**Title:** Southern Root-Knot Nematode in Maturity Group 4 Soybean: Characterization of Resistance Mechanisms and Breeding for Resistance

Date: July 22, 2025

Report: Final Report (2022 to 2024)

This is a summary of the southern root-knot nematode project from 2022 to 2025. Initially led by Leandro Mozzoni with Tristan Watson and Travis Faske as nematologists and Henry Nugyen and Pengyin Chen as geneticist and plant breeder, respectively. Over the duration of the project, Grover Shannon filled in at Missouri until Feng Lin was hired and Mozzoni was replaced by Caio Vieira.

**Obj. 1: Characterization of the mechanism of resistance to SRKN. (Faske and Watson)**

A series of greenhouse and developmental studies assessed resistance to Meloidogyne incognita in soybean lines. In Watson’s study, nematodes developed on the susceptible cultivar ‘Magellan’ but not on the moderately resistant ‘Forrest’ by 14 days after inoculation (DAI). However, Faske found nematode development on both ‘Anand’ and ‘Forrest’, indicating variability in resistance expression.

Greenhouse tests at the Lonoke Extension Center showed lower root galling in ‘Forrest’, PI 567516C, and PI 567305, though PI 567305 supported high nematode reproduction—making it less ideal for breeding. PI 438489 and its near-isogenic line (NIL) had high galling but low reproduction, reinforcing the need to evaluate both traits when selecting resistance sources.

A second developmental study confirmed that resistance is linked to delayed nematode maturity. While PI 567305 and ‘Forrest’ shared similar development patterns, PI 438489B and PI 567516C differed, suggesting distinct resistance mechanisms despite all carrying a known QTL on chromosome 10.

Notably, PI 567516C showed delayed development but higher reproduction than PI 438489B, further supporting differing resistance pathways. These findings highlight the opportunity to stack complementary resistance genes from multiple sources to enhance and prolong resistance.

Full-scale tests with PI 567516C, PI 438489B, NIL-PI, and NIL-Mag are planned for spring to validate these mechanisms.

**Objective 2: Genetic characterization and development of functional markers for new sources of resistance to SRKN. (Nguyen, Univ. of Missouri)**

Recent work focused on evaluating and advancing resistance to *Meloidogyne incognita* in soybean using key donor lines, including Forrest, PI 567516C, PI 438489B, PI 567305, and Magellan. Seeds from these lines and recombinant inbred lines (RILs) have been harvested and are being threshed for ongoing genotyping and phenotyping studies.

Genomic DNA was extracted for marker development. A DNA marker for the major resistance QTL on chromosome 10 was successfully developed and distinguishes resistant from susceptible lines. Additionally, a 2 Mb region on chromosome 13 was used to develop 10 KASP markers, now being validated across diverse genotypes.

A set of 38 RILs from Magellan × PI 438489B, carrying combinations of QTLs on chromosomes 10 and 13, was analyzed. These lines will help dissect mechanisms of nematode reproduction and galling.

Six new KASP markers from the chromosome 13 QTL (from PI 567516C) were also developed and are being tested for broader application. These tools will support marker-assisted selection and the development of soybean lines with stacked resistance mechanisms.

**Obj. 3: Development of breeding populations and MG4 soybean varieties with resistance to SRKN.**

Caio Vieira, Univ of Arkansas

The soybean breeding program across institutions (University of Arkansas, LSU, University of Missouri) continues to make significant advances in developing southern root-knot nematode (SRKN)-resistant cultivars using integrated approaches including phenotyping, genotyping, marker-assisted selection, and genomic prediction.

**1. Breeding Progress and Generation Advancement**

* Over **70 cross combinations** involving SRKN-resistant and high-yielding parents were developed between 2022–2024. Early generations (EG1–EG4) are being advanced in winter nurseries in Puerto Rico.
* **79 new populations from 2024 crosses** (1,006 F1 seeds) were planted for off-season advancement to F4, including resistance to SRKN and other stressors (drought, flooding, SCN).
* **124 populations**, 47 with SRKN-resistant parents, will be evaluated in 2025 progeny rows in Stuttgart, AR.
* **Ten low-galling lines** identified via genomic prediction (lacking Chr. 10 resistance allele) showed promising performance and are undergoing further validation.

**2. Marker Development and Molecular Screening**

* Major QTL on **Chromosome 10** and minor QTL on **Chromosome 13** were targeted.
* **Six KASP markers** developed from Chr. 13 efficiently distinguish between resistant (PI 567516C) and susceptible (Magellan) genotypes.
* 38 recombinant inbred lines (RILs) from Magellan × PI 438489B with varying QTL combinations are being used to study resistance mechanisms.
* Over **1,300 breeding lines** were screened with molecular markers in 2023–2024; ~50 lines were identified with SRKN resistance.

**3. Mechanisms of Resistance (Faske & Watson)**

* Time-course and greenhouse studies reveal that SRKN resistance is associated with **delayed nematode maturity and suppressed reproduction**.
* PI 567305 exhibits low galling but high reproduction, while PI 438489B and PI 567516C show both reduced galling and reproduction—indicating **distinct resistance mechanisms**.
* This supports stacking multiple genes for improved, durable resistance.

**4. Field Screening and Yield Trials**

* Field screening in Kerr, AR showed gall severity between 4–15%. Resistant control rated at 3%, susceptible control at 11%.
* Yield trials at **five Arkansas locations**, plus USDA and OVT sites, identified **SRKN-resistant lines with strong agronomic traits**.
* 96 AYT lines were screened in Georgia; 26 showed low galling scores (1–2). 23 had the Chr. 10 marker.

**5. Advancements Toward Commercial Release**

* **R19-45980** is a candidate for **2025 commercial release** with strong performance (100.5% and 97% of test mean in ARVT) and 3rd place in 2023 USDA Uniform Trials.
* **R21KB-05522 and R22KB-16609** are in pre-commercial stages and undergoing herbicide trait conversion (Enlist-E3® and XtendFlex®).
* Ten elite SRKN-resistant lines advanced to **2025 Final Yield Trials**; one (R24PR-00010E) already contains both SRKN resistance and Enlist-E3®.
* **Eight lines** from AYT 2024 were selected for 2025 USDA Uniform Trials; all confirmed SRKN-resistant.

**6. Infrastructure & Screening Capacity**

* A new **SRKN screening protocol** is being implemented at Fayetteville to enhance phenotyping speed and accuracy.
* Highly infested soil collected from Clarkton, MO (315–4,140 nematodes/100 cc) will be used in future trials.
* Winter nursery efforts continue for **herbicide trait conversions**, particularly in four RKN-resistant lines now being converted to XtendFlex.

Grover Shannon and Feng Lin – University of Missouri.

2023 Line Releases

Two nematode-resistant conventional soybean lines were released in 2023 based on multi-environment performance:

* **S18-6013 (MG 5.2)**: High yield (69.2 bu/ac), high oil, resistance to SCN, RKN, stem canker, SDS, frogeye leaf spot, charcoal rot, and metribuzin.
* **S19-19923HOLL (MG 5.0)**: High oleic, low linolenic (HOLL), resistance to SCN, RKN, reniform nematode (RN), PRR, SDS, SC, BSR, and metribuzin. Yield: 58.8 bu/ac.

**2. Field Screening & Performance of RKN-Resistant Lines**

* **Field Trial in Hope, AR** on sandy soil (Pf = 373 J2/100 cm³) evaluated 13 varieties. Six Missouri lines showed strong resistance (≤3.0 galling score).
* **Top performers**:
	+ S19-10701C (1.6% galled)
	+ S19-7867RR (2.2%)
	+ S19-14797C (1.0%)

These MG IV lines are being considered for release.

**3. Regional & Advanced Trials**

* **Regional Trials (2023)**: 32 high-yielding MG III–V breeding lines, each with resistance to SRKN, SCN, or RN. Awaiting Southern Regional Uniform trial results.
* **Advanced Yield Trials (AYT)**: 72 lines tested in 10 environments (MO and 6 states). 11 confirmed RKN-resistant lines identified via molecular markers.

**4. Preliminary Yield Trials (PYT)**

* **1,224 breeding lines** planted across MO and AR.
* ~60% had at least one nematode-resistant parent.
* **130 lines** selected for advancement to AYT 2024 and RKN marker screening.

**5. Progeny Rows & Population Advancement**

* **2023**: 208 bi-parental populations (~20,800 F4:5 lines) evaluated.
	+ **1,366 lines** selected for 2024 PYT (MG3L to MG4L).
* **Winter nurseries** in Costa Rica and Puerto Rico are advancing ~100 nematode-resistant populations (~15,000 F4:5 plants) for 2024.

**6. New Crosses (2023–2024)**

* **150 crosses** attempted in 2023 and **88 additional** in 2024 with RKN resistance as a key trait.
* Flood damage in 2024 reduced success; remaining crosses sent to winter nursery for regeneration and advancement.

**7. Screening for Resistance**

* **96 AYT lines** screened at University of Georgia for galling scores.
	+ **26 lines** showed low galling (1–2); 23 had RKN resistance marker on Chr. 10.
* Soil samples collected from Clarkton, MO (315–4,140 SRKN/100 cc) for future screening use.

**8. USDA & Uniform Trial Selections**

* From AYT 2024, **8 RKN-resistant lines** selected for 2025 USDA Uniform Preliminary Trial (UP), covering MG 3L–4L.
* Yield testing across 8 locations showed promising performance (4 lines >100% check yield at multiple sites).

**9. Planned 2025 Releases**

* Based on Uniform Trial data, **4 promising SRKN-resistant lines** are being considered for release in 2025.

**10. Technology Conversion**

Four RKN-resistant lines are undergoing conversion to XtendFlex technology in winter nursery:

| **Line** | **RKN Resistance** | **XtendFlex Conversion** |
| --- | --- | --- |
| S20-7901 | Yes | Yes |
| S21-2267 | Yes | Yes |
| S21-11972 | Yes | Yes |
| S19-10701 | Yes | Yes |