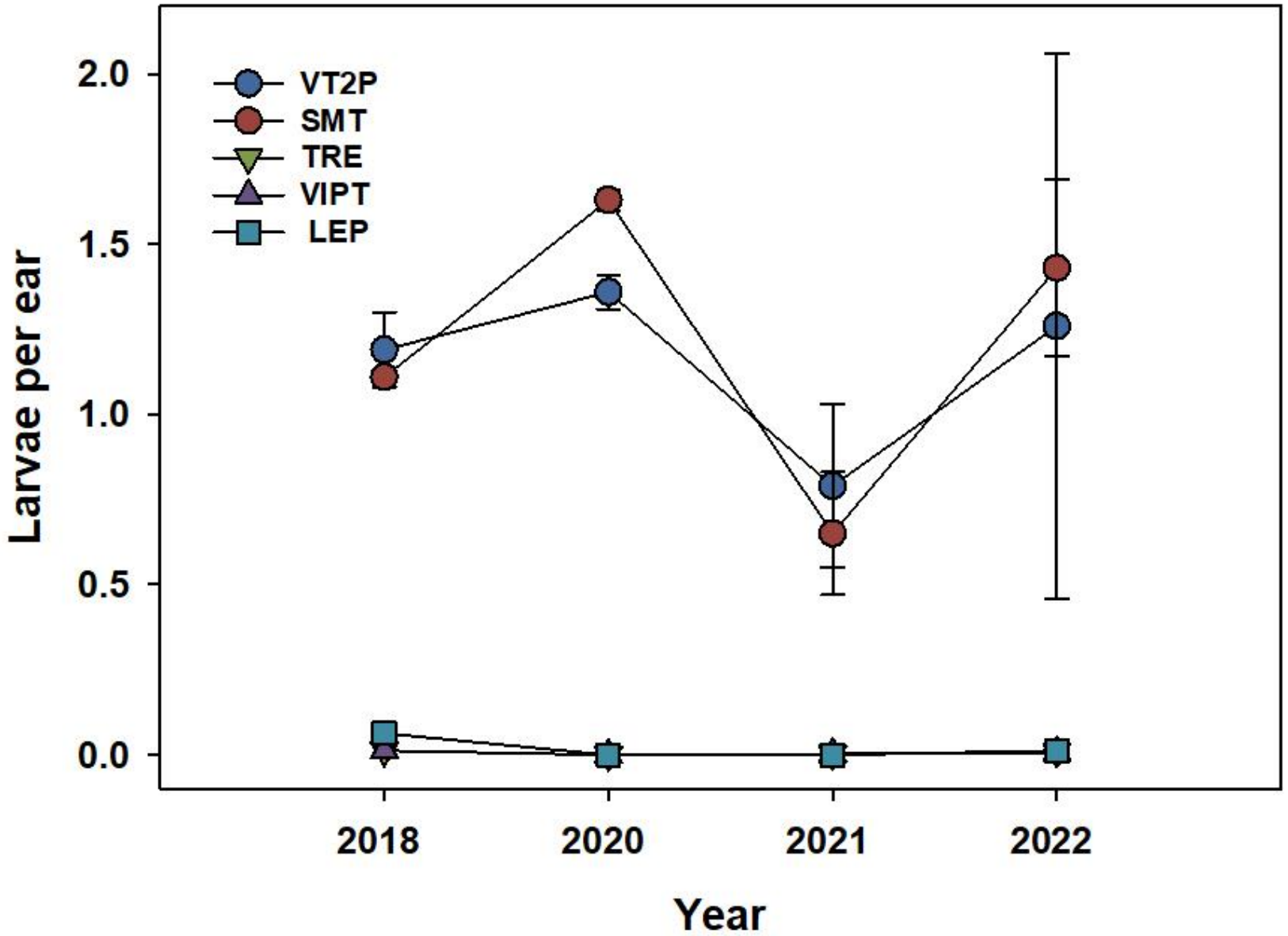
Yield (2022)



Yield (2022)

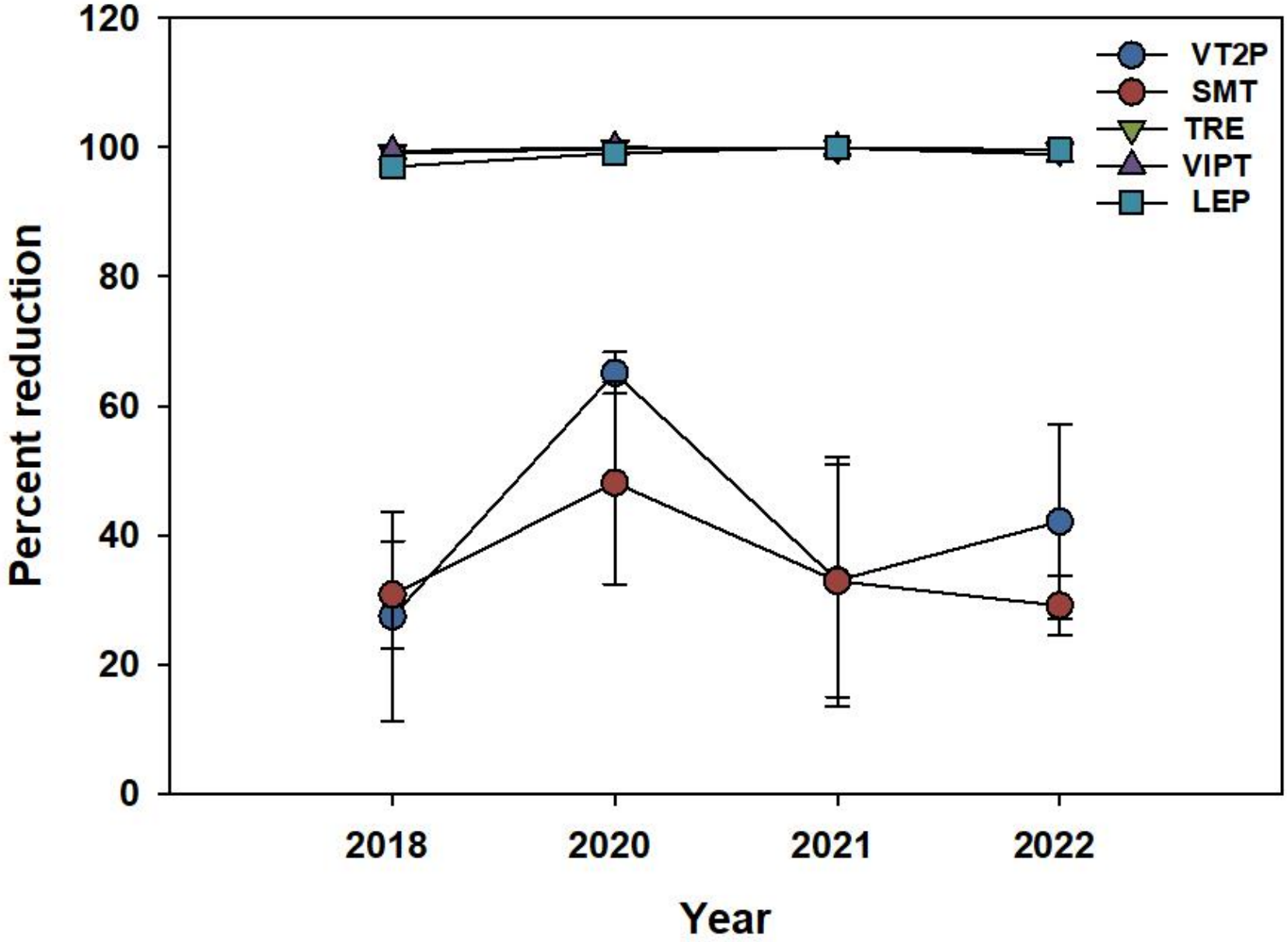

140
120
100
80
60
40
20
0
Yied (Bu/acre)
Alexandria
Winnsboro
St. Joseph
Location

Larval Occurrence



Huang et al. 2022

Ear Injury Reduction



Huang et al. 2022

Ear Injury Reduction

Although CEW injury was higher in NonBt and VT2P varieties, yields were minimally affected.

Huang et al. 2022

Ongoing Research

PLANTING DATE

MULTIPLE VARIETY AT 3 LOCATIONS

RESISTANCE MONITORING

Bt resistance monitoring

Survey Bioassays (collaboration with Dr. Kerns and Dr. Huang)

- 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.

Table 1. LC_{50} and 95% confidence limits (CL) based on larval mortality of *Helicoverpa zea* to Cry1Ac protein in the Midsouth in 2022, n=19

Insect strain	N	LC_{50} (95% CL) (µg/cm^2)	Slope ± SE	X^2	df	Resistance ratio
CBW-BZ-SS	512	0.14 (0.10, 0.20)	0.85 ± 0.08	37.2	26	1.0
CBW-Alexandria LA-NBT	384	17.36 (10.13, 33.33)	0.85 ± 0.08	29.5	18	124.0*
CBW-Alexandria LA-VT2P	512	78.95 (41.37, 201.92)	0.64 ± 0.08	16.2	26	563.9*
CBW-Epps LA-Crimson Clover	512	49.16 (20.14, 216.70)	0.39 ± 0.07	27.2	26	351.1*
CBW-Jackson TN-NBT	512	45.97 (29.00, 83.98)	0.84 ± 0.09	20	26	328.4*
CBW-Jackson TN-VT2P	512	64.31 (39.25, 125.63)	0.85 ± 0.09	26.6	26	459.4*
CBW-Leland MS-NBT	512	10101 (1012, 4601252)	0.47 ± 0.11	20.4	26	72150.0*
CBW-Leland MS-VT2P	512	497.91 (177.3, 3106)	0.63 ± 0.10	21.2	26	3556.5*
CBW-Marianna AR-NBT	512	209.81 (93.99, 753.75)	0.66 ± 0.09	21.5	26	1498.6*
CBW-Pine Bluff AR-NBT	384	52630 (1315, 1.3169E17)	0.35 ± 0.14	19.5	18	375928.6*
CBW-Winnsboro LA-NBT	512	56.11 (35.23, 104.38)	0.87 ± 0.10	21.1	26	400.8*
CBW-Winnsboro LA-VT2P	512	97.30 (54.03, 227.03)	0.77 ± 0.09	15.5	26	695.0*
CBW-BZ-SS	512	0.17 (0.14, 0.21)	2.24 ± 0.21	111.36	26	1.0
CBW-CA-MS-CC	512	> 31.60	0.007 ± 0.09	0.01	/	> 185 *
CBW-CT-MS-NBt corn	512	> 31.60	0.73 ± 0.11	42.11	/	> 185 *
CBW-HB-LA-CC	512	> 31.60	0.47 ± 0.10	23.13	/	> 185 *
CBW-LY-MS-CC	512	> 31.60	0.66 ± 0.14	21.61	/	> 185 *
CBW-PK-AR-Bt corn	512	> 31.60	0.43 ± 0.11	14.75	/	> 185 *
CBW-PK-AR-NBt corn	512	> 31.60	0.83 ± 0.19	18.68	/	> 185 *
CBW-YC-MS-CC	512	> 31.60	0.91 ± 0.12	57.21	/	> 185 *

Resistance ratio = LC50 of a field population / LC50 of the susceptible strain.

≥ 10 = resistant
19:19

Table 3. LC_{50} and 95% confidence limits (CL) based on larval mortality of *Helicoverpa zea* to Cry2Ab2 protein the Midsouth in 2022, n=19

Insect strain	N	LC_{50} (95% CL) (µg/cm^2)	Slope ± SE	X^2	df	Resistance ratio
CBW-BZ-SS	576	0.53 (0.33, 0.85)	1.27 ± 0.14	78.5	30	1.0
CBW-Alexandria LA-NBT	512	3.29 (1.53, 7.91)	1.43 ± 0.31	70.1	26	6.2
CBW-Alexandria LA-VT2P	512	41.80 (20.07, 152.97)	0.89 ± 0.15	21.3	26	78.9*
CBW-Epps LA-Crimson Clover	512	392.59 (88.53, 9052)	0.53 ± 0.10	32.2	26	740.7*
CBW-Jackson TN-NBT	512	3.12 (2.16, 4.73)	0.83 ± 0.08	11.4	26	5.9
CBW-Jackson TN-VT2P	512	8.59 (5.70, 14.44)	0.88 ± 0.09	37.5	26	16.2*
CBW-Leland MS-NBT	512	7.00 (5.23, 9.82)	1.25 ± 0.12	30	26	13.2*
CBW-Leland MS-VT2P	512	10.77 (7.50, 17.04)	1.06 ± 0.11	16.8	26	20.3*
CBW-Marianna AR-NBT	512	4.23 (3.04, 6.15)	0.99 ± 0.09	19.6	26	8.0
CBW-Pine Bluff AR-NBT	512	6.37 (4.67, 9.15)	1.14 ± 0.10	31.3	26	12.0*
CBW-Winnsboro LA-NBT	512	6.80 (4.45, 11.58)	0.80 ± 0.08	15.4	26	12.8*
CBW-Winnsboro LA-VT2P	512	8.39 (5.34, 15.01)	0.78 ± 0.08	15.1	26	15.8*
CBW-BZ-SS	512	1.61 (1.27, 2.04)	1.60 ± 0.12	169.03	26	1.0
CBW-CA-MS-CC	512	> 20.0	0.76 ± 0.11	45.02	/	> 12 *
CBW-CT-MS-NBt corn	512	> 20.0	1.0 ± 0.15	44.3	/	> 12 *
CBW-HB-LA-CC	512	> 20.0	0.69 ± 0.11	41.09	/	> 12 *
CBW-LY-MS-CC	512	> 20.0	0.52 ± 0.11	23.58	/	> 12 *
CBW-PK-AR-Bt corn	512	> 20.0	0.63 ± 0.15	18.01	/	> 12 *
CBW-PK-AR-NBt corn	512	> 20.0	0.52 ± 0.10	29.65	/	> 12 *
CBW-YC-MS-CC	512	> 20.0	0.91 ± 0.14	42.72	/	> 12 *

Resistance ratio = LC50 of a field population / LC50 of the susceptible strain.

≥ 10 = resistant
16:19

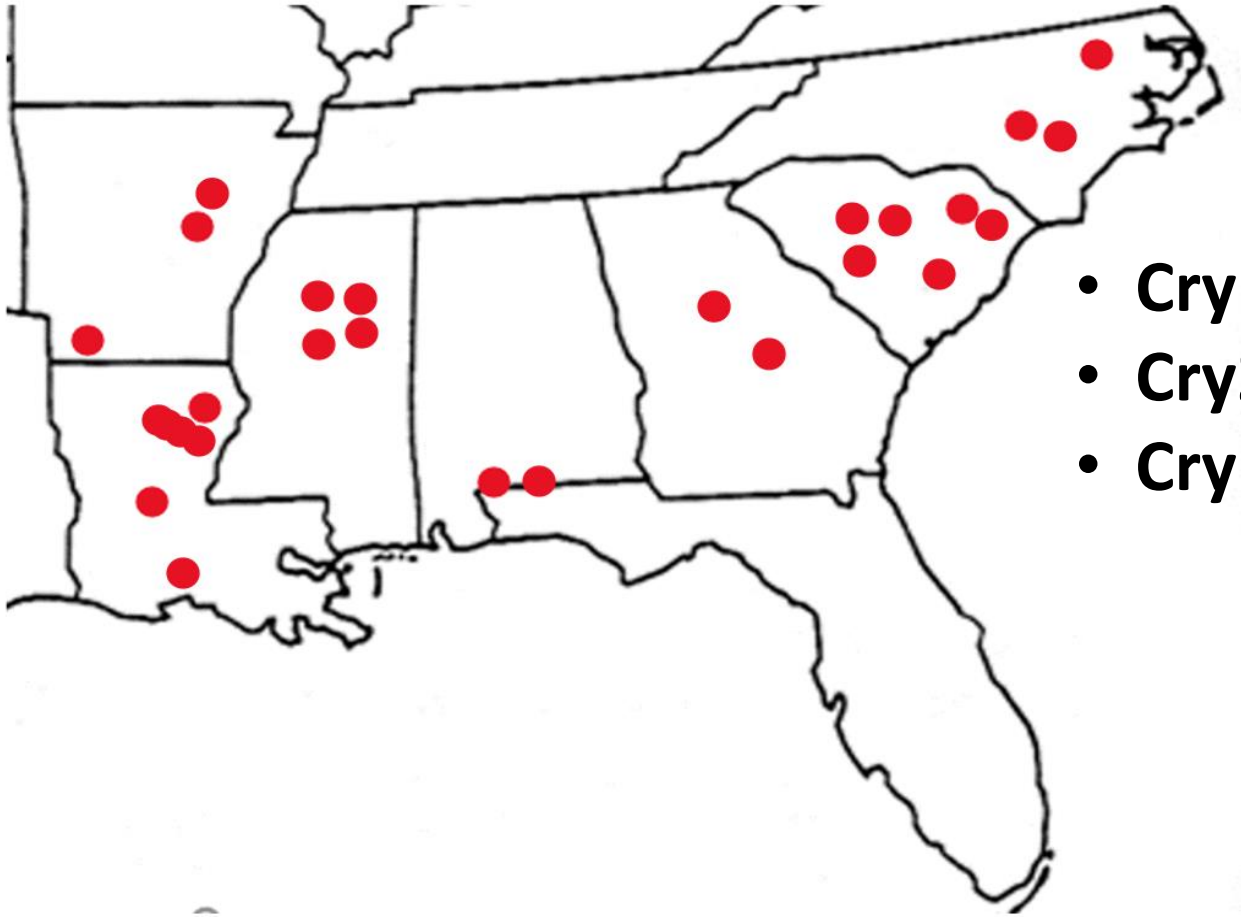
Table 5. LC_{50} and 95% confidence limits (CL) based on larval mortality of *Helicoverpa zea* to Vip3Aa39 protein in the Midsouth in 2022, n=19

Insect strain	N	LC_{50} (95% CL) (µg/cm^2)	Slope ± SE	X^2	df	Resistance ratio
CBW-BZ-SS	512	0.109 (0.087, 0.136)	1.90 ± 0.16	20.3	26	1.0
CBW-Alexandria LA-NBT	448	0.033 (0.028, 0.039)	4.54 ± 0.85	11.6	22	0.3
CBW-Alexandria LA-VT2P	448	0.037 (0.028, 0.046)	2.61 ± 0.40	8.6	22	0.3
CBW-Epps LA-Crimson Clover	448	0.208 (0.167, 0.258)	2.02 ± 0.18	25.1	22	1.9
CBW-Jackson TN-NBT	448	0.022 (0.012, 0.029)	2.83 ± 0.65	4.8	22	0.2
CBW-Jackson TN-VT2P	448	0.021 (0.011, 0.030)	2.13 ± 0.42	14.8	22	0.2
CBW-Leland MS-NBT	448	0.040 (0.032, 0.054)	2.85 ± 0.41	14.9	22	0.4
CBW-Leland MS-VT2P	448	0.033 (0.022, 0.042)	2.22 ± 0.33	16.7	22	0.3
CBW-Marianna AR-NBT	448	0.030 (0.021, 0.038)	2.65 ± 0.45	10.9	22	0.3
CBW-Pine Bluff AR-NBT	448	0.032 (0.023, 0.041)	2.43 ± 0.39	14.5	22	0.3
CBW-Winnsboro LA-NBT	448	0.043 (0.028, 0.058)	1.60 ± 0.21	16.8	22	0.4
CBW-Winnsboro LA-VT2P	448	0.107 (0.086, 0.133)	2.09 ± 0.21	10.7	22	1.0
CBW-BZ-SS	512	3.12 (2.42, 4.14)	1.68 ± 0.15	119.74	26	1.0
CBW-CA-MS-CC	512	0.24 (0.20, 0.30)	2.11 ± 0.18	136.77	26	0.08
CBW-CT-MS-NBt corn	512	0.12 (0.10, 0.15)	2.32 ± 0.21	125.76	26	0.04
CBW-HB-LA-CC	512	0.33 (0.27, 0.40)	2.36 ± 0.21	121.92	26	0.11
CBW-LY-MS-CC	512	0.22 (0.17, 0.27)	1.71 ± 0.14	149.17	26	0.07
CBW-PK-AR-Bt corn	512	0.33 (0.27, 0.41)	2.17 ± 0.18	139.63	26	0.11
CBW-PK-AR-NBt corn	512	0.43 (0.36, 0.53)	2.40 ± 0.22	123.39	26	0.14
CBW-YC-MS-CC	512	0.32 (0.26, 0.39)	2.30 ± 0.20	126.22	26	0.1

Resistance ratio = LC50 of a field population / LC50 of the susceptible strain.

≥ 10 = resistant
0:19

CEW collections during 2018-2019



- Cry1A.105 – RR varied from 4 – 2107 fold
- Cry2Ab2 – RR varied from 2 – 145 fold
- Cry1Ab – RR varied from 9 – 55 fold

Dr. Fangneng Huang's Lab
LSU AgCenter

Summary of Bt Resistance Surveys

Bt protein	Texas and Mid-South Percentage of populations with RR > 10X						
	2016 *n*=5	2017 *n*=14	2018 *n*=13	2019 *n*=13	2020 *n*=5	2021 *n*=12	2022 *n*=37
Cry1Ac	40%*	100%	94%	96%	100%	92%	100%
Cry2Ab2	80%	77%	73%	73%	100%	92%	74%
Cry1F	ND	100%	100%	100%	ND	ND	ND
Vip3Aa	0%	0%	0%*	0%*	0%	0%	0%

- Field resistance to Cry1Ab, Cry1A.105, and Cry2Ab2 in CEW in Louisiana and other southern states was common.
- CEW populations in the region including Louisiana are still susceptible to Vip3A.
- Vip3A is effective against Cry1/Cry2-resistant CEW.

Current Bt resistance status

"Practical resistance"
- **> 50% of individuals resistant**
- **Reduced efficacy reported**

- **Cry1Ac**
- **Cry2Ab2**

"Early warning"

- **Vip3A**

No significant decrease in susceptibility

Susceptible

Tabashnik et al. JEE (2014), Tabashnik & Carrière Nature Biotechnology (2017)

To preserve Vip3Aa susceptibility, it is vital that we comply with corn refuge planting requirements

- **Minimal impact of CEW on yields, particularly when planted within the recommended planting window**
- **Bt corn does not necessarily mean higher yields**
- **Consider the price difference between non-Bt and Bt corn when selecting varieties**

Thank you

James Villegas
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