Project Number:	
Project Title:	Screening soybean germplasm and breeding soybeans for flood tolerance
Organization:	University of Missouri-Fisher Delta Research Center
Project Lead Name:	Drs. Caio Vieira, Tessie Wilkerson, David Moseley, Chengjun Wu, Francia Ravelombola
Reporting Period: *Please select the appropriate reporting period for this report.*	☐ December ☐ March ☐ June ☒ September ☐ Final

The information included in this detailed report should reflect quantifiable results that can be used to evaluate and measure project success.
If Progress Report – What key activities were undertaken and what were the key accomplishments during this reporting period? List each key deliverable from the proposal and describe progress made (or not made) toward achieving it, including metrics were appropriate.

If Final Report – What were the key accomplishments during the life of the project? List each deliverable from the proposal and describe progress made (or not made) toward achieving it, including metrics where appropriate.

University of Missouri (Lin):

Publication:
Argenta, J., Lin, F., Ravelombola, F., Adeva, C., Chen, P., Viera, C, Wu, C., Ye, H., Shannon, G., Nguyen, HT. Registration of 'S12-1362': a productive and flood-tolerant soybean germplasm. Journal of Plant Registrations. Under Author Review.

The 2025 Flood breeding pipeline at the University Missouri is outlined in Table 1. The soybean breeding and genetics program at MU FDREEC screens over 5,000 plots annually for flood tolerance.

The vegetative stages have been successfully flooded, and visual scoring has been completed. Drone flights were conducted. Phenotypic data analysis is currently in progress. We are continuing to flood the reproductive stages and will be conducting visual phenotyping in the next few days using flood damage scores. Additional drone flights will also be carried out, and the images will be processed.

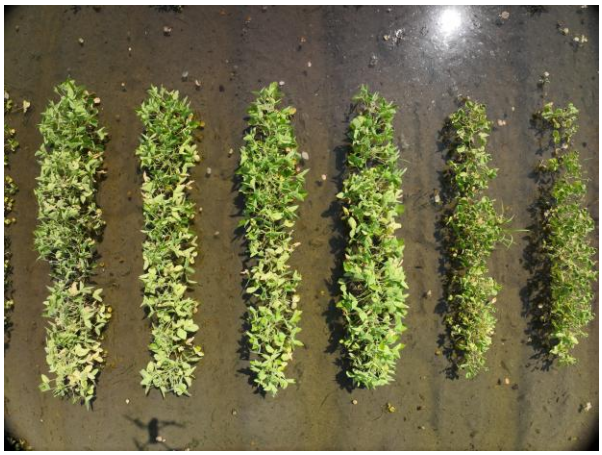

Figure 1. Soybean lines flooded at Flowering stages in Portageville, MO (2025)

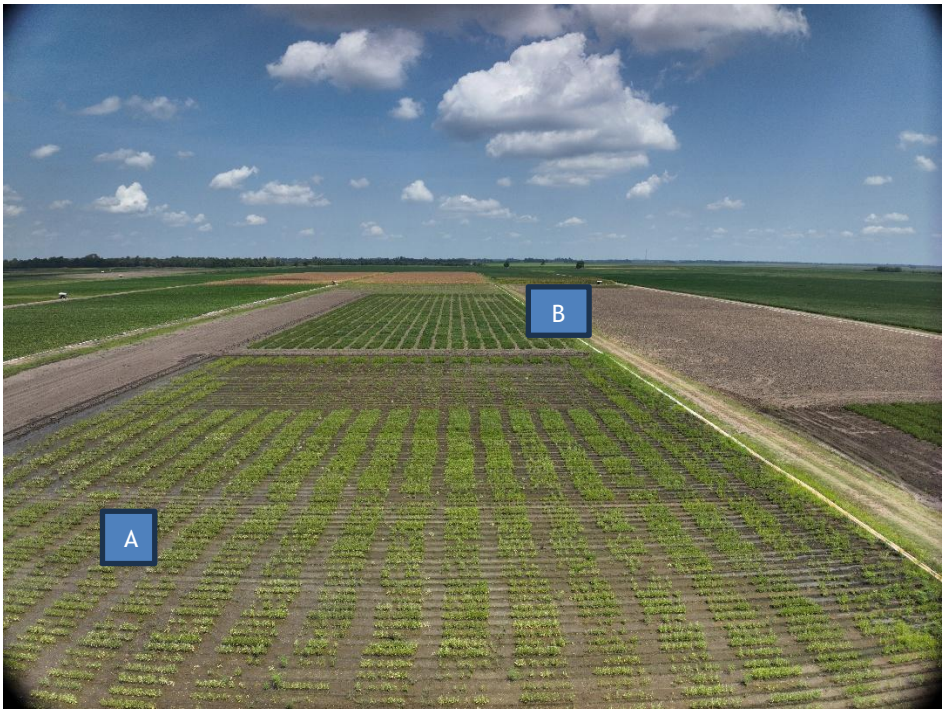

Figure 2. Aerial view of flood experiments in Portageville, MO (2025) (A) flooded experiment (B) non flooded experiments

Table 1. 2025 Flood breeding summary in Missouri

Test/Line	Description	Entry #
S20-1492	Germplasm	1
AYT-FLD	Flood advanced yield trials	10
PYT-FLD	Flood preliminary yield trails	98
MSSB_FLD	Advanced breeding lines and promising lines	250

MOCVT_FLD	Variety Test Flood Screening	40
Progeny	Visual Selection	~500
Population	F_1 to F_4 generation	4
New Crosses	Population development	6

1. 2025 Flood-tolerant germplasm potential release:
S20-1492 has the potential to be released as germplasm for flood tolerance. It demonstrated a flood damage score (FDS) of <2 at both the V2 and R1 growth stages, with yield exceeding 20 bu/ac under flooded conditions at these stages. Additionally, under non-flooded conditions, it exhibited a high yield of 70.1 bu/ac, which was not significantly different from the commercial checks. Data from multiple states and environments will be analyzed to further assess its performance and stability.

S20-1492 carries the favorable allele for flood tolerance on chromosome 3. It also carries the beneficial allele for stem canker *(Rdc3*).
Two years of the Uniform Trial data showed that the following characteristics for S20-1492 (Table 2)

Table 2. Comparison of seed composition and seed yield between S20-1492 and conventional checks

Experiment	Line	Seed Yield (bu/ac)	Height (in)	Protein (% dry basis)	Oil (% dry basis)
2023 UP	S20-1492	63.8	36	33.2	20.3
	Check	62.7	28	33.7	19.8
2024 UT	S20-1492	48.7	34	33.3	21.3
	Check	49.7	31	34.0	20.7
Overall	S20-1492	56.3	35	33.3	20.8
	Check	56.2	30	33.9	20.3
	% Check	100	119	98	103

Checks are:

- S16-14869 and TN09-008 in 2023
- S16-14869, TN09-008, and TN11-5140 in 2024

2. 2025 Flood advanced yield trials: A total of 10 MG4L, were evaluated for flooding tolerance and yield. The test lines include selections of lines with stable flood damage score and potential high yielding lines from 2024 flood yield trials. One tolerant check and sensitive commercial varieties along with conventional checks have also been included. The tests were conducted in 4-row plots with 3 replications under both flooding stress conditions (at V2 and R1 stages) and non-stress conditions (non-flooded field). In addition, soil electrical conductivity (EC in mS/cm), temperature (T in °C), and moisture (H in %) were recorded across three replications (R1, R2, and R3). EC values showed slight variation, with 0.77 in R1, decreasing to 0.58 in R2, and then rising to 0.64 in R3. Soil temperature remained relatively stable, ranging from 27.5°C in R1 to 27.8°C in R2

and 28.5°C in R3. Soil moisture (H) also showed minimal fluctuation, with values of 36% in R1, 36.40% in R2, and 36.30% in R3. Preliminary results for vegetative stages showed a slightly left-skewed distribution (Figure 3), with most values concentrated between 2.5 and 3.5, and a few observations falling below 2.0. Values less than 2 indicate flood tolerant lines, making this portion of the distribution especially important.

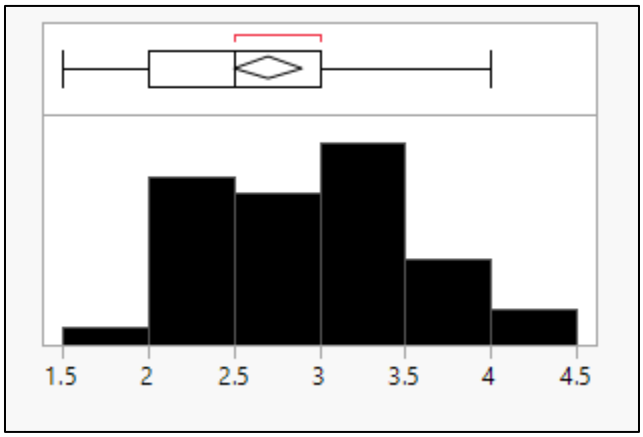

Figure 3. Distribution of vegetative stage flood damage score for flood advanced yield trials

3. 2025 Preliminary Flood Tolerance Screening: We include 98 potentially flood tolerant lines (MG4E and MG4L) in the Preliminary Flood Tolerance Screening. These lines will be evaluated for flood tolerance at V2 and R1 stages, with three replications, grown in single 7-foot rows across four different states. Additionally, the lines will be grown in Loam soil with two replications in 12-foot-long, four-row plots for yield evaluation and seed increase. Preliminary results showed that the distribution of flood damage scores appeared approximately normal, with most values centered around 2.5 to 3.0 (Figure 4).

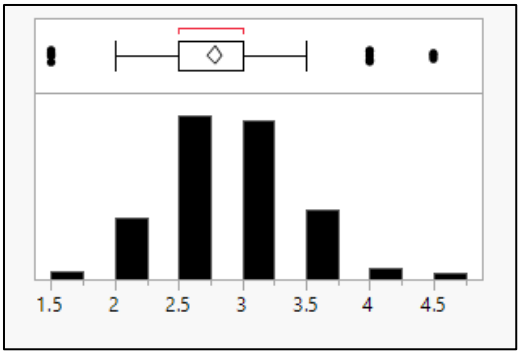

Figure 4. Distribution of vegetative stage flood damage score for PFT trials

4. 2025 Flood Tolerant Progeny rows: Approximately 500 F4 plant rows from 5 crosses were planted in Portageville, MO as a single row at the Lee Farm, Portageville, MO. At maturity, selections will be made visually based on agronomic traits and pod load.

POPULATION	PEDIGREE
CR23-132	S17-1146/S19-17313

CR23-134	S17-1494/S19-17313
CR23-157	S19-10701/PI 407788 A
CR23-158	S12-1362/PI 407788 A
CR23-159	S12-1362/PI 567305

5. 2025 Breeding population advancement: Four flood tolerant breeding populations were developed in 2024. The F_1 seeds of these crosses were sent to the winter nurseries where the populations will be advanced to F_4 for progeny row testing in 2026.

6. 2025 crosses for Flood tolerance: We attempted 6 new crosses for the season of 2025.

7. 2025 Missouri commercial variety testing for flood tolerance: We will evaluate commercial varieties developed by different seed companies with 3 replications under flooding stress for at R1/R2 stage during and non-flooded treatment the summer of 2025 at the Lee Farm Portageville, MO (heavy clay soil).

8. 2025 MSSB Flood screening for flood tolerance: The 2025 MSSB test includes approximately 250 advanced and promising breeding lines from the University of Missouri, specifically selected for flood tolerance, along with advanced and promising lines from the University of Arkansas. These lines will undergo genotyping. Flood tolerance screening was conducted at the V2 and R1 growth stages (soon), with three replications across multiple states, including Arkansas, Missouri, Louisiana, and Mississippi, and drone data was collected. Figure 5 showed that the advanced lines in both breeding program generally responds with moderate flood damage during the vegetative stages, with most values between 2.0 and 2.5. A few cases show lower stress, while some indicate higher susceptibility. The slight right skew suggests that although performance is mostly stable, there is some variability in flood response.

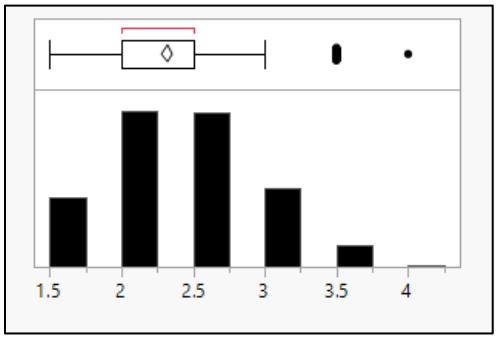

Figure 5. Distribution of vegetative stage flood damage score for MSSB trials

9. Marker data analysis: Lines entered in the preliminary flood screening were screened for the 2 flood markers and other markers including salt and root knot nematode. The bar graph (Figure 6) represents the genotypic screening results for the flood tolerance marker Gm03-3255212, categorizing the samples into Resistant (R), Susceptible (S), and Heterozygous (H) genotypes

(Figure 1). A significant number of samples (approximately 28) were identified as Resistant (R), indicating a strong presence of the favorable allele associated with flood tolerance.

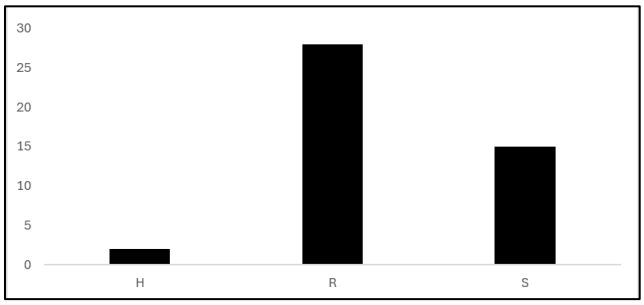

Figure 6. Genotypic distribution of soybean lines in the PFT Trials for flood tolerance marker Gm03-3255212

10. UAVs data image for flood damage score: For the 2024 modeling of flood damage assessment (vegetative stage), we are enhancing our pipeline using UAV derived imagery by incorporating a diverse set of features and by adding new data collected this year. The UAV features include (i) vegetation indices such as NGRDI, VARI, SCI, BI, and SI, which reflect plant health and flood-induced stress; (ii) color components from multiple color spaces (HSV, HSL, YCbCr, Lab, and Y) that capture chromatic and brightness variations related to flooding; (iii) texture descriptors from the Gray-Level Co-occurrence Matrix (GLCM), including contrast, dissimilarity, homogeneity, energy, correlation, mean, variance, and ASM, which help quantify surface texture changes; and (iv) geometric metrics like PixelCount, AreaPercentage, Perimeter, PlantHeight, and PlantBiomass, which describe the structure and extent of vegetation. A Random Forest model was applied to assess variable importance for predicting the Flood Damage Score (FDS), with results showing that features such as HSV_V, HSL_H, and GLCM_Variance were among the most influential. Model performance was evaluated using a multi-class classification framework, with a prediction accuracy of 0.784. The model demonstrates strong capability in detecting tolerant cs susceptible damage classes, which are most prevalent, and provides a solid foundation for improving flood damage classification from UAV data.

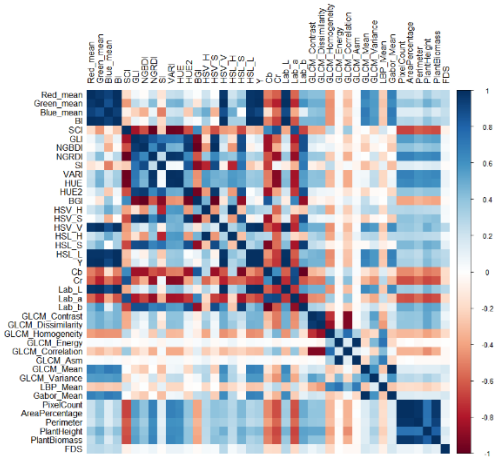

Figure 7. Correlation Heatmap of UAV-Derived Features Used for Flood Damage Assessment

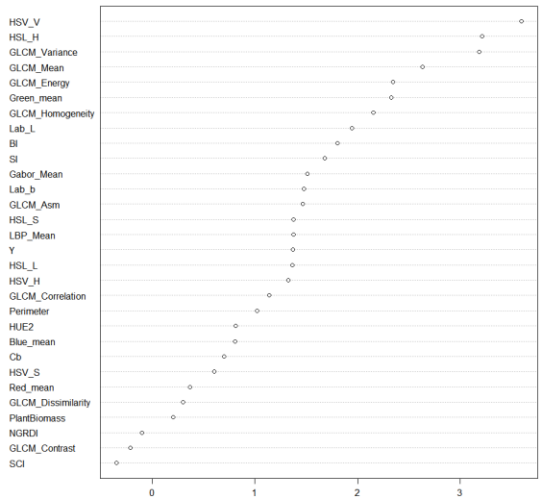

Figure 8. Variable Importance Plot from Random Forest Model for Flood Damage Score Prediction

University of Arkansas (Vieira):

1. Flood tolerance screening in Arkansas: In 2025, 270 advanced soybean lines from the Arkansas and Missouri Breeding Programs, along with five commercial checks, were evaluated for flood tolerance in a three-replicate MSSB flood screening trial at Stuttgart, AR. Trials were conducted at both the early vegetative (V2) and mid-reproductive (R1) stages. Flood damage scores (FDS) were collected visually and by drone from July to August. These same 270 lines were also tested in MSSB flood trials at three additional locations (MO, MS, and LA). Combined multi-location data will be analyzed further. Results from these trials will support the prediction, development, and release of flood-tolerant soybean germplasm.

At the V2 stage (7-day flooding), the mean FDS was 2.6, with significant variation among entries ($p < 0.0001$). Forty-six lines showed tolerance (FDS 1.0–1.7), with R23KB-04284 the most tolerant (FDS = 1.0). Eleven lines were highly susceptible (FDS 4.0–4.3).

At the R1 stage (7-day flooding), the mean FDS was 3.0, also with significant variation ($p < 0.0001$). Eleven lines were tolerant (FDS 1.0–1.7), with S23-10293 the most tolerant (FDS = 1.0). Thirty-seven lines were highly susceptible (FDS 4.0–5.0), with R23KB-09711 the most susceptible (FDS = 5.0). Notably, S23-12895 performed well at both V2 and R1 (FDS = 1.7).

2. Flood tolerance breeding in Arkansas: In 2025, four elite pre-commercial MG4/5 lines (R19C-1035, R19C-1081, R21KB-05522, and R20-1429) with flood-tolerant pedigrees are being tested in multiple regional and local yield and flood trials for potential release as flood-tolerant varieties. Thirty-five preliminary lines from flood-tolerant pedigrees are being evaluated in 2-rep yield trials (FLP5) across three Arkansas locations and in 3-rep flood screening tests (FLP5-FLD) at Stuttgart, AR, at both V2 and R1 stages. In addition, 874 progeny rows with flood-tolerant pedigrees are under yield evaluation in Stuttgart.

About 30 breeding populations from flood-tolerant parents are being advanced in the winter nursery. Ten new crosses combining flood tolerance with diverse value-added traits were also made in Fayetteville during summer 2025. Yield and agronomic data will be collected at harvest.

3. Flood tolerance evaluation for commercial varieties in Arkansas: In 2025, 53 commercial varieties and breeding lines from multiple companies and the Arkansas Soybean Breeding Program are being tested for yield and flood tolerance under both flooded and non-flooded conditions in Stuttgart, AR. After 5 days of flooding at the V5 stage, 19 varieties/lines showed good tolerance (FDS = 1.0–1.7). Two commercial varieties, AG50XF5 and Pioneer P44Z67BE, were highly tolerant

(FDS = 1.0). Five breeding lines (R23PR-00100E, R19C-1035, R19-45980, R23PR-00037E, and R22KB-00989) also performed well (FDS = 1.3–1.7).
The overall test mean was 2.1 (range 1.0–3.7), with significant variation among entries (p = 0.0523). Yield data under both flooding and non-flooding conditions will be collected and reported in the next quarterly update.

Mississippi State University (Wilkerson)
One complete set of the Mississippi State University official variety trial (110 entries) was planted on June 4, 2025. Plots were planted 2 rows wide and 20 ft in length to allow for harvest and replicated 3 times. Plots consisting of breeding line seed sent from both Arkansas and Missouri were planted on June 6, 2025 as single rows with 3 replications. Both the flood OVT and flood breeding line trials were flooded on July 15, 2025 at approximately R1/R2 growth stage for 96 hours. Plots were rated 7 days post flood removal for flood incidence. Data will presented in the final report.
Drone has be flown for both fields.

Figure 1. Flood screening in Mississippi

Louisiana State University (Moseley)
The MSSB trials and the variety tests were planted on June 12, 2025. The plots are currently at the flooding stage, and the stand is looking good. The growth so far has been very promising. We will likely begin taking flood damage score soon alone drone flights.