KANSAS SOYBEAN COMMISSION FINAL REPORT OF PROGRESS

Title: "Develop valuable soybean varieties and germplasm for use as genetic resources for companies and for direct on-farm production"

Accomplishments for FY2023 (March 1, 2022 – February 28, 2023)

Variety Development

Population Development

- About 80 new populations were created in 2022 using over 36 different parents.
- Fifteen single cross populations involved **drought resistant** parents.
- About 1/3 of the single cross populations involved parents tolerant to **STS** herbicides.
- Over 50% of the single cross populations involved at least one parent resistant to **soybean nematodes**.
- Seven cross populations involved at least one parent that possessed genes from a plant introduction that has not contributed to the genetic improvement of US northern soybean varieties to increase the **genetic diversity** of US germplasm to increase, or at least, maintain genetic gain.
- Five populations were developed to incorporate the n**on-nodulating** trait into adapted germplasm to better characterize the importance of nitrogen fixation and nitrogen fertility in modern soybean varieties.
- Thirty-one populations were created to incorporate **high oleic and/or low linolenic acid** traits into elite germplasm.

Yield Trials and Progeny Rows

- We completed evaluations of over 10,000 **genotypes** in over 21,000 plots in Kansas.
- Over 7000 F4:5 lines were evaluated in progeny rows, including 926 high oleic progeny.
- Over 1600 K-lines were evaluated in our preliminary trials, including 16 high oleic lines.
- Over 292 K-lines were evaluated in our KS advanced yield trials, including several high oleic lines, some of which were evaluated in the 2022 Soybean Performance Tests, as shown below.

2022 Soybean Performance, Pittsburg, KS.							
brand	entry	seedyield	yld_pm	maturity	lodging	height	2002 seed oleic
		bu/a		days after Aug. 31		inches	%
BECKS	4113XF	43.3	96	34	1	29	
BECKS	4553XF	45.4	101	41	1	27	
BECKS	4887XF	42.3	94	40	1	31	
CHECK	21MG3.9	44.8	100	40	1	29	
CHECK	21MG4.8	47.3	105	48	1	25	
INDIGO	INDIGOC	45.2	101	34	1	28	
INDIGO	M34FP	44.5	99	35	1	29	
INDIGO	M34N13E13	43.9	98	35	1	29	
KANSAS AES	K179222-13	43.9	98	49	1	37	88
KANSAS AES	K179228-5	48.8	109	47	1	32	86
KANSAS AES	K179229-8	44.0	98	47	1	30	64
KANSAS AES	K179233-16	45.4	101	48	1	33	82
KANSAS AES	K179247-8 GT	43.5	97	50	1	37	85
KANSAS AES	K18-6652	46.3	103	48	1	39	
KANSAS AES	K18-6996 GT	44.9	100	44	1	27	
KANSAS AES	K18-7069 GT	46.3	103	49	1	30	
KANSAS AES	KS4520NS	44.6	99	34	1	24	
KANSAS AES	KS4822NS	44.8	100	43	1	28	
KANSAS AES	KS4919N	45.8	102	45	1	31	
KANSAS AES	KS5120NS	49.5	110	48	1	32	2020 release
VA AES	HUTCHESON	43.2	96	48	1	31	
WILLCROSS	WXE8049N	48.9	109	44	1	28	
WILLCROSS	WXE8146NS	37.4	83	36	1	26	
WILLCROSS	WXE8248NS	45.6	102	41	1	28	
CV		5.6		3.5		6.8	
GRAND MEAN		45		42.7		29.9	
LSD		3		1.8		2.4	

- Over 550 (including 59 K-lines) breeding lines from programs across the country were evaluated in Uniform and cooperative trials.
- Over 1,500 genotypes, (experimental breeding lines and **plant introductions**) were evaluated in our drought, remote sensing, and diversity yield trials.

Releases

- This project enabled the development and release of KS4323NS and KS4423N in FY23. Description of the lines are shown in Appendix 1. The lines are being licensed for commercial production and for use in breeding.

SCN Resistance Screening and Management

SCN Screening Populations

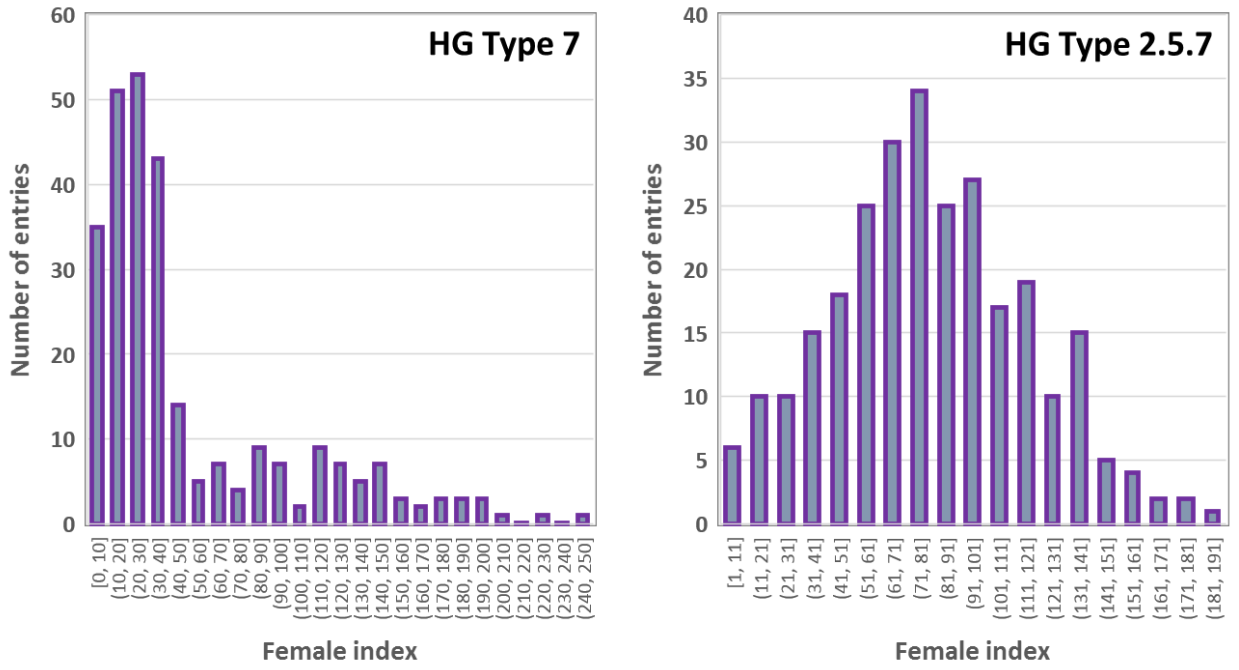
Primary SCN screening populations for 2022 and throughout this project included HG Types 7, 2.5.7, and 1.2.3.5.6.7. Female indices (FI) on the HG Type 1.2.3.5.6.7 population were >10% on all indicator lines except PI 437654 (line 4), while female indices on the HG Type 7 population

were <10% on all indicator lines except PI 548316 (line 7). The third screening population, HG Type 2.5.7, is characterized by female indices >10% on PI 88788 (line 2), PI209332 (line 5) and PI 548316 (line 7). Female indices on PI 88788, the most common source of deployed SCN resistance, averaged 23% for the HG Type 2 populations vs. 5% for the HG Type 7 population.

SCN Resistance Screening

Breeding lines: Soybean resistance to SCN was evaluated in replicated screening trials for 275 breeding lines in 2022. Approximately 50% of 2022 lines were rated as resistant or moderately resistant to the HG Type 7 SCN screening population, while 9% were rated as resistant or moderately resistant to the HG Type 2.5.7 SCN screening population (Figure 1). Three soybean lines were resistant to both SCN populations, while 17 lines were moderately resistant to both SCN populations.

Figure 1. 2022 SCN screening results for HG Types 7 (left) and 2.5.7 (right): number of entries sorted by female index.



Kansas Soybean Performance Test: Soybean resistance to SCN was evaluated in replicated screening trials for 25 KAES entries and 28 non-KAES entries in the Kansas Soybean Variety Performance Test (KSVPT). Evaluations involved SCN populations that varied in their virulence to the common resistance source PI 88788. Six KAES entries and 10 non-KAES entries were resistant (FI < 10) or moderately resistant (FI ≤ 30) to the HG Type 7 population (Figure 2), while only three KAES entries and one non-KAES entry were resistant or moderately resistant to the GH Type 2.5.7 population. Female indices for the HG Type 7 population were strongly predictive of FI for the HG Type 2.5.7 population (Figure 3 top), confirming that most KSVPT entries shared a

common source of resistance (PI 88788). Female indices for the HG Type 7 population were similarly predictive of FI for the HG Type 1.2.3.5.6.7 population for non-KAES entries but not for KAES entries (Figure 3 bottom), reflecting the greater prevalence of resistance sources other than PI 88788 (e.g. Peking) in the KAES entries. No entry had a FI ≤ 30 for all three HG Type populations.

Figure 2. 2022 KSVPT SCN screening results: number of KAES entries (left) and non-KAES entries (right) sorted by HG Type 7 female index.

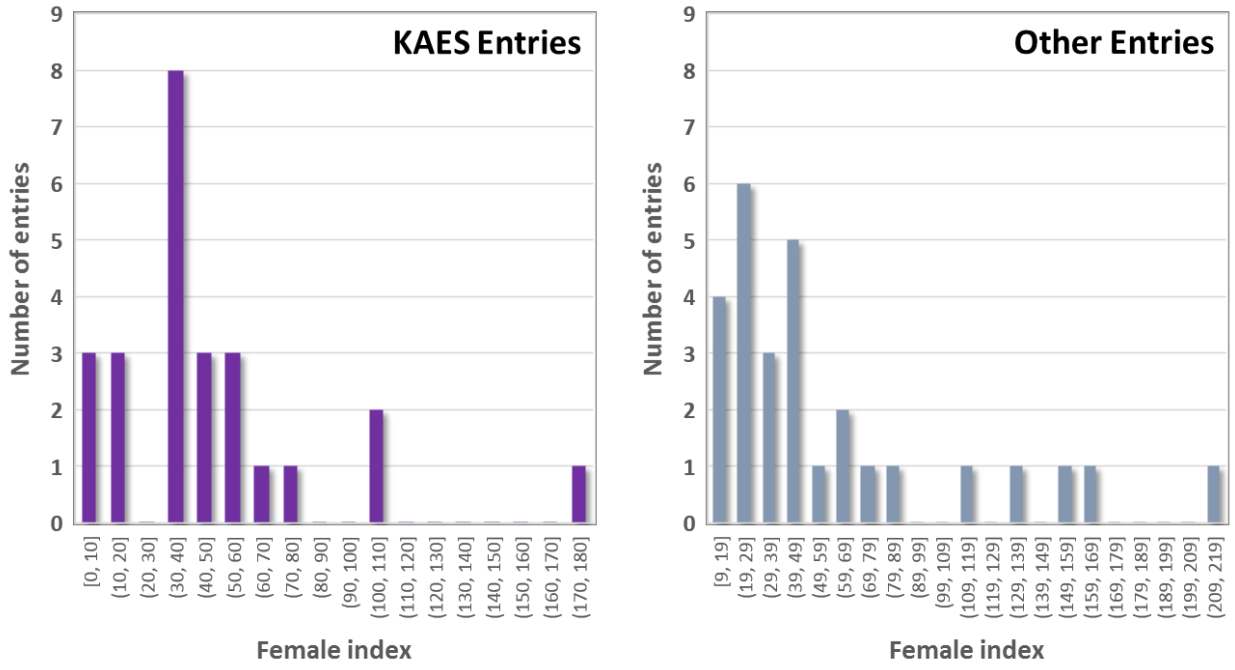
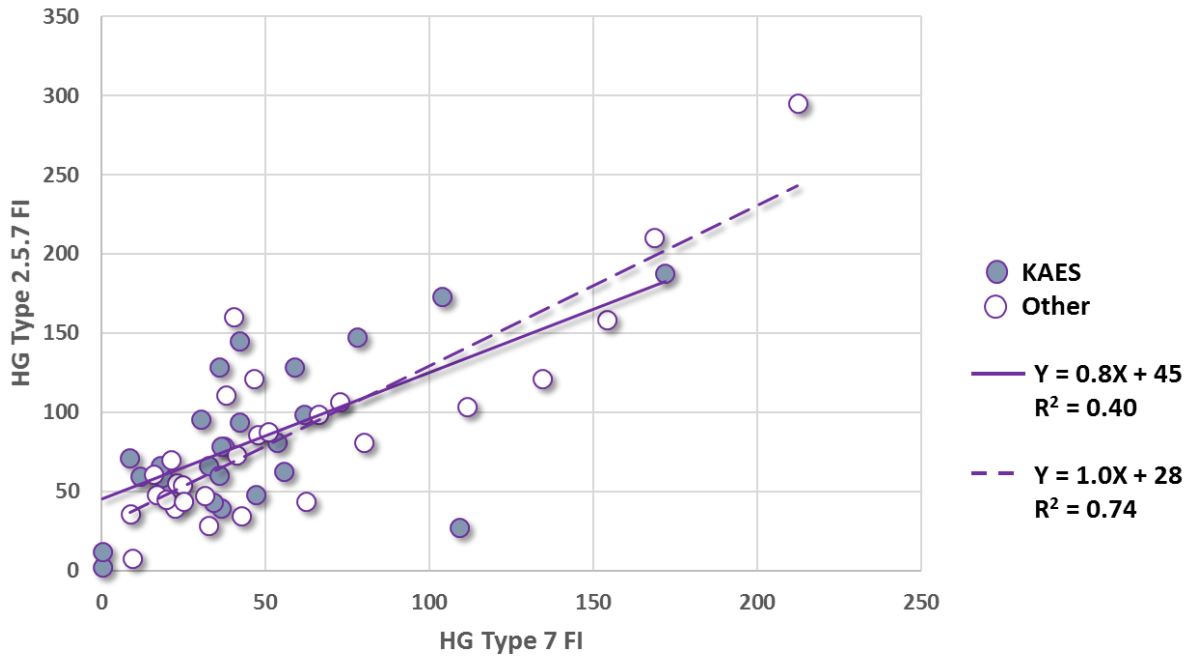
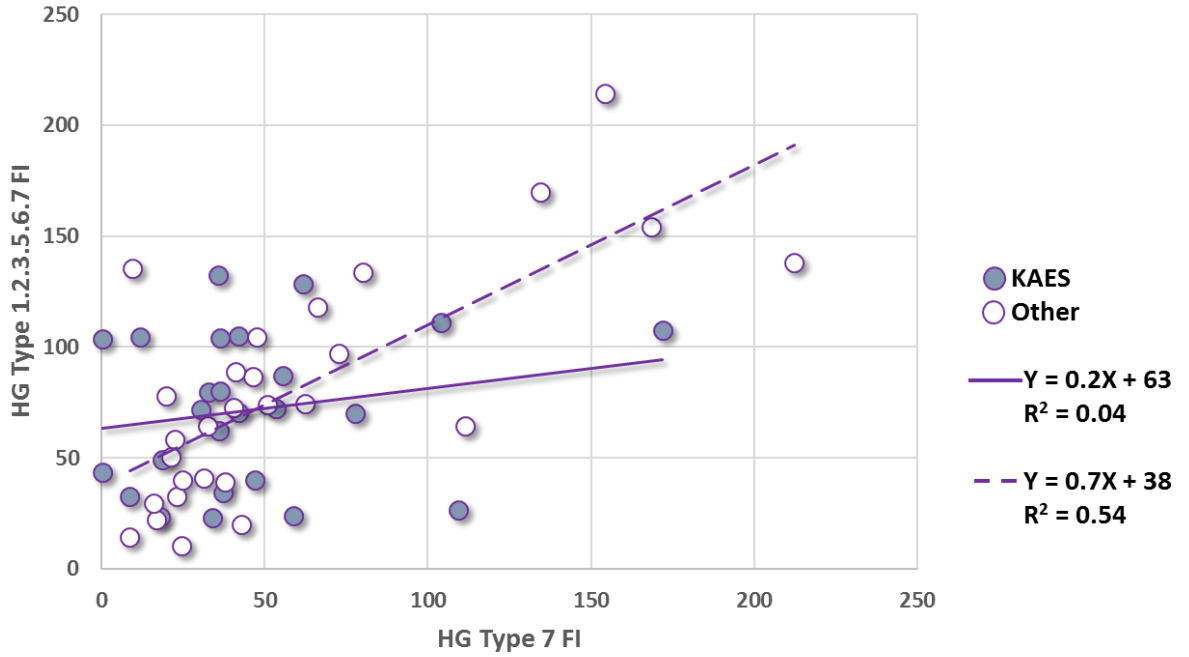


Figure 3. 2022 KSVPT SCN screening results: relationship between HG Type 2.5.7 and HG Type 7 female indices (top) and between HG Type 1.2.3.5.6.7 and HG Type 7 female indices (bottom) for KAES and non-KAES entries.





Related Projects

SCN Coalition: A total of 580 Coalition samples were submitted during 2020-2022. Of these, 236 or 41% were positive for SCN. Prevalence was highest in east central (66%) and south central (60%) Kansas.

Breeding Technologies

- **Genetic gain.** Following three generations of selection where we used genomic predictions for yield, genetic variation, and seed composition to select, intermate and rapidly cycle F1 plants, progeny from the initial base population and the rapid cycling generations were evaluated at three locations in 2022 for seed yield, maturity, lodging, plant height, and seed protein and oil. These progeny will be evaluated again in 2023 at three locations. Results of these field trials will be used in 2023 and 2024 to characterize the effectiveness of the genomic selection and rapid cycling methodology. We also used the same genomic prediction model to create populations from elite public breeding lines that are predicted to produce superior progeny and have a negligible negative correlation between seed yield and seed protein content. The progeny of these crosses will be in progeny rows in 2023, with plans to evaluate the progeny in replicated field trials in 2024.

Opportunities for Training and Professional Development

Four undergraduate students completed internships with the breeding project during the summer of 2022. One graduate student working on objectives related to this project has completed her M.S. degree requirements and will receive her diploma in May 2023. One post-doc on this project completed work on a manuscript, which was published, and moved to a position in private industry. One additional post-doctoral scientist has joined the team to focus on the applying remote sensing and genomic selection technology to our breeding project.

Dissemination of Results

Extension publications, news releases, radio interviews, 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 FY23

- **Journal articles**

Alencar Xavier, William Beavis, James Specht, Brian Diers, Rouf Mian, Reka Howard, George Graef, Randall Nelson, William Schapaugh, Dechun Wang, Grover Shannon, Leah McHale, Perry Cregan, Qijian Song, Miguel Lopez, William Muir, Katy Rainey. (2022).

Soybean Nested Association Mapping Dataset. https://scholar.google.com/scholar?oi=bibs&cluster=5938341747497625123&btnI=1&hl=en .

Ayalew, H., Schapaugh, W., Vuong, T., & Nguyen, H. T. (2022). Genome-wide association analysis identified consistent QTL for seed yield in a soybean diversity panel tested across multiple environments. The Plant Genome, 15, e20268. https://doi.org/10.1002/tpg2.20268.

Acknowledgment

The faculty, graduate students, post-doctoral scientists and staff cooperating on this project greatly appreciate the opportunity to interact with the Kansas Soybean Commission. We also appreciate the financial support of Kansas Soybean farmers to develop new varieties, germplasm and information that supports the improvement of soybean production.

Appendix 1: Release of KS4323NS and KS4423N, Kansas Agricultural Experiment Station

Scientists contributing to these releases are William Schapaugh, Professor; Rene Hessel, Assistant Scientist; Dennis Hitz, Assistant Scientist; Garrett Glazner, Assistant Scientist; and Addie Clary, Assistant Scientist; Department of Agronomy; and Tim Todd, Instructor; and Tom Oakley, Assistant Scientist, Department of Plant Pathology.

KS4323NS is an F4 single plant selection from the cross LG11-6210 by KS4117NS. KS4323NS has white flowers, light tawny pubescence, tan pods at maturity, indeterminate growth habit, and seeds with imperfect black hila. KS4323NS is an early group 4 variety (4.3). It is well adapted to a wide range of soil types and climates throughout Kansas and where other maturity group 4 varieties are grown.

KS4323NS was tested as experimental line K17-6185 in Kansas and regionally beginning in 2018. From 2020 to 2022, K17-6185 performed well in the Northern Uniform Maturity Group IV Tests (Table 1). The average yield of K17-6185 was higher than the checks (LD15-3818, LD00-2817P and LD07-3395bf). Average maturity for K17-6185 was slightly later than the checks. Agronomic traits of K17-6185, including lodging and seed protein and oil, were similar to the checks. K17-6185 is moderately resistant to Race 3 (HG Type 7) of Soybean Cyst Nematode, which is similar to the resistance possessed by KS4117NS and KS4520NS (Table 2). In head-to-head comparisons with KS4520NS in Kansas, average yield of K17-6185 was superior to KS4520NS. The plant height is taller than KS4520NS and maturity of K17-6185 is slightly earlier than KS4520NS (Table 3). Plant lodging resistance of K17-6185 was equal to KS4520NS. Like KS4520NS, K17-6185 is not resistant to glyphosate herbicide but possesses tolerance to specific STS® herbicides (Table 4).

KS4423N is an F4 single plant selection from the cross LG11-6210 by K11-2363T. KS4423N has purple flowers, light tawny pubescence, tan pods at maturity, indeterminate growth habit, and seeds with black hila. KS4423N is an early group 4 variety (4.4). It is well adapted to a wide range of soil types and climates throughout Kansas and where other maturity group 4 varieties are grown.

KS4423N was tested as experimental line K17-6388 in Kansas and regionally beginning in 2018. From 2020 to 2022, K17-6388 performed well in the Northern Regional Soybean Cyst Nematode Maturity Group IV Tests (Table 5). The average yield of K17-6388 was higher than the checks (LD15-3818, LD00-2817P and LD07-3395bf). Average maturity for K17-6388 was slightly later than the checks. Agronomic traits of K17-6388, including lodging and seed protein and oil, were similar to the checks. K17-6388 is moderately resistant to Race 3 (HG Type 7) of Soybean Cyst Nematode, which is similar to the resistance possessed by KS4117NS and KS4520NS (Table 2). In head-to-head comparisons with KS4520NS in Kansas, average yield of K17-6388 was superior to KS4520NS (Table 6). The plant height is taller than KS4520NS and maturity of K17-6388 is slightly earlier than KS4520NS. Plant lodging resistance of K17-6388 was equal to KS4520NS. K17-6388 is not resistant to glyphosate herbicide nor tolerant to STS® herbicides.

The Foundation Seed Program, Department of Agronomy, Kansas State University will maintain breeder's seed of this cultivar. Information on licensing for commercialization can be obtained from Christopher D. Brandt, President/CEO, Kansas State University Research Foundation, 2005 Research Park Circle, Suite 105, Manhattan, KS 66502-5020 (phone: 785-532-5720; email: tech.transfer@k-state.edu).

Information about the variety or requests for small quantities of seed for research purposes can be obtained from William Schapaugh (phone: 785-770-7906; email: wts@ksu.edu) or Addie Clary, (phone: 620-222-6115; email: addierclary@ksu.edu) Department of Agronomy, Kansas State University, Manhattan, KS.

Table 1. Summary of performance of K17-6185 in uniform and preliminary regional trials (2020 to 2022).

					Seed		
	Yield	Maturity	Lodging	Height	weight	protein	oil
Entry	bu/a	date	score	in.	g/100	@13%	@13%
No. of Locations	24	25	24	23	20	17	17
LD15-3818	63.8b†	9/30b	1.3a	31b	15.1b	34.3c	19.9a
LD00-2817P	59.8c	10/3d	1.6b	35c	13.5a	33.1b	20.0a
LD07-3395bf	63.5b	9/28a	1.3a	29a	15.5b	32.4a	20.6b
K17-6185	**66.7a**	**10/1c**	**1.4a**	**32b**	**13.4a**	**33.9c**	**19.9a**

†Means within a column followed by the same letter are not significantly different at the 0.05 level of probability.

Table 2. Summary of SCN reactions for select entries in the Kansas Soybean Performance tests for 2021 and 2022.

	2022 SCN Female Index*			2021 SCN Female Index		
Strain	Race 1 (HG Type 2.5.7)	Race 3 (HG Type 7)	Race 4 (HG Type 1.2.3.5.6.7)	Race 1 (HG Type 2.5.7)	Race 3 (HG Type 7)	Race 4 (HG Type 1.2.3.5.6.7)
21MG3.1	45	27	68	71	38	81
21MG3.9	18	24	23	63	33	82
21MG4.8	60	25	56	75	38	78
K17-6185	39	22	31	83	22	65
K17-6388	56	24	50	57	37	78
KS4117NS	51	35	90	26	51	57
KS4520NS	67	33	23	62	44	92
KS4822NS	7	0	85	13	1	100
CV	48	48.6	69.8	40	27	44
GRAND MEAN	41.6	30	59.3	54	68	65
LSD	27	20	56	35	29	46
No. of Reps	3	3	3	3	3	3

* 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. Reproduction rates were measured on plants grown in the greenhouse.

Table 3. K17-6185 head-to-head comparison with KS4520NS in Northern and East Central Kansas.

	Yield (bu/ac)	Maturity (mo/day)	Lodging (score)	Plant Height (inches)
No. of environments	12	14	14	14
Combined results (2020-2022)				
K17-6185	54.9 a†	10/6 a	1.0 a	34 a
KS4520NS	51.6 b	10/8 b	1.0 a	31 b

By location	**Years**	**K17-6185**	**KS4520NS**
		Seed Yield (bu/ac)	
Manhattan	2020-2022	64 a	60 b
Ottawa	2020-2022	48 a	46 a
Salina	2021-2022	49 a	46 a

†Combined means within a column, or location means within a row followed by the same letter are not significantly different at the 0.05 level of probability.

Table 4. Roundup and STS tolerance results from KCIA.

Seed Analysis Report
Kansas Crop Improvement Association

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

Sample Number K-23-0481

Sender's information - provided by the sender, not the laboratory

Report Date: 2/21/2023

Variety / Kind: K17-6185 Soybean
Glycine max
Lot Number: 2RL34477
Cert. Class: Breeders
Seed Enhancements: (none)

KSU AGRONOMY DEPT
2200 KIMBALL AVENUE
MANHATTAN, KS 66502

Test(s) Requested: Deluxe Test Package, Roundup Tol., STS

Total Charge $98.00

Purity Analysis			Germination Analysis			Other Tests
Work Wt. 500.0 grams		%	Germ.%	Hard %	Dormant %	Moisture: 9.3 %
Soybean		99.97	87	0	--	Test Weight: 56.5 pounds / bushel
						Seed Count: 4009 seeds / pound
						TKW: 113.1 grams
						Accelerated Aging: 83 %
						Roundup Tolerance: 0 % Tolerance
						STS Tolerance: 100 % Tolerance
	Inert Matter	0.03	Test Date: 2/21/2023			
	Other Crop	0.00	Days Tested: 8	Seed Tested: 400		Weight of Submitted Sample 5675 g.
	Weed Seed	0.00				

Other Crop Seeds	# / pound *	Common Weed Seeds	# / pound *	Noxious Weed Contaminants		
				Nox. Wt. 4540 grams	# found	#/pound
None Found		None Found		None Found		

* Other Crop and Common Weed seed rates found in 4540 grams

Comments:

Carbon Copy to:

Lab Results / Reports available at https://lab.kscrop.org or link through the KCIA website www.kscrop.org

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 Lab Manager
Rayahell Colson, RST #70

Table 5. Summary of performance of K17-6388 in SCN regional trials (2020 to 2022).

					Seed		
	Yield	Maturity	Lodging	Height	weight	protein	oil
Entry	bu/a	date	score	in.	g/100	@13%	@13%
No. of Locations	21	21	20	21	17	16	16
LD15-3818	59.7b†	9/28b	1.3a	31c	14.4	34.7	19.7
LD00-2817P	56.5c	10/1c	1.7b	34a	12.9	33.7	19.5
LD07-3395bf	57.1bc	9/27a	1.4ab	28d	14.8	33.1	19.8
K17-6388	**62.9a**	**10/2c**	**1.3a**	**32b**	**13.9**	**33.4**	**18.9**

†Means within a column followed by the same letter are not significantly different at the 0.05 level of probability.

Table 6. K17-6388 head-to-head comparison with KS4520NS in Northern and East Central Kansas.

	Yield (bu/ac)	Maturity (mo/day)	Lodging (score)	Plant Height (inches)
No. of environments	14	15	7	14
Combined results (2020-2022)				
K17-6388	58.4 a†	10/6 a	1.0 a	40 a
KS4520NS	51.7 b	10/8 a	1.0 a	35 b

By location	**Years**	**K17-6388**	**KS4520NS**
		Seed Yield (bu/ac)	
Manhattan	2020-2022	67 a	60 b
Ottawa	2020-2022	51 a	45 b
Salina	2021-2022	53 a	45 a

†Combined means within a column, or location means within a row followed by the same letter are not significantly different at the 0.05 level of probability.