Project Number:	
Project Title:	Screening soybean germplasm and breeding soybeans for flood tolerance
Organization:	University of Missouri-Fisher Delta Research Center
Project Lead Name:	Caio Vieira
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:
Registration of 'S12-1362': a soybean germplasm with two QTLs for flood tolerance at the reproductive growth stages. Journal of plant Registration (Under Review)

Presentations:
2026 North American Plant Phenotyping Network (NAPPN) Conference:
Flood Duration Shapes Soybean Physiological Responses to Vegetative-Stage Waterlogging: Growth, Root Plasticity, and Gas Exchange

2026 Soybean Symposium:
UAV-Based Image Features for Classifying Flood Tolerance in Soybean at Vegetative and Reproductive Stages

The 2025 flood breeding pipeline at the University of Missouri is outlined in Table 1. The soybean breeding and genetics program at MU-FDREEC planted and screened more than 5,000 plots annually for flood tolerance. Vegetative-stage flooding and all visual scoring at the vegetative stages were completed to identify promising lines for advancement. Drone flights were conducted to support high-throughput phenotyping, providing a more scalable and objective approach for screening flood tolerance. At the same time, efforts are underway to develop and refine a UAV-based phenotyping pipeline for routine implementation in the breeding program. Seeds from harvested trials have been stored in the cold room, and data analysis is being finalized to support potential germplasm release.

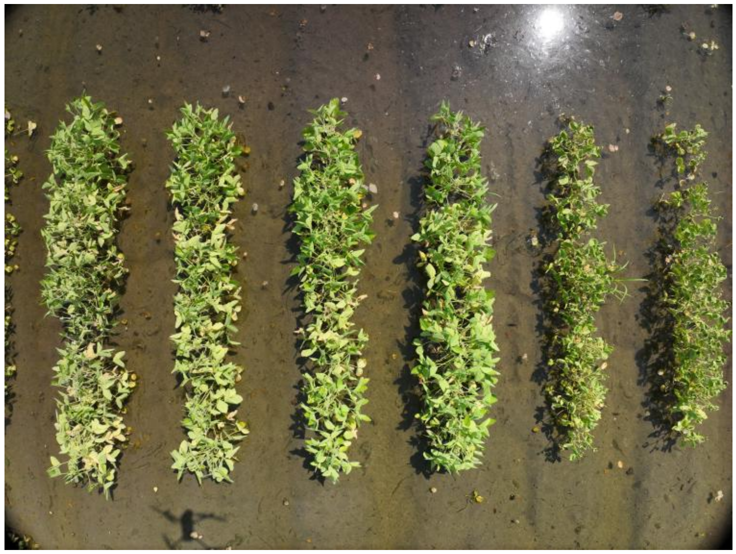

Figure 1. Soybean lines flooded at Flowering stages in Portageville, MO (2025)

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

Table 1. 2025 Flood breeding summary in Missouri

Test/Line	Description	Entry #
S17-1146, S20-1492	Potential germplasm release	1
AYT-FLD	Flood advanced yield trials	4
PYT-FLD	Flood preliminary yield trails	48
MSSB_FLD	Advanced breeding lines and promising lines	250
MOCVT_FLD	Variety Test Flood Screening	40
Progeny Rows	Visual Selection	~500
Population	F_1 to F_4 generation	7
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 S16-14869 and TN09-008 in 2023; and S16-14869, TN09-008, and TN11-5140 in 2024.

2. 2025 Flood advanced yield trials: A total of 4 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 vegetative 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. 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. The scatter plot (Figure 4) highlights S17-1146, S22-14279, and S22-14289 as the top performers on the CLAY (flooded V2) site. S17-1146 showed the strongest overall performance, combining the highest clay yield (37.5 bu/ac) with the highest loam yield (80.3 bu/ac). S22-14279 (35.2 bu/ac on clay; 63.2 bu/ac on loam) and S22-14289 (34.1 bu/ac on clay; 62.1 bu/ac on loam) also ranked among the best under flooded clay conditions while maintaining solid yield potential on loam.

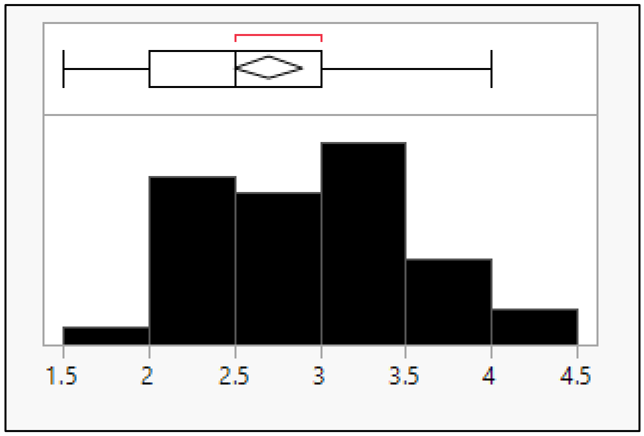

Figure 3. Distribution of vegetative stage flood damage score for flood advanced yield trials

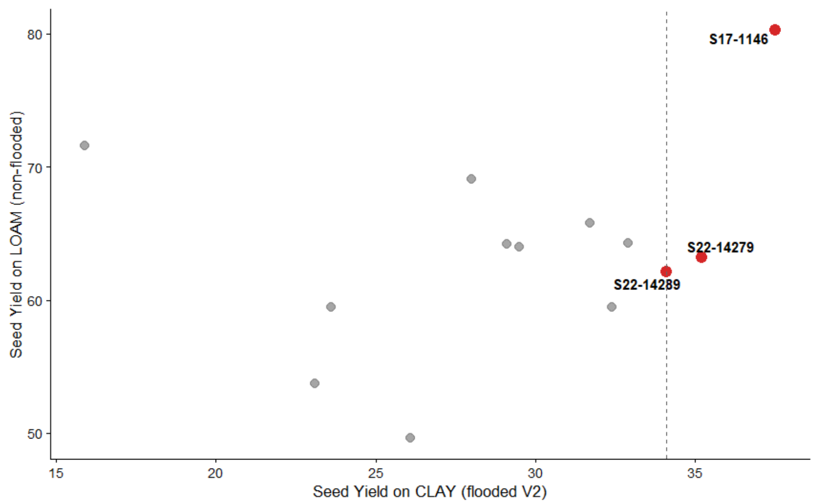

Figure 4. Lines seed yield comparison: clay (flooded at V2) vs loam (non flooded)

3. 2025 Preliminary Flood Tolerance Screening: We include 98 potentially flood tolerant lines (MG4E and MG4L from Missouri Arkansas Breeding Program) in the Preliminary Flood Tolerance Screening. These lines were evaluated for flood tolerance at V2 stages, with three replications, grown in single 7-foot rows across four different states. Additionally, the lines were grown in Loam soil with two replications in 12-foot-long, four-row plots for yield evaluation and seed increase. Results showed that flood damage scores were approximately normally distributed, with most values centered around 2.5 to 3.0 (Figure 5). In addition, the lines were grown in loam soil with two replications in 12-foot-long, four-row plots for seed yield evaluation and seed increase. Seeds from University of Missouri will be stored in cold room.

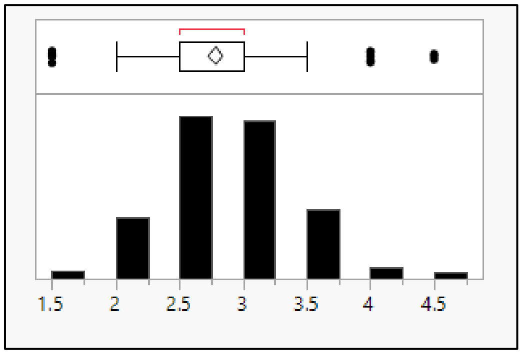

Figure 5. Distribution of vegetative stage flood damage score for PFT trials

4. 2025 Flood Tolerant Progeny rows: Approximately 500 F_4 plant rows from 5 crosses were planted in Portageville, MO as a single row at the Lee Farm, Portageville, MO. At maturity, visual selections were made based on agronomic traits and pod load, resulting in the selection of 6 4E lines, and 8 4L lines. Seeds have been stored in the cold room.

POPULATION	PEDIGREE
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: Seven flood tolerant breeding populations were developed in 2024. The populations will be back in Portageville this year and will be stored in the cold room.

6. 2025 crosses for Flood tolerance: We made 4 new crosses for the season of 2025. The F_1 seeds of these crosses are stored in the cold room at Soybean Breeding Program in Portageville, MO.

7. 2025 Missouri commercial variety testing for flood tolerance: We evaluated commercial soybean varieties from different seed companies under flooding stress at the reproductive growth stages with three replications at Lee Farm in Portageville, Missouri (heavy clay soil) during the summer of 2025. Under prolonged flooding during the reproductive stages, we identified several lines that yielded more than 15 bu/ac: FS HiSoy HS 41F50, AgVenture AV46C3E, AgVenture AV45B2E, and Golden Harvest GH4452XFS.

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. 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 6 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. We have received and are compiling the data from our collaborators.

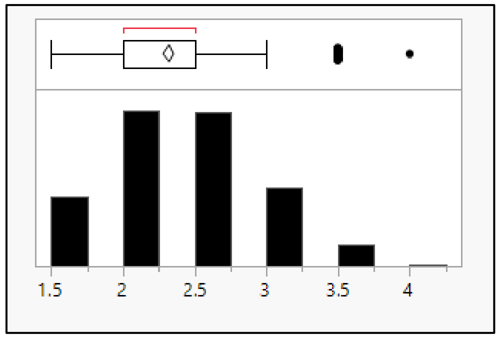

Figure 6. Distribution of vegetative stage flood damage score for MSSB trials

10. UAVs data image for flood damage score: This study evaluated the use of unmanned aerial vehicles (UAVs) as a high-throughput phenotyping tool to assess flood tolerance in soybean. A total of 245 soybean genotypes from advanced yield trials were exposed to flooding stress at the V2 (vegetative) and R1 (reproductive) growth stages in a randomized complete block design with three replications in Portageville, Missouri. Flood tolerance was visually scored on a 1-5 scale and grouped into four tolerance classes. UAV-based RGB imagery was collected and processed through a pipeline that included orthomosaic generation, plot gridding, image segmentation, and extraction of canopy features such as RGB indices, texture traits, and color-space variables (Figure 7). Correlation analysis showed that relationships among image-derived traits were generally weaker at V2 but became stronger and more structured at R1, suggesting that canopy responses to flooding were more clearly expressed as plants developed (Figure 8). Variable importance analysis further revealed that canopy structural and texture-related traits were among the strongest contributors to flood tolerance prediction at both stages, although the ranking of key traits differed between V2 and R1 (Figure 8). Classification results showed that model performance was higher at V2, where accuracy reached 0.784, while prediction at R1 was lower, with an accuracy of 0.534 and greater confusion among neighboring tolerance classes (Figure 8). Overall, these results demonstrate that UAV-based phenotyping can provide reliable, rapid, and scalable assessment of soybean flood tolerance and has strong potential for integration into breeding pipelines. Future work will focus on testing additional modeling approaches and incorporating multispectral imagery to improve prediction accuracy and better capture physiological differences associated with flood tolerance. These results demonstrate that UAV-based phenotyping can provide a reliable, rapid, and scalable approach for assessing soybean flood tolerance, with strong potential for integration into breeding pipelines. This means faster and more objective identification of flood-tolerant lines, improving selection efficiency and accelerating the development of resilient cultivars. For farmers, this means improved access in the future to soybean varieties with greater tolerance to flooding stress, helping reduce yield losses and improve productivity in the flood-prone, clay-dominated environments common across much of the Mid-South.

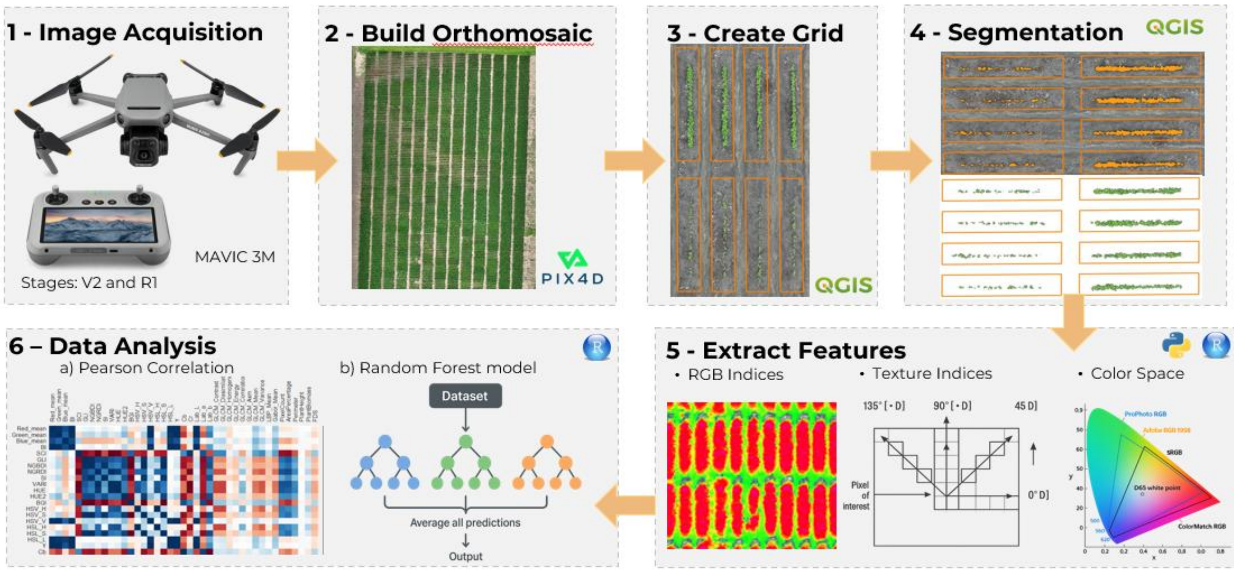

Figure 7: UAV-Based Image Analysis Pipeline for High-Throughput Assessment of Soybean Flood Tolerance

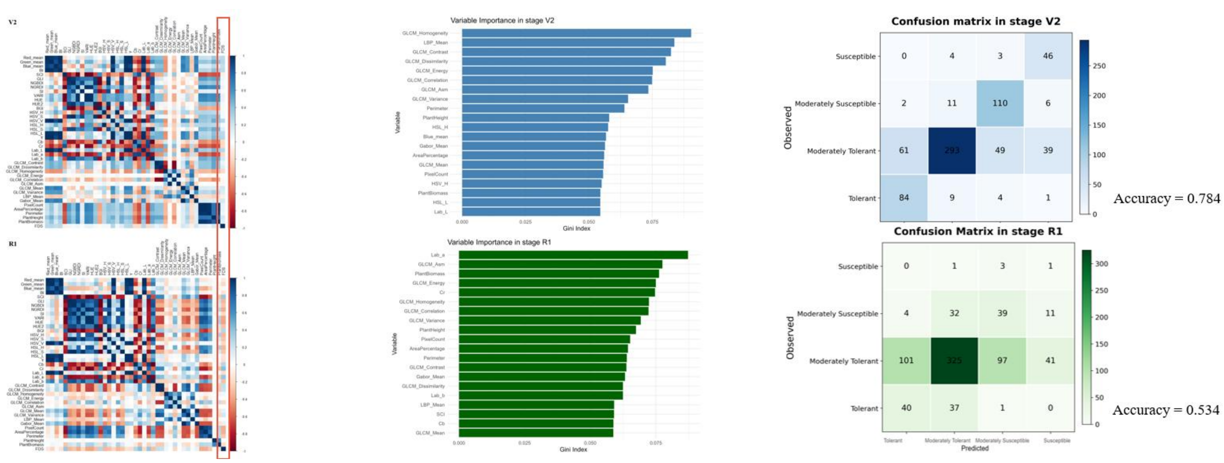

Figure 8: Correlation Patterns, Variable Importance, and Classification Accuracy of UAV-Derived Traits for Soybean Flood Tolerance at V2 and R1 Stages