KANSAS SOYBEAN COMMISSION FINAL REPORT OF PROGRESS

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Title: "Breeding and Management of Soybean for Improved Performance"

Amount of Funding: $266,444

Department Heads: Gary Pierzynski, Erik De Wolf

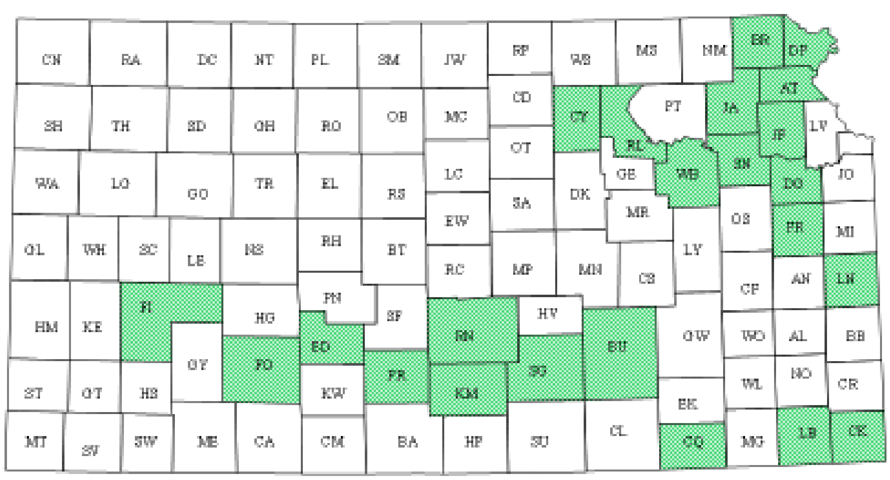
Accomplishments for FY2016 (March 1, 2015 – February 29, 2016)

SCN Breeding and Management

SCN populations

Approximately 40 SCN populations from 23 Kansas counties are currently being maintained or increased in the greenhouse for use in resistance screening and virulence characterization (Appendix I, Fig. 1). Most of these population were collected from a 2010-2011 survey of Kansas soybean production fields. **The populations represent the full range of virulence found in Kansas for all major sources of SCN resistance**.

Figure 1. Source locations for SCN populations maintained for screening and HG Type testing.



Primary SCN screening populations included HG Types 7 and 1.2.3.5.6.7. Female indices on the HG Type 1.2.3.5.6.7 were >10% on all indicator lines except PI 437654 (line #4), and >20% on PI 88788 (line #2), the most common source of SCN resistance (Fig. 2). Female indices on the HG Type 7 population were <10% on all indicator lines except PI 548316 (line #7).

Representative commercial cultivars are also included in all HG Type Tests. Commercial cultivars with resistance derived from standard resistance sources typically present lower levels of resistance than their source of resistance. KS4313N, for example, is only moderately resistant to our HG Type 7 population, while its resistance source PI 88788 is fully resistant (Fig. 3). This discrepancy increases as the level of resistance in PI 88788 decreases, with KS4313N exhibiting full susceptibility to HG Type 1.2.3.5.6.7, even though PI88788 displays moderate resistance to this population.

Figure 2. HG Type designations for primary SCN screening populations, FY 2016.

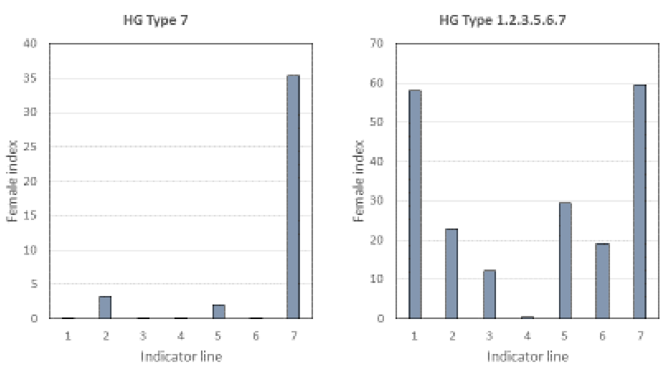
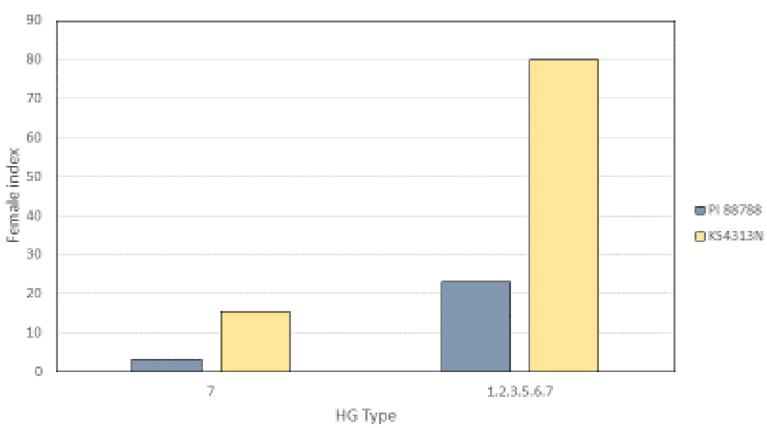


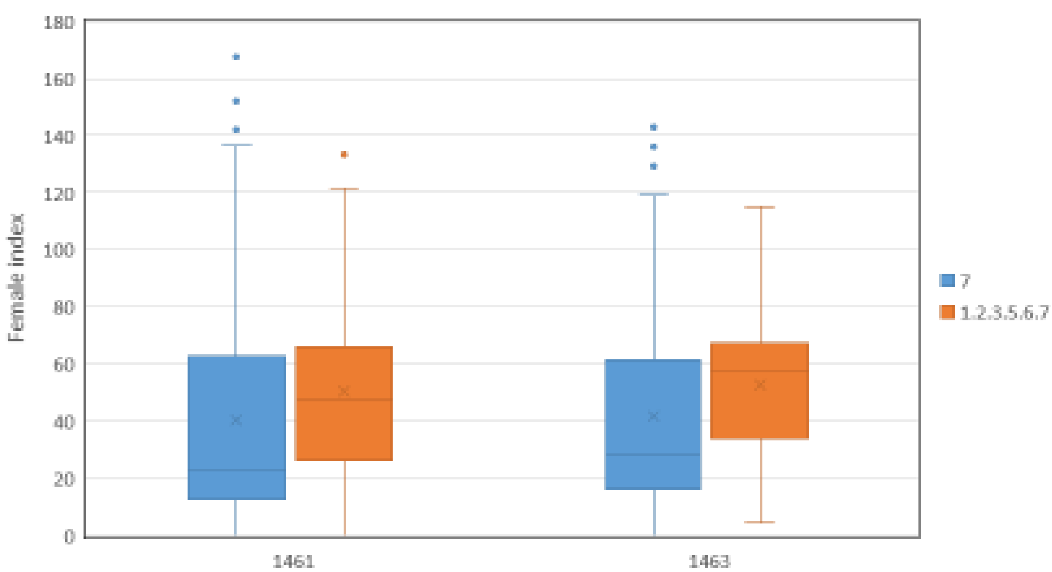
Figure 3. Female indices on KS4313N and its source of resistance PI 88788.



SCN resistance screening

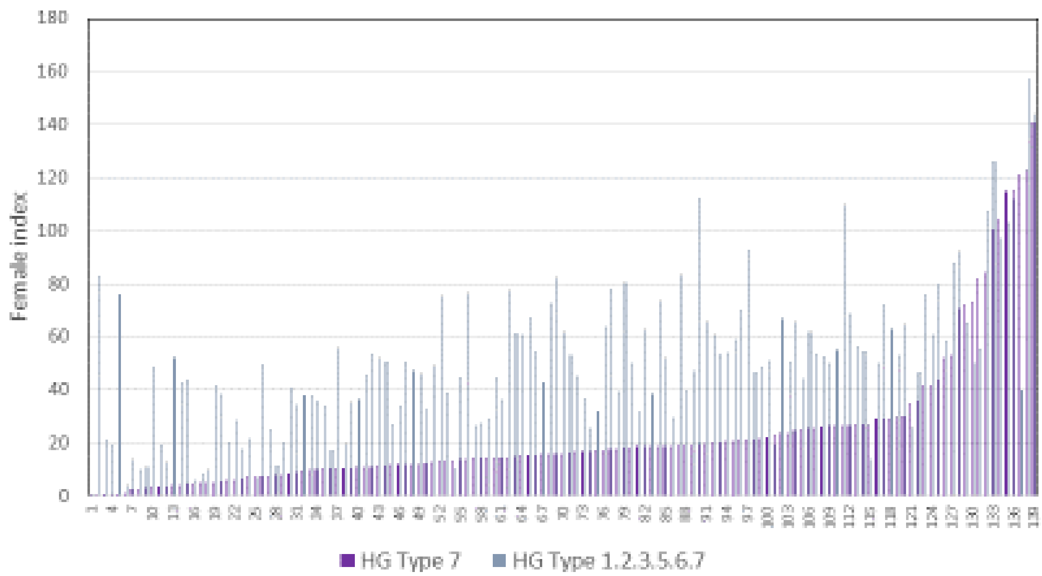
Breeding lines: Approximately 200 Kansas soybean breeding lines were screened in replicated trials for resistance to SCN in 2015. Results are summarized for two groups of breeding lines in Fig. 4. Lines were derived from crosses representing diverse sources of resistance. Approximately one-half of tested lines displayed useful resistance to HG Type 7, but fewer than one-quarter of tested lines were resistant or moderately resistant to HG Type 1.2.3.5.6.7. Most lines displayed a high level of resistance to only one SCN population, but **approximately 10% of lines exhibited useful resistance to both populations**. Some of these lines represent potentially new combinations of resistance alleles and are being evaluated against a broader diversity of nematode populations.

Figure 4. Summary of FY 2016 SCN screening results for Kansas soybean breeding lines.



Kansas Soybean Performance Test: One hundred thirty-nine entries from the Kansas Soybean Performance Test were evaluated in replicated greenhouse trials for resistance to HG Type 7 and 1.2.3.5.6.7 populations. Average female indices are reported in Appendix II. Most entries exhibited a useful level of SCN resistance (FI < 30) to HG Type 7. As was observed for the soybean breeding lines, however, resistance to HG Type 7 (PI 88788 FI = 3) was not a good indicator of resistance to HG Type 1.2.3.5.6.7 (PI 88788 FI = 23), even though most entries derived their resistance from PI 88788 (Fig. 5).

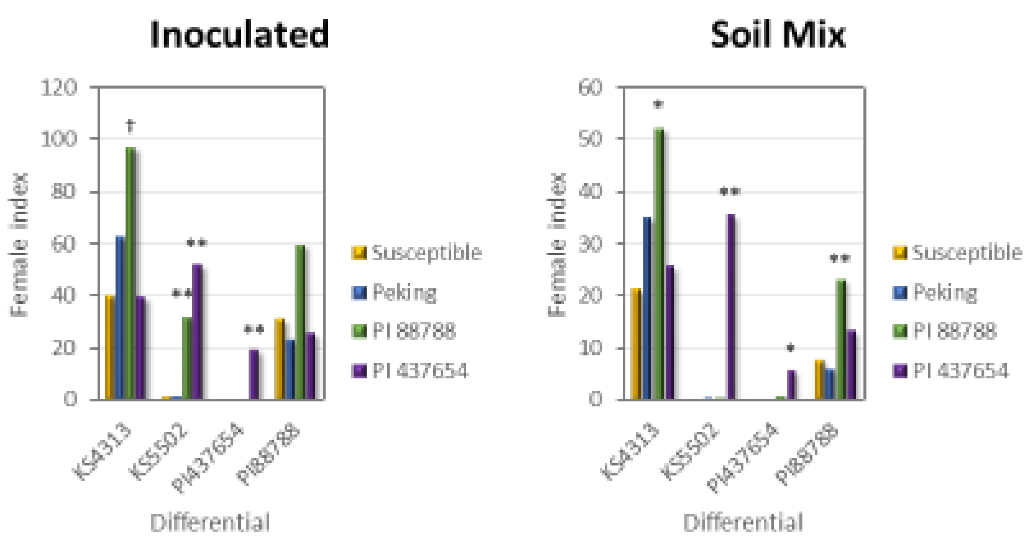
Figure 5. Distribution of female indices for FY 2016 Kansas Soybean Performance Test Entries.



Field virulence trials

The effect of virulence selection on soybean cultivars representing the major sources of SCN resistance is being investigated in a long–term field experiment at the Rossville Kansas River Valley Experiment Field. Female indices on KS4313N and KS5502, as well as their sources of resistance (PI 88788 and PI 437654, respectively) were determined from HG Type tests using both naturally-infested soil and egg inoculum. Soil populations and inoculum came from field plots that were previously planted to either a susceptible soybean cultivar or to cultivars representing one of three sources of SCN resistance. FY 2016 results are shown in Fig. 6. **Female indices have increased to susceptible levels on KS4313N and KS5502 following prior exposure to PI 88788-derived and PI 437654-derived cultivars**, respectively, and have remained high even after several years of relaxed selection (i.e. exposure only to a susceptible soybean cultivar).

Figure 6. Effect of prior selection on female indices for two soybean cultivars and their resistance sources.



Incorporation of transgenic soybean lines into elite cultivars

Currently, we have developed several lines with enhanced SCN resistance that have good for potential crossing into adapted cultivars. These events are expressing small RNAs targeting the down regulation of the SCN genes identified as Y25 and Prp17. The Y25 E12P3 and Y25 E13 transgenic lines are in the background, Jack and are homozygous at the T3 generation. The expression of RNAi constructs of these two plants were relatively high confirmed by RT-qPCR and the SCN bioassays have consistently demonstrated between a **50-60% SCN cyst reduction** (Figure 7). The transgenic lines Prp17 01-03 P6 and Prp17 01-03 P8 (T3 seeds) were also shown significant SCN reduction (~50-60% in cyst reduction and between 50 -70% egg reduction) in the SCN bioassays Figure 8).

Figure 7. Y25: different transgenic lines showed significant resistance to SCN

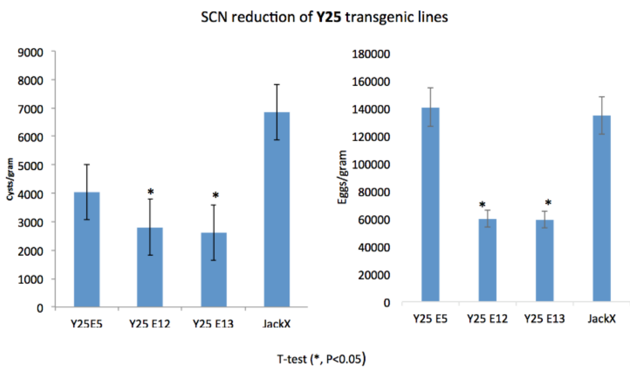
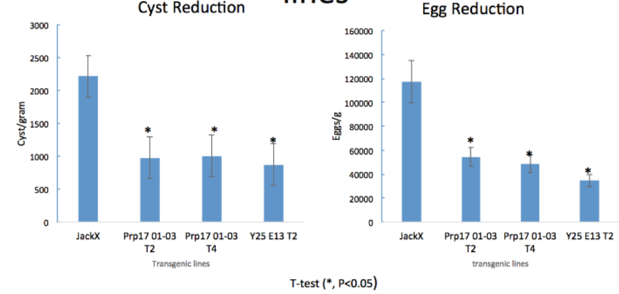


Figure 8. Recent SCN bioassay with different generations of transgenic lines



Host induced RNAi transgenic soybean had consistent and stable resistance to SCN during different generations.

Variety Development/Genetics

Development of new populations

- A total of about 80 new populations were created in 2015 using over 25 different parents (Appendices III and IV).
- Twenty-seven, single cross populations involving **drought resistant** parents.
- About half of the single cross populations involved parents **tolerant to STS** herbicides.
- About 75% of the single cross populations involved at least **one parent resistant to SCN**. Several of these parents possessed SCN resistance genes currently not used in commercial varieties.
- About 25% of the single cross populations involved at least one parent that possessed genes from a plant introduction that has not contributed to the genetic improvement of US soybean varieties. The goal of using these parents is to **increase the genetic diversity** of US germplasm to increase, or at least, maintain genetic gain.
- A cross between LD00-3309 (high yield, good **pollen germination**) and parent PI423932 (high seed germinability, poor adaptation) was made to combine high seed germinability with good yield and pollen germination.
- Several populations involved converting a conventional line to a line possessing the **RR1** trait.

Yield trials

- We completed evaluations of **over 3600 genotypes** in over 14,000 yield plots in Kansas (APPENDIX V).
- Over 1000 K-lines were evaluated in our preliminary trials.
- Over 300 K-lines were evaluated in our KS advanced yield trials.
- Over 300 (including 29 K-lines) breeding lines from programs across the country were evaluated in our KS Uniform Tests and Uniform Preliminary yield trials.
- Over 1200 genotypes, (experimental breeding lines and **plant introductions**) were evaluated in our drought, remote sensing, and diversity yield trials.

Seed Increases

- All K-lines entered into the 2015 Uniform Preliminary, Uniform Tests or final testing in KS were place in seed increase blocks (APPENDIX VI). Of the 32 experimental varieties under increase, seven will be advanced for more testing and increase, two will be advanced to a large-scale increase, with the intent to release in 2017.

Increase with intent to release in 2017: K11-2363 (Conventional Variety)

K11-2363 is an F3 single plant selection from the cross 435.TCS X LD05-30578a. K11-2363 has been high yielding, and possesses resistance to SCN and tolerance to STS herbicide. A large-scale increase will be conducted in 2016 with the goal of producing about 3000 bushels of breeders seed that can be released in 2017.

K11-2363 has purple flowers, tawny pubescence, brown pods at maturity, indeterminate growth habit, and seeds with black hila. K11-2363 is an early group IV maturity variety and is well adapted to a wide range of soil types and climates throughout the central soybean belt.

K11-2363 has been extensively tested throughout Kansas and the United States in the Soybean Cyst Nematode (SCN) Regional tests from 2013 through 2015 and in the K-State Soybean Breeding program. K11-2363 possesses resistance to SCN and is tolerant to STS herbicide. As summary of its performance is shown in Tables 1 to 7.

TABLE 1. 3-YEAR SUMMARY, SCN UNIFORM AND PRELIM IV.

					Seed			
		Maturity	Lodging	Height	quality	weight	protein	oil
Strain	Yield	date	score	inches	score	g/100	@13%	@13%
Locations	23	20	23	23	23	23	16	16
K11-2363	58.5a†	9/27b	1.4b	29b	2.1b	15.7a	33.7ab	18.9b
LD00-2817P	56.1b	9/28a	2.0a	35a	2.4a	13.3c	33.2b	19.4a
LD06-7620	57.1ab	9/26b	1.6b	30b	2.3a	14.2b	34.0a	18.9b

† Numbers followed by the same letter, not significantly different at the 0.05 level of probability.

Table 2. 2013 SCN PRELIM TEST IV

	Strain	FPhlm	Parentage	Gen. Comp.	SCN res source	Traits
1	**LD06-7620**	PGbl	IA3023 x LD00- 3309	F5	PI88788	
2	**IA4005**	WLtbl	IA3023 x IA3025	F4	None	1% linolenic
3	**LD00- 2817P**	PGibl	Ina x Dwight	F5	PI88788 / PI437654	
4	**K11-1336**	PTbl	IA3024 x LD04-13265	F4	PI88788	
5	**K11-1666**	PTbl	IA3024 x LG04-5190	F4	PI88788	
6	**K11-1868**	P+WGibl/bf	U98-311422 x LG04-5187	F4	PI88788	
7	**K11-2006**	PLtbl	K03-3825 x LD04-13265	F4	PI88788	
8	**K11-2363**	PLtbl	435.TCS x LD05-30578a	F4	PI88788	
9	**K11-2371**	PLtbl	435.TCS x LD04-12754	F4	PI88788	
10	**LD10- 3482**	PLtbl	LD04-13296 x LD01-5907	F5	PI88788 / PI437654	
11	**LD10- 4612**	WTblbl	LD05-7565 x LD04-12754	F5	PI88788	
12	**LD10- 8610**	PLtbl	LD01-5907 x U03-100612	F5	PI88788 / PI437654	
13	**LD10- 9409**	PLtbl	LD05-8517 x Syngenta 03JR101916	F5	PI88788	
14	**LD10- 9434**	PLtbl	LD05-8517 x Syngenta 03JR101916	F5	PI88788	
15	**LD10- 9491**	PLtbl+ibl	LD05-8517 x Syngenta 03JR101916	F5	PI88788	
16	**S10-11227**	WGbf	S04-8882 X R00-1194F	F4	PI437654	

Table 3. 2013 SCN Prelim 4 Summary

	Yield							Seed			
	Infested		Non-infested		Maturity	Lodging	Height	quality	weight	protein	oil
Entry	bu/a	rank	bu/a	rank	date	score	in.	score	g/100	@13%	@13%
Locations	4		4		6	8	8	8	8	6	6
1 LD06-7620	53.9	10	63.6	1	926	1.5	33	2.0	13.9	33.2	19.3
2 IA4005	47.6	16	54.2	15	-3	1.2	31	2.0	13.6	33.9	19.2
3 LD00- 2817P	54.5	9	57.1	10	1	1.9	37	2.0	13.0	32.7	19.4
4 K11-1336	50.0	15	55.7	12	-6	2.2	34	2.7	13.0	33.7	19.9
5 K11-1666	51.4	12	59.4	6	-8	1.6	33	2.1	15.9	33.3	19.9
6 K11-1868	55.9	4	60.4	4	-4	1.2	34	2.1	15.9	35.1	18.6
7 K11-2006	55.3	6	51.6	16	1	1.3	33	1.7	14.6	34.2	18.7
8 K11-2363	57.3	1	58.6	7	-1	1.2	30	1.7	15.2	33.2	19.7
9 K11-2371	55.8	5	60.9	3	-3	1.3	34	1.6	13.6	34.5	19.0
10 LD10- 3482	52.9	11	63.1	2	-3	1.1	31	2.1	15.1	33.8	19.8
11 LD10- 4612	54.7	8	55.2	13	-3	1.8	34	1.6	13.9	33.2	19.3
12 LD10- 8610	55.2	7	57.0	11	-7	1.4	31	2.3	14.1	33.6	19.7
13 LD10- 9409	56.8	2	58.5	8	-5	1.5	33	2.0	13.8	33.5	19.7
14 LD10- 9434	56.7	3	60.3	5	-6	1.2	32	1.8	13.0	32.7	20.3
15 LD10- 9491	50.5	13	57.2	9	-7	1.3	32	2.0	13.4	33.0	20.4
16 S10-11227	50.4	14	54.3	14	0	1.6	37	1.8	12.9	33.9	19.5

Table 4. 2014 SCN Uniform 4 Summary.

	Yield									Seed			
	All		Infested		Non-infested		Maturity	Lodging	Height	quality	weight	protein	oil
Entry	bu/a	rank	bu/a	rank	bu/a	rank	date	score	in.	score	g/100	@13%	@13%
Locations			5		2		7	7	7	7	7	6	6
1 LD06-7620	**52.7**	**11**	50.0	13	59.8	10	927	1.7	29	2.5	14.9	34.7	18.1
2 IA4005	**52.3**	**13**	49.5	15	59.6	11	-1	1.3	28	2.2	15.0	35.2	18.4
3 LD00- 2817P	**53.2**	**10**	51.4	8	57.6	14	2	2.0	34	2.6	14.0	33.6	18.9
4 AR13-331019	**51.6**	**17**	50.6	9	55.0	18	-3	3.1	38	2.9	13.3	34.0	18.0
5 K11-1868	**48.8**	**20**	46.6	20	54.3	19	-3	1.2	28	2.8	16.1	34.0	18.3
6 K11-2363	**57.5**	**1**	55.5	1	61.7	9	1	1.2	27	2.3	16.8	34.3	17.4
7 K11-2371	**53.8**	**7**	50.1	12	62.6	5	0	1.4	30	2.3	14.7	35.2	17.8
8 LD07-3395bf	**57.2**	**2**	54.4	2	64.3	3	-2	1.7	27	2.5	16.9	33.2	19.3
9 LD11-2009	**51.7**	**16**	48.0	19	62.0	8	-5	2.5	31	2.4	15.6	34.1	18.3
10 LD11-3920	**52.3**	**13**	48.5	18	62.9	4	-3	1.7	32	2.8	16.0	33.6	19.6
11 LD11-7311	**56.2**	**3**	53.2	4	65.7	1	-4	1.9	32	2.3	17.1	34.3	18.3
12 LD11-10310	**55.4**	**4**	51.9	6	64.8	2	-2	1.8	32	2.5	14.9	33.9	18.8
13 LD11-10649	**53.5**	**8**	50.4	10	62.4	7	-4	2.2	34	2.4	16.3	33.9	19.3
14 LD11-11013	**52.6**	**12**	48.9	17	62.5	6	-1	1.8	30	2.2	15.1	32.9	18.6
15 LS07-2935	**53.3**	**9**	51.5	7	58.1	13	3	2.4	39	2.6	15.6	34.9	18.3
16 LS07-3125	**45.3**	**23**	42.2	23	52.2	21	2	1.5	32	2.5	13.6	33.3	18.6
17 LS07-3131	**51.6**	**17**	50.4	10	53.3	20	4	1.9	34	2.7	15.4	34.1	18.2
18 LS08-5515	**39.9**	**24**	39.4	24	40.3	24	1	2.0	34	2.2	12.3	35.3	18.3
19 LS08-5837	**45.6**	**21**	43.8	22	50.0	22	2	1.9	33	2.4	13.6	34.3	17.5
20 LS09-1527	**54.5**	**5**	53.4	3	57.5	15	3	2.3	33	2.5	17.3	34.5	18.0
21 LS09-1803	**45.5**	**22**	44.1	21	48.7	23	4	2.8	35	2.6	12.7	34.9	17.7
22 LS09-2342	**52.0**	**15**	49.6	14	58.3	12	4	2.4	35	2.6	16.3	35.1	19.4
23 LS09-2655	**30.8**	**25**	29.8	25	31.0	25	3	1.7	30	2.7	17.0	34.9	18.6
24 LS09-2722	**51.1**	**19**	49.3	16	55.1	17	4	1.5	29	2.4	16.8	36.9	17.6
25 S10-11227	**54.1**	**6**	52.8	5	56.7	16	1	1.8	31	2.7	13.8	35.6	18.2
Mean	**50.9**		48.6		56.6		0.0	1.9	31.8				
LSD(.05)	**4.2**		5.1		5.2		1.6	0.4	1.5				
C.V. %	**13.6**		14.5		8.0		9.6	34.3	8.0				

Table 5. 2015 SCN Uniform 4 Summary.

	Yield									Seed			
	All		Infested		Non-infested		Maturity	Lodging	Height	quality	weight	protein	oil
Entry	bu/a	rank	bu/a	rank	bu/a	rank	date	score	in.	score	g/100	@13%	@13%
Locations	**9**		5		4		8	9	9	8	8	4	4
1 LD06-7620	**55.7**	**6**	55.5	3	56.4	12	9/23	1.5	29	2.5	13.9	34.0	19.5
2 LD07-3395bf	**53.8**	**13**	52.3	9	56.0	13	0	1.6	29	2.5	14.6	33.0	20.6
3 LD00-2817P	**56.2**	**5**	54.3	6	59.0	6	3	2.0	34	2.5	12.8	33.0	20.3
4 AR13-331019	**49.8**	**15**	48.2	15	52.2	15	-2	2.9	38	2.5	12.4	35.0	19.9
5 K11-2363	**56.2**	**4**	52.3	9	61.6	2	3	1.7	28	2.2	15.5	34.0	19.7
6 K13-1385	**55.1**	**8**	53.6	7	57.3	10	2	2.3	31	2.3	13.2	34.0	19.8
7 K13-1515	**57.4**	**3**	55.7	2	59.8	5	6	2.5	35	2.4	13.8	33.0	19.9
8 K13-1613	**54.5**	**11**	49.7	13	60.9	3	5	2.0	35	2.5	13.4	35.0	19.4
9 K13-1615	**58.1**	**2**	54.4	5	63.3	1	3	1.6	33	2.2	13.5	34.0	20.2
10 K13-1636	**54.1**	**12**	50.7	12	58.8	7	4	1.9	32	2.2	14.4	35.0	19.8
11 K13-1643	**52.8**	**14**	49.5	14	57.2	11	5	1.8	32	2.1	14.4	36.0	18.5
12 K13-1644	**55.1**	**8**	53.3	9	57.5	9	4	1.7	34	2.3	13.5	36.0	19.4
13 LD12-2117	**55.0**	**10**	54.7	4	55.7	14	-1	1.5	30	2.5	14.7	34.0	19.1
14 LD12-7900	**55.4**	**7**	53.6	8	58.2	8	-2	1.8	34	2.3	13.7	34.0	20.0
15 LD12-8677	**59.3**	**1**	58.4	1	60.9	3	0	1.9	33	2.5	15.4	35.0	20.6
Mean	**55.2**		53.1		58.3		25.1	1.9	32.5	2.4	13.9	34.3	19.8
LSD(.05)	**3.4**		5.2		4.1		1.7	0.2	1.4				
C.V. %	**11.6**		13.5		8.7		12.0	20.3	7.8				
Replications	**25**		13		12		22	25	25				

Table 6. Disease rating for K11-2363 (HG, Soybean Cyst Nematode; SDS, Soybean Sudden Death.

2013 SCN Prelim 4

	IL SCN screening			
	HG 0		HG 2.5.7	
Entry	FI†	rating	FI	rating
1 LD06-7620	6	HR	52	LR
2 IA4005	63	NR	65	NR
3 LD00- 2817P	0	HR	4	HR
4 K11-1336	5	HR	50	LR
5 K11-1666	3	HR	59	LR
6 K11-1868	6	HR	61	NR
7 K11-2006	9	HR	63	NR
8 K11-2363	6	HR	63	NR
9 K11-2371	2	HR	68	NR

2014 SCN Uniform 4

	IL SCN screening				SIU SDS	SIU SDS	
	HG 0		HG 2.5.7		Shawneetown	Valmeyer	
Entry	FI	rating	FI	rating	DX‡	DX	
1 LD06-7620	8	HR	40	LR	7	2	
2 IA4005	77	NR	83	NR	10	28	
3 LD00- 2817P	0	HR	3	HR	1	1	
4 AR13-331019	0	HR	2	HR	0	2	
5 K11-1868	9	HR	34	MR	20	17	
6 K11-2363	9	HR	37	MR	9	23	
					0	0	Ripley (res)
					25	62	S03-007CR(sus)
					10	22	LSD

2015 SCN Uniform 4

	IL SCN screening				SIU SDS	
	HG 0		HG 2.5.7		Valmeyer	
Entry	FI (Lee 74)	rating	FI (Lee 74)	rating	DX	
1 LD06-7620	14	R	23	R	12	
2 LD07-3395bf	1	HR	1	HR	6	
3 LD00-2817P	1	HR	1	HR	3	
4 AR13-331019	1	HR	2	HR	6	
5 K11-2363	11	R	27	MR	14	
					0	Ripley (res)
					56	Spencer(sus)
					16	LSD

† SCN Female Index = Soybean Cyst Nematode female index, where the female index (FI) = (mean # of cysts on tested variety/mean # of cysts on susceptible checks) x 100. A low FI (<10) means that the SCN population was not able to reproduce well on the differential line, and a high FI means that the SCN population was able to reproduce well.

‡ Illinois Sudden Death Syndrome rating: Plots were scored by Southern Illinois University. All disease scores were interpolated to the R 6.2 growth stage.

DX = SDS Disease index (DI x DS/9)
DI = SDS Disease Incidence (% of plants with visible leaf symptoms)
DS = SDS Disease Severity (1=mild chlorosis, 5=severe leaf scorch, 9=premature death of the plant)

Table 7. STS evaluation of K11-2363.

Seed Analysis Report

Kansas Crop Improvement Association

2000 Kimball Avenue
Manhattan, Kansas 66502
Phone (785) 532-6118
Fax (785) 532-6551

EV

Sample Number
K-16-0206

Report Date: 2/15/2016

Variety / Kind: K11-2363 B Soybean
Lot Number: 2015 Foundation

Seed Enhancements:

Test(s) Requested: Roundup Tol.
STS

Total Charge
$20.00

KSU AGRONOMY DEPT
3008 THROCKMORTON
MANHATTAN, KS 66506

Purity Analysis			Germination Analysis		Other Tests
Work Wt.	grams	%	Germ.%	Hard/Dorm. %	
		**	***		Roundup Tolerance: 0.25 % Tolerance STS Tolerance: 100 % Tolerance
	Inert Matter		Test Date		
	Other Crop		** Purity and Noxious Tests not requested		Weight of Submitted Sample 163 g.
	Weed Seed		*** Germination Test not requested		

Other Crop Seeds	# / pound	Common Weed Seeds	# / pound	Noxious Weed Contaminants	
				Nox. Wt. grams	# / pound

Comments:

Carbon Copy to:

Tests were conducted according to Association of Official Seed Analysts rules where applicable. Unless otherwise stated, all other analysis were performed according to generally accepted practices. Kansas Crop Improvement Association (KCIA) warrants only that the analysis report is accurate for the sample as it was submitted to the laboratory. Unless otherwise stated, KCIA makes no claim as to the accuracy of the variety. KCIA makes no statement of fitness for any purpose of the seed represented by this analysis.

Eric Fabrizius, Seed Laboratory Manager | Rayshell Colson, RST #70 | Pam Steinmeyer, RST #95

Increase with intent to release in 2017: K4313NRR (RR1 Variety)

K4313NRR is backcross derived line using the recurrent parent KS4314N, which KAES released in 2013. The pedigree of K4313NRR is KS4313N (5) X KS3406RR. This line has only been tested in KS for one year, but its performance appears to be similar to KS4313NRR, with the exception of being resistant to glyphosate herbicides (Tables 5 and 6). K4313NRR has white flowers, light tawny pubescence, tan pods at maturity, indeterminate growth habit, and seeds with black hila. K4313N is an early group IV maturity variety, resistant to SCN and should be adapted to conditions similar to KS4313N.

TABLE 8. K4313NRR IN 2015 SVPT.

Strain	Yield	Maturity date	Lodging score	Height inches
Locations	10	6	10	10
K4313NRR	52.6b†	10/7b	1.6a	31b
AG4232	55.3a	10/12a	1.6a	36a
P39T67R	55.3a	10/8b	1.3b	27c

† Numbers followed by the same letter, not significantly different at the 0.05 level of probability.

TABLE 9. K4313NRR vs KS4313N IN 2015 SVPT.

Strain	Yield	Maturity date	Lodging score	Height inches
Locations	3	3	3	3
K4313NRR	49.6a†	10/5a	1.0a	27a
KS4313N	51.2a	10/5a	1.0a	28a

† Numbers followed by the same letter, not significantly different at the 0.05 level of probability.

Outcomes of Research on Heat, Drought, Remote Sensing

- **Canopy temperature and chlorophyll content change with breeding advancements.** We characterized the changes in physiological traits in soybean that occurred in cultivars released from the 1920's through 2010, and published this research in 2016. The research evaluated the genetic differences in pollen germination, leaf chlorophyll content, electrolyte leakage, antioxidant capacity and leaf canopy temperature among the genotypes, and examined if changes in these traits occurred over time and were associated with increases in seed yield. This work provided evidence that canopy temperature and chlorophyll content changed over time along with changes in maturity, plant height, lodging, and disease resistance. The changes were associated with improvements in seed yield in both irrigated and dryland environments. The relationships between canopy temperature and leaf chlorophyll content with seed yield provide support to intentionally select for these traits in plant breeding programs, possibly using a high-throughput evaluation process, as a means to improve genetic gain in stress environments.

- **Canopy reflectance represents high-throughput opportunity for phenotyping in stress environments.** We continue to develop models utilizing canopy reflectance to estimate relative soybean maturity and seed yield, and published an update on this research in 2016. Performance of the canopy reflectance models continues to account for a significant portion of variability among genotypes for maturity in some environments and for seed yield in most environments, including drought and heat stressed environments. These models may help develop high-throughput platforms necessary to utilize this technology on a large scale.

- **Evaluations of plant introductions offers opportunities to identify new genetic variability for response to drought and heat stress and improved yield potential.** We conducted evaluations on nearly 1000 maturity group 3, 4 and 5 plant introductions along with checks, in KS in 2015. Data collected on the plots included traits such as: maturity, lodging, height, seed yield, shattering, 100 seed weight, seed quality, and wilting scores. Many PI's possess good agronomic traits, compared to the commercial checks. Environmental conditions favorable for wilting scores were limited, but several of the PI's showed limited to no wilting under these conditions. Data will be combined with data from the Univ. of MO, Univ. of AR, and Univ. of GE for additional analysis and selection of genotypes for further study.

- **Evaluations of recombinant inbred lines (RILs) in populations segregating for wilting offer insight into the genetic and physiological basis of drought stress resistance.** Analysis of agronomic data from KS was completed on a total of 460 RIL's from two populations (Pana X PI537690 and Magellan X PI567731). Maturity, lodging, height, seed yield, shattering, 100 seed weight, seed quality, and wilting scores were collected on the RILs. Analysis of the KS data only, revealed several RIL's that were similar in yield to the high parent, and superior in yield to the low parent. Environmental conditions favorable for wilting scores were limited, but several of the RIL's with good yield potential showed limited to no wilting under these conditions. Data combined with data collected by the Univ. of MO, and in KS from previous seasons will be further analyzed to identify molecular markers for resistance to wilting and determine if specific RILs merit release.

Opportunities for Training and Professional Development

- Three graduate students worked on projects related to the objectives of this project. One graduate student is projected to complete here degree in 2016.

Dissemination of Results

- Extension publications, news releases, and experiment station reports, field days, extension meetings and tours are used to share the results of this project. Web pages have been developed to disseminate information on new releases and germplasm and pests. Distribution of results of genotype characterization for resistance published online. Distribution of SCN survey results to cliental will provide much-needed information for making informed decisions by producers regarding variety selections for SCN management and by soybean breeders for the development of varieties with improved levels of resistance. Effects of high temperature stress on soybean, and evaluations of host plant resistance were published at scientific conferences and published in peer reviewed publications.

Publications for 2016

Journal articles

- Keep, N.R., **W.T. Schapaugh, Jr.,** P.V.V. Prasad, and J.E. Boyer, Jr. 2016. Changes in physiological traits in soybean with breeding advancements. Crop Sci. 56: 1: 122-131.

- Christenson, B., **W.T. Schapaugh**, N. An, K. Price, and Allan Fritz. 2016. Predicting soybean relative maturity and seed yield using canopy reflectance. Crop Sci. 56: 2: 625-643.

Conference papers and presentations

- **William T. Schapaugh**. Predicting soybean relative performance using spectral reflectance. Nebraska Soybean Innovation Conference, September 8, 2015. Lincoln, NE. (invited presentation)

- **William T. Schapaugh**. Soybean genetic gain and phenotyping. Agronomy Institute, January 19, 2016. Parsons, KS. (invited presentation)

Acknowledgment

The researchers cooperating in this project greatly appreciate the opportunity to interact with the Kansas Soybean Commission. We also appreciate the financial support of the Kansas Soybean farmer to develop new varieties, germplasm and information that improves soybean production.

Appendix I. SCN populations currently being maintained or increased in the Plant Nematology greenhouse.

Population	Source location (Co.)
Ashland	RL
Rossville	SN
14	CK
21	CK
23	CK
29	JA
36	KM
108	DP
141	JF
161	AT
162	AT
174	DG
178	CQ
234	ED
237	FI
247	BU
271	CY
299	SG
330	FO
433	BR
434	BR
455	LN
519	WB
533	ED
534	ED
548	AT
549	AT
550	AT
596	SN
617	FR
619	FR
628	CD
632	LB
1159	PT
1206	RN
1208	RN
1211	RN
Pratt	PR

Appendix II. Kansas Soybean Variety Performance Test FY 2016 SCN ratings.

		Female index	
SOURCE	**ENTRY**	**HG Type 7**	**HG Type 1.2.3.5.6.7**
KANSAS AES	KS5502N	0.088	0.1
WILLCROSS	WXR2524N	0.543	82.799
BAYER	CZ 4181 RY	0.562	21.132
BAYER	CZ 3383 RY	0.792	19.444
KANSAS AES	KS5004N	0.897	76.18
BAYER	CZ 4959 RY	1.071	4.331
BAYER	CZ 4105 LL	2.481	13.877
BAYER	CZ 3991 RY	2.562	10.005
BAYER	HBK LL4950	2.991	11.093
KANSAS AES	K12-1348	3.4	48.812
BAYER	CZ 3060 RY	3.738	19.307
BAYER	CZ 3737 LL	3.799	12.985
BAYER	CZ 5147 LL	3.939	51.908
BAYER	CZ 3443 LL	4.011	42.598
LG SEEDS	C4867R2	4.481	43.943
BAYER	CZ 4590 RY	4.803	6.086
BAYER	CZ 3945 LL	4.887	8.539
BAYER	CZ 4044 LL	5.065	10.21
BAYER	CZ 4818 LL	5.103	42.039
KANSAS AES	K04-3083RR	5.575	38.458
KANSAS AES	K4313NRRT	5.936	20.07
BAYER	CZ 3233 LL	6.03	28.734
BAYER	CZ 4748 LL	6.6	17.662
KANSAS AES	K10-8556	7.333	21.573
BAYER	CZ 2915 LL	7.41	7.107
MORSOY	48x22	7.68	49.562
ASGROW	AG5335	7.8	25.102
BAYER	CZ 3560 RY	7.888	11.37
MIDLAND	4806NRS2	8.258	20.445
PHILLIPS	499 NR2YS	8.319	40.849
BAYER	CZ 2810 LL	8.811	34.588
MIDLAND	4263NRS2	9.402	37.93
WILLCROSS	WXE2535NS	9.866	37.981
PIONEER	P35T58R	10.047	35.91
MORSOY	MS XP 1517	10.307	34.038
FRONTIER SEE	3SR92	10.353	17.418
MORSOY	43x53	10.367	56.284

NK	S39-U2	10.447	20.029
WILLCROSS	WXE2435N	10.71	35.355
KANSAS AES	KS4313N F1	10.764	36.312
MORSOY	41x04	10.83	45.575
PHILLIPS	363 NR2YE	11.011	53.615
MORSOY	41x45	11.433	52.122
WILLCROSS	WXR2494NS	11.692	50.9
MIDLAND	3926NRS2	12.021	27.001
LG SEEDS	C4696R2	12.096	33.8
WILLCROSS	WXR2395N	12.099	50.878
KANSAS AES	K11-2363T	12.149	47.189
NK	S39-T3	12.187	46.125
MIDLAND	3465NR2	12.577	33.085
LG SEEDS	C3321R2	12.845	49.212
WILLCROSS	WXE2495N	13.37	75.78
LG SEEDS	C3915R2	13.448	38.876
KANSAS AES	KS4313N Foun	13.492	10.713
MIDLAND	3884NR2	13.7	44.615
MIDLAND	3746NR2	14.034	76.491
LG SEEDS	C4780R2	14.199	26.854
MORSOY	47x12	14.397	27.841
MORSOY	LL 4524	14.403	29.328
PIONEER	50T15BR	14.406	44.913
BAYER	CZ 3841 LL	14.567	36.532
KANSAS AES	K11-2363B	14.643	77.592
MORSOY	38x85	14.754	61.37
PHILLIPS	411 NR2Y	15.3	60.819
LG SEEDS	C3555R2	15.549	67.506
LG SEEDS	C3647R2	15.598	54.819
MIDLAND	3976NR2	15.828	42.817
KANSAS AES	K4313NRRB	15.924	72.679
MORSOY	42x55	15.996	82.503
MIDLAND	4256NR2	16.074	61.847
MIDLAND	4566NR2	16.175	53.222
LG SEEDS	C3070R2	16.962	45.422
MIDLAND	4745NRS2	17.015	37.185
ASGROW	AG4232	17.047	25.831
MORSOY	52x25	17.264	31.907
LG SEEDS	C3989R2	17.594	63.897
ARKANSAS	UA 5014C	17.663	78.218
MORSOY	MS XP 1510	17.978	39.403

PHILLIPS	384 NR2YS	18.496	80.385
MIDLAND	5286NRS2	18.535	50.067
PIONEER	48T53R	18.683	31.923
LG SEEDS	C4221R2	18.686	62.96
WILLCROSS	WXE2465N	18.699	38.188
NK	S35-A5	18.785	73.568
PHILLIPS	469 NR2YS	18.93	51.935
MIDLAND	4963NRS2	19.059	29.4
WILLCROSS	WXE2485N	19.308	83.717
MIDLAND	4373NR2	19.47	39.713
EMERGE GENET	e3692s	19.519	47.024
MORSOY	37X15	19.791	112.58
MIDLAND	4044NR2	19.805	66.072
MIDLAND	3983NR2	20.341	60.816
PIONEER	49T80R	20.532	53.405
EMERGE GENET	e4310s	20.683	53.912
NK	S31-F1	20.702	59.223
LG SEEDS	C4010R2	21.059	70.243
NK	S34-P7	21.077	92.841
MORSOY	MS XP 1516	21.144	46.554
MIDLAND	4123NR2	21.79	48.572
MORSOY	39x14	22.129	51.314
BAYER	CZ 5242 LL	23.177	19.104
MORSOY	45x73	23.665	66.731
NK	S38-W4	23.692	50.911
MORSOY	38x52	24.495	65.761
PHILLIPS	392 NR2YS	25.003	44.412
MORSOY	50x64	25.803	61.885
ASGROW	AG3432	25.908	53.432
LG SEEDS	C3220R2	26.253	52.521
MIDLAND	3686NR2	26.494	50.059
MORSOY	LL 3944	26.771	55.059
MIDLAND	4614NRS2	26.776	109.797
PHILLIPS	383 NR2YE	26.777	68.873
PIONEER	53T73STS	26.942	56.744
PHILLIPS	375 NR2YS	27.102	54.396
BAYER	HBK LL4953	27.371	13.703
PIONEER	49T09BR	28.909	50.019
ARKANSAS	R09-430	29.279	72.101
MIDLAND	3633NR2	29.357	62.746
ARKANSAS	UA 5213C	29.945	52.914

PIONEER	50T40	30.03	64.974
PIONEER	P39T67R	34.851	26.05
BAYER	CZ 4540 LL	36.157	46.603
EMERGE GENET	e4993s	41.881	76.194
PHILLIPS	433 NR2YS	41.946	61.102
NK	S30-C1	43.88	80.244
FRONTIER SEE	4SR62	52.114	58.653
ARKANSAS	UA 5612C	53.006	87.925
IOWA AES	IA3023	70.683	92.535
KANSAS AES	K12-1575	72.006	65.189
ARKANSAS	OSAGE	73.039	50.303
KANSAS AES	K12-1355	81.991	55.545
MIDLAND	4580RS2	84.728	107.672
EMERGE GENET	e5110	100.479	125.963
KANSAS AES	K12-2333	104.744	97.391
KANSAS AES	KS3406RR	114.714	103.349
PHILLIPS	454 R2YSE	115.427	111.859
IOWA AES	IA4004	121.293	39.713
ARKANSAS	UA 5814HP	123.226	157.564
ARKANSAS	R09-1589	141.086	144.468

APPENDIX III. Parents used in 2015 Crossing Block.

NAME	MATURITY GROUP	TRAITS	PEDIGREE
LD00-3309	4	YLD, SCN	Maverick/Dwight
LD07-3395bf	4	YLD, SCN	LD07-3395 RESELECTION
LD09-30224	3	YLD, SCN	LD05-3230 x LDX07-178a-1-7
LD10-10226	3	YLD, SCN	LD05-3230 x LD00-3309
LG11-6208	4	Diversity	LG03-3020 x LG03-3780
LG11-6210	3	Diversity	LG03-3020 x LG03-3780
LG11-6760	4	Diversity	LG00-3372 x LD00-3309
LG12-3475	4	Diversity	LG03-1686 x LG04-5993
LG11-2963	3	Diversity	F6 Dwight (4) x PI 441001 (Tomentella)
LG11-3370	4	Diversity	F6 Dwight (4) x PI 441001 (Tomentella)
LG10-12313	2	Diversity	F3 Dwight (5) x PI 441001 (Tomentella)
U11-614093	3	Rps1k, SCN	U02-242055 x LD04-13265
K12-1575	4	YLD, diversity	reselection of LG09-5256
K12-2333	4	YLD, diversity	LG04-5993 x LG04-5187
K11-2363B	4	YLD, SCN, STS, Drought	435.TCS / LD05-30578a
K11-2363T	4	YLD, SCN, STS, Drought	435.TCS / LD05-30578a
K4313NRRB	4	YLD, SCN, RR1	KS4313N_5/KS3406RR
K4313NRRT	4	YLD, SCN, RR1	KS4313N_5/KS3406RR
K12-1348	5	YLD, SCN	R04-357/JTN-5503
K12-1355	5	YLD, SCN	R04-357/JTN-5503
JTN-5110	5	YLD, SCN	J98-32 X Anand
R10-2346	5	YLD, Drought	R01-52F/R02-6268F
R10-2436	5	YLD, Drought	R01-52F/R02-6232F
R10-2622	5	YLD, Drought	R01-888F/R05-5559
N10-7404	7	Drought, diversity	N01-11136 x N98-7265 (25% PI471938)
PI423932	5	Drought, heat, diversity	
N05-7432	7	Drought, diversity	N7002 x N98-7265 (12.5% PI)

APPENDIX IV. 2015 populations created.			
POPULATION		**PEDIGREE**	**SCN Cross**
K15-	1	K11-2363B / K4313NRRB	Y
K15-	2	K11-2363T / K4313NRRB	Y
K15-	3	LD00-3309 / K11-2363B	Y
K15-	4	LD07-3395bf / K11-2363B	Y
K15-	5	LD09-30224 / K11-2363B	Y
K15-	6	LD10-10226 / K11-2363B	Y
K15-	7	LG11-6208 / K11-2363B	Y
K15-	8	LG11-6210 / K11-2363B	Y
K15-	10	LG12-3475 / K11-2363B	Y
K15-	11	LG11-2963 / K11-2363B	Y
K15-	12	LG11-3370 / K11-2363B	Y
K15-	13	LG10-12313 / K11-2363B	Y
K15-	14	U11-614093 / K11-2363B	Y
K15-	15	LD00-3309 / K11-2363T	Y
K15-	16	LD07-3395bf / K11-2363T	Y
K15-	17	LD09-30224 / K11-2363T	Y
K15-	18	LD10-10226 / K11-2363T	Y
K15-	19	LG11-6208 / K11-2363T	Y
K15-	20	LG11-6210 / K11-2363T	Y
K15-	21	LG11-6760 / K11-2363T	Y
K15-	22	LG12-3475 / K11-2363T	Y
K15-	23	LG11-2963 / K11-2363T	Y
K15-	24	LG11-3370 / K11-2363T	Y
K15-	25	LG10-12313 / K11-2363T	Y
K15-	27	LD00-3309 / PI423932	Y
K15-	28	K12-1348 / JTN-5110	Y
K15-	29	K12-1348 / R10-2346	Y
K15-	30	K12-1348 / R10-2436	Y
K15-	31	K12-1348 / R10-2622	Y
K15-	32	K12-1348 / N10-7404	Y
K15-	33	K12-1348 / N05-7432	Y
K15-	34	K12-1355 / JTN-5110	Y
K15-	35	K12-1355 / R10-2346	Y
K15-	36	K12-1355 / R10-2436	Y
K15-	37	K12-1355 / R10-2622	Y
K15-	38	K12-1355 / N10-7404	Y
K15-	40	K11-2363T / R10-2346	Y
K15-	41	K11-2363T / R10-2436	Y
K15-	42	K11-2363T / R10-2622	Y
K15-	45	LG11-6208 / R10-2346	

K15-	46	LG11-6208 / R10-2436	
K15-	47	LG11-6208 / R10-2622	
K15-	49	LG11-6208 / N05-7432	
K15-	50	LG11-6760 / R10-2346	
K15-	51	LG11-6760 / R10-2436	
K15-	55	U11-614093 / R10-2346	Y
K15-	56	U11-614093 / R10-2436	Y
K15-	57	U11-614093 / R10-2622	Y
K15-	60	K12-1575 / K11-2363B	Y
K15-	63	K12-1575 / U11-614093	Y
K15-	65	K12-1575 / LD09-30224	Y
K15-	66	K12-2333 / K11-2363T	Y
K15-	67	K12-2333 / K12-1348	Y
K15-	69	K12-2333 / U11-614093	Y
K15-	70	K12-2333 / LD07-3395bf	Y
K15-	71	K12-2333 / LD10-10226	
K15-	72	N10-7404 / JTN-5110	Y
K15-	74	K12-1348 / K4313NRRB	Y
K15-	75	K12-1355 / K4313NRRB	Y
K15-	76	K12-1355 / K11-2363T	Y
K15-	77	K12-1355 / K12-1575	Y
K15-	78	R10-2622 / R10-2346	
K15-	79	K12-1348 / K12-1575	Y
K15-	80	N10-7404 / LG11-6208	
K15-	81	R10-2622 / K11-2363T	Y
K15-	82	LD07-3395bf / K12-1575	
K15-	83	R10-2346 / N05-7432	
K15-	84	K12-1348 / K12-1355	Y
K15-	85	N05-7432 / R10-2436	
K15-	86	N10-7404 / K11/2363T	Y
K15-	87	N05-7432 / LG11-6760	
K15-	88	N10-7404 / R10-2436	
K15-	89	N05-7432 / R10-2622	
K15-	90	N10-7404 / LG11-6760	
K15-	91	N10-7404 / R10-2622	
K15-	92	N10-7404 / R10-2346	
K15-	93	JTN-5110 / N05-7432	Y
K15-	94	N05-7432 / U11-614093	

APPENDIX V. 2015 Yield Trials.													
			Entries	Plots/	LOCATIONS_ NUMBER OF PLOTS								
EXPT	TEST		Total	TEST	MAN (Irr)	Onaga	MAN (Dry)	OTT	MCC	PIT	PITDC	SAL	OTHER
KANSAS ADVANCED TESTS													
1501	KAE2,MG 3&4		20	80	80	80		80					
1503	KAE3,MG 3&4	Remote Sensing	80	240		240							
1502	KAE1, G3/4	Remote Sensing	80	240	240		240					480	
1505	KAE5, G5 + inc		50	200	200				200	200			
1504	Emerge		15	30		30	30	30				60	
		TOTAL ENTRIES	225										
KANSAS PRELIMINARY TESTS													
1561	KPE-1		556	556	556								
1563	KPL-1		678	678	678								
		TOTAL ENTRIES	1234	1234									
Northern Uniform Tests													
1530	U3	+ shattering	30	90	90	90		90					
1531	P3A	+ shattering	30	60	60			60					
1532	P3B	+ shattering	30	60	60			60					
1540	U4	+ shattering	15	45	45	45		45					
1541	P4	+ shattering	25	50	50	50		50					
SCN Uniform Tests													
1534	U3SCN		20	60	60			60					
1535	P3SCN		25	50	50								
1543	U4SCN		20	60	60			60					
	P4SCN			0									
Southern Uniform Test													
1546 RS	U4S		30	120					120	120			
1547 RS	P4S		30	60					60	60			
1550 RS	U5		30	120					120	120			
1551 RS	P5		45	90					90	90			
		TOTAL ENTRIES	330										
MISC Tests													
15	SP1	ONAGA	35	140		140							
15	SP6E	MCCUNE 4'S	11	44					44				
15	SP6L	MCCUNE 5'S	19	76					76				
15	SP10	ASSARIA	21	84									84
15	SP14	PIT DC	28	112							112		
15	SP16E	OTTAWA	28	112				112					
15	SP16L	OTTAWA	14	56				56					
15	SP19	SVPT SDS SCREEN, remote sensing	145	435	435								
15	NAM10sds	SDS SCREEN, remote sensing	160	480	480								
DROUGHT Tests													
15 SEQ	MO Drought	PI Germplasm	455	910	910								
15 CR09-2850	MO Drought	Pana X PI	324	648	648							648	
15 CR08-911	MO Drought	MAG X PI	140	280	280							280	
15 YT MO	MO Drought	RIL Yield Trials	22	66	66							132	
		TOTAL ENTRIES	941	2964									
Drought/Remote Sensing/NAM Tests													
15NAM10	remote sensing		150	450	450		450					900	
15NAM46	remote sensing		120	360	360		360					720	
15NAMYSL	Purdue		72	144	144								
15 ARK	GWAS Arkansas		373	746								746	
15 DT-03	Georgia		192	576								576	
15 NE	Wilting, Nebraska		25	100								100	
		TOTAL ENTRIES	932										
					MAN (Irr)	Onaga	MAN (Dry)	OTT	MCC	PIT	PITDC	SAL	OTHER
	Total # yield plots at each location, 2015				6002	675	1080	703	710	590	112	4642	84
	Total # yield plots for 2015		14598										

APPENDIX VI. 2015 Seed Increases.

ENTRY	2015 TEST*	PEDIGREE	**2016 STATUS****
NON-GMO CONVENTIONAL ENTRIES			
Breeder's Seed plots			
K12-1355	UT5	R04-357/JTN-5503	SVPT/Increase
K12-1575	UT 4	reselection of LG09-5256	SVPT
K12-2333	UT 4	LG04-5993 x LG04-5187	SVPT
K12-1348	SVPT	R04-357/JTN-5503	SVPT
K13-1385	U4 SCN	LD00-3309 / 435.TCS	D
K13-1515	U4 SCN	LG06-5920 / LD04-13265	U4 SCN
K13-1613	U4 SCN	LS07-3125 / 435.TCS	D
K13-1615	U4 SCN	LS07-3125 / 435.TCS	U4 SCN
K13-1636	U4 SCN	LS07-3125 / 435.TCS	D
K13-1643	U4 SCN	LS07-3125 / 435.TCS	D
K13-1644	U4 SCN	LS07-3125 / 435.TCS	D
K13-1519	UP3	LG06-5920 / LD04-13265	D
K13-1523	UP3	LG06-5920 / LD04-13265	D
K13-1156	UP4	LG06-2284 / LD00-3309	D
K13-1231	UP4	LG07-2309 / 435.TCS	D
K13-1234	UP4	LG07-2309 / 435.TCS	D
K13-1289	UP4	LG06-5920 / 435.TCS	SAVE FOR PARENT
K13-1290	UP4	LG06-5920 / 435.TCS	D
K13-1620	UP4	LS07-3125 / 435.TCS	D
K13-1627	UP4	LS07-3125 / 435.TCS	SAVE FOR PARENT
K13-1737	UP4S	KS5004N / NCC06-339	D
K13-1845	UP4S	NCC05-1261 / 435.TCS	D
K13-1897	UP4S	NCC05-1261 / LD00-3309	D
K13-1910	UP4S	NCC05-1261 / LD00-3309	D
K13-1763	UP5	5002T / DS-880	D
K13-1777	UP5	S05-11482 / KS5004N	D
K13-1786	UP5	KS5004N / R04-357	D
K13-1809	UP5	KS5004N / R04-357	D
K13-1830	UP5	DS-880 / R04-357	UT5
Foundation Seed Production			
K11-2363B	SCN U4, SVPT	435.TCS / LD05-30578a	large-scale increase
K11-2363T	SCN U4, SVPT	435.TCS / LD05-30578a	
	GMO ENTRIES (RR1)		
K4313NRRT	SVPT	KS4313N_5/KS3406RR	large-scale increase

***UP, UT, SVPT = Uniform Preliminary Test, Uniform Test and Soybean Variety Performance Tests, respectively. ** D = discard.**