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., 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 of Missouri is outlined in Table 1. The soybean breeding and genetics program at MU FDREEC screens more than 5,000 plots annually for flood tolerance. Vegetative-stage flooding has been completed, along with all visual scoring. Drone flights were conducted. Due to excessive rainfall during the reproductive period, plants matured early and turned yellow, so planned reproductive-stage flooding and phenotyping could not be carried out. The yield trials for flood were harvested to evaluate seed yield and report yield data under two conditions: non-flooded and flooded at the vegetative stage to assess yield loss for each line.

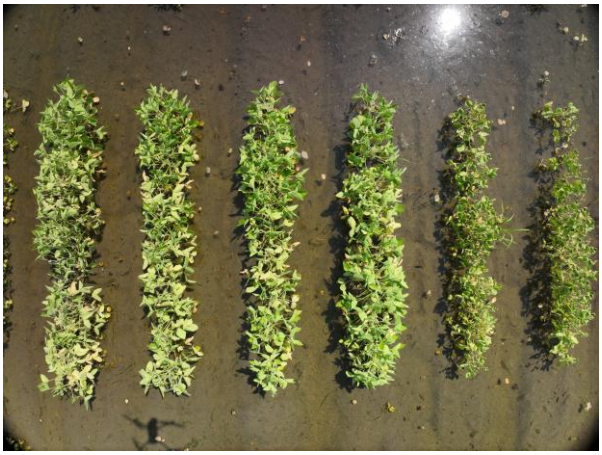

Figure 1. Soybean lines flooded at Flowering stages in Portageville, MO (2025)

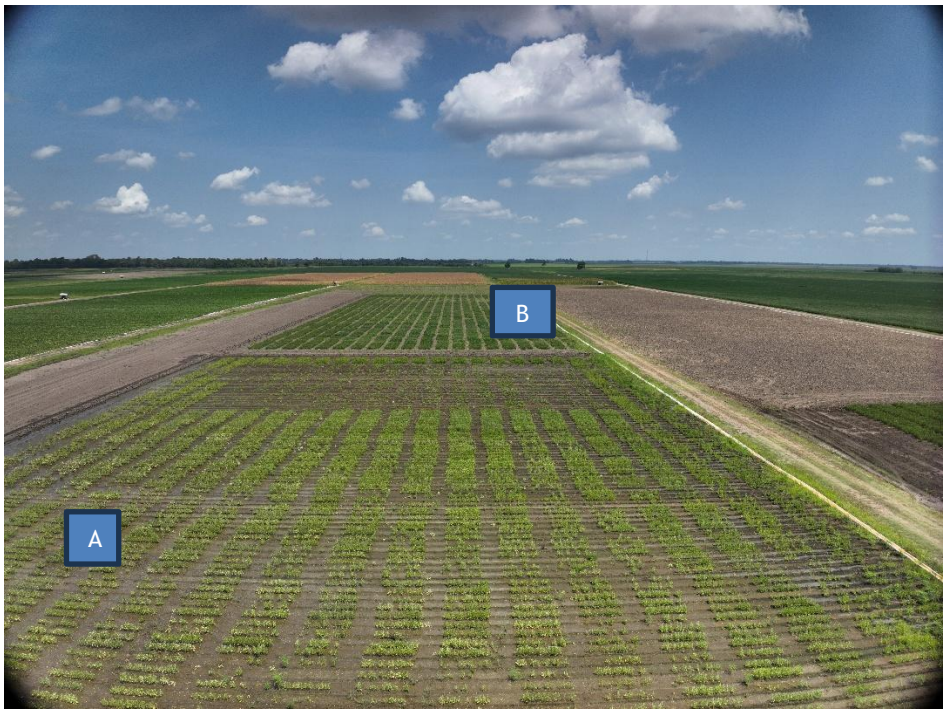

Figure 2. Aerial view of flood experiments in Portageville, MO (2025) (A) flooded experiment (B) non flooded experiments

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. Harvest has been completed. 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, supporting their advancement for further testing.

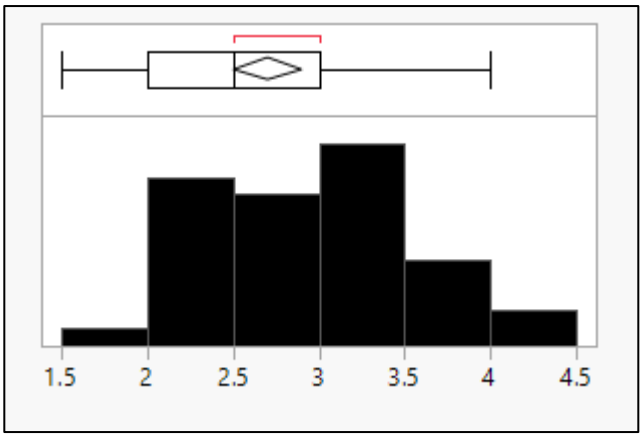

Figure 3. Distribution of vegetative stage flood damage score for flood advanced yield trials

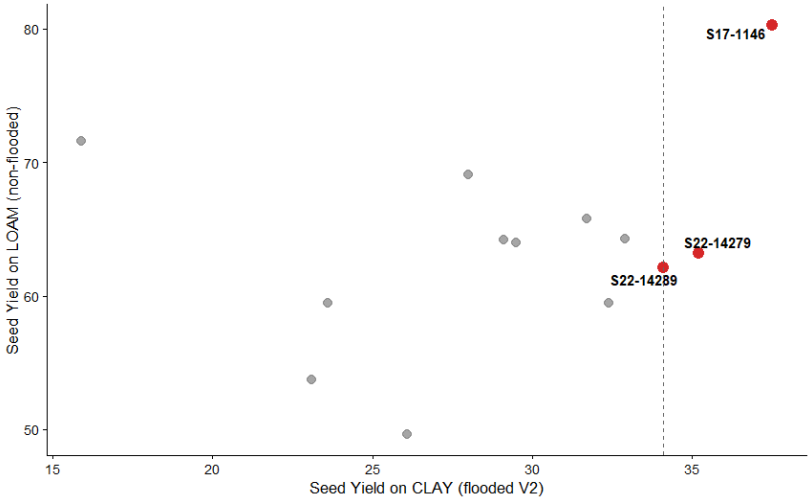

Figure 4. Lines seed yield comparison: clay (flooded at V2) vs loam (non flooded)

3. 2025 Preliminary Flood Tolerance Screening: We include 98 potentially flood tolerant lines (MG4E and MG4L) 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 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 yield evaluation and seed increase. Based on visual performance under flooding and high yield in loam soil, we will advance selected lines to advanced yield flood trials.

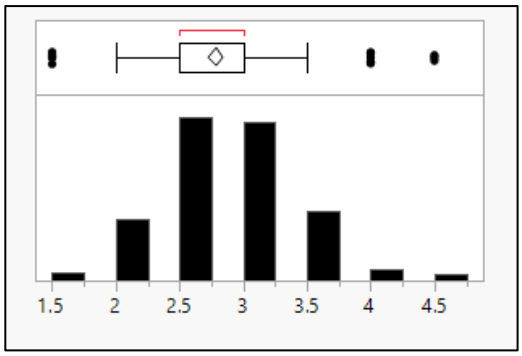

Figure 5. Distribution of vegetative stage flood damage score for PFT trials

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, visual selections were made based on agronomic traits and pod load, resulting in the selection of 10 3L lines, 6 4E lines, and 8 4L lines.

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 F1 seeds of these crosses were sent to the winter nurseries where the populations will be in Portageville, MO 2026.

6. 2025 crosses for Flood tolerance: We made 4 new crosses for the season of 2025.

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. 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 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 the data from our collaborators, and we are currently working on a combined analysis. Our goal is to identify soybean lines that show stable flood tolerance across environments.

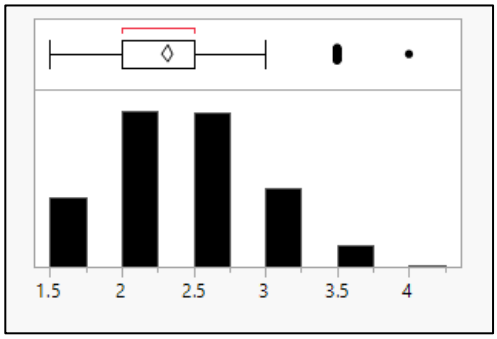

Figure 6. Distribution of vegetative stage flood damage score for MSSB trials

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

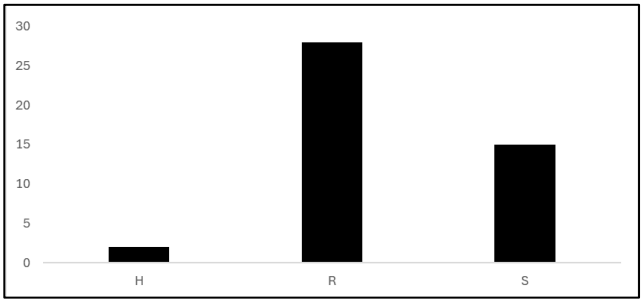

Figure 7. Genotypic distribution of soybean lines in the PFT Trials for flood tolerance marker Gm03-3255212

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. We are in the process of analyzing data for 2025 trying to improve the model and generate a publication out of it two years data. For 2025, we are expanding the dataset by conducting UAV flights before flooding, during flooding, and after flooding, and we are collecting data at the same time of day as the visual ratings to better align UAV measurements with field assessments. These additions are expected to improve model performance and support a publication based on two years of data.

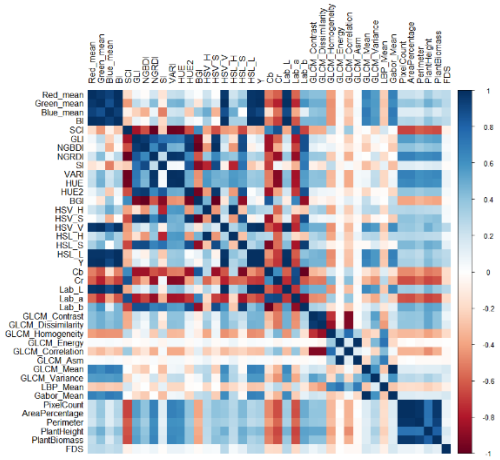

Figure 8. Correlation Heatmap of UAV-Derived Features Used for Flood Damage Assessment

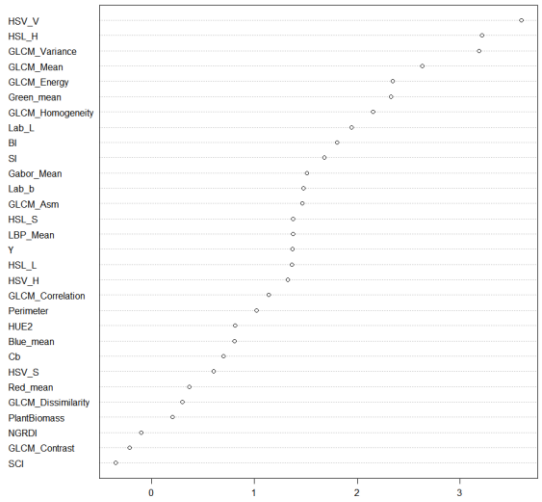

Figure 9. Variable Importance Plot from Random Forest Model for Flood Damage Score Prediction

University of Arkansas (Vieira):

Arkansas (Vieira):

1. Flood-tolerant germplasm potential release in Arkansas

In 2025, two pre-commercial MG5 lines (R20-1429 and R21KB-05522), developed from high-yielding and flood-tolerant pedigrees, were evaluated across five Arkansas locations in the two-rep pre-commercial trial (25PCM5E). Under irrigated conditions, both lines performed well, yielding 69.7 and 68.4 bu/ac, respectively (Table 1). In flood screening trials, both lines showed strong tolerance at vegetative and reproductive stages, reflected by low flood damage scores (FDS). They also displayed additional desirable traits, including resistance to nematodes and diseases and tolerance to salt stress. These two lines are being evaluated as candidates for release as high-yielding and flood-tolerant germplasm.

Table 1. R20-1429 and R21KB-05522 performance in 2025 pre-commercial yield trial and flood screening trial in Arkansas.

Test	Line	Pedigree	Yield (bu/ac)	% CK	BLUP	Visual Selection	FDS V2	FDS R1
25PCM5E	R20-1429	S12-1362/Walters	69.7	99.0	3.45	5	2.0	1.7
	R21KB-05522	R16-141/R13-13997	68.4	97.2	1.16	5	1.0	1.7
	Grand mean		68.5					
	Check mean		70.4					

2. Flood tolerance breeding in Arkansas

During the 2025 season, thirty-five preliminary breeding lines with high-yielding and flood-tolerant pedigrees were evaluated for yield and agronomic performance in a two-rep yield trial (25FLP) across three Arkansas locations. These same lines were also evaluated for flood tolerance at both vegetative and reproductive stages under 7-day flooding conditions in Stuttgart, AR. Elite lines combining high yield and strong flood tolerance will be advanced to 2026 flood advanced trials.

In parallel, 874 progeny rows derived from flood-tolerant pedigrees were visually evaluated for yield potential and uniformity in Stuttgart, AR, resulting in the selection of 52 lines for 2026 flood preliminary trials. Approximately 30 breeding populations derived from flood-tolerant parents were advanced in off-season nurseries. Additionally, 46 new crosses integrating high yield, flood tolerance, drought tolerance, and other value-added traits were made during the 2025 summer crossing season in Fayetteville, AR, with seed advanced to off-season nurseries for population development.

3. Flood tolerance screening trials in Arkansas

In 2025, a total of 275 advanced breeding lines from the Arkansas and Missouri Soybean Breeding Programs, along with commercial checks, were evaluated for flood tolerance at early vegetative (V2) and mid-reproductive (R1) stages in three-rep flood screening trials (25MSSB) in Stuttgart, AR. Following a 7-day flooding treatment, visual flood damage scores (FDS; 1-5 scale) were collected, and summary results are presented in Table 2.

In the V2 screening trial (25MSSBV2), 46 lines exhibited high flood tolerance (FDS < 2.0), with a test mean FDS of 2.6 and a range from 1.0 to 4.3. Line R23KB-04284 showed the strongest tolerance, with an FDS of 1.0. In the R1 screening trial (25MSSBR1), 11 lines showed high tolerance (FDS < 2.0), with a test mean FDS of 3.0 and a range from 1.0 to 5.0. Line S23-10293 had the lowest FDS (1.0) at R1. Line S23-12895 demonstrated consistent tolerance at both stages, with FDS values of 1.7 at V2 and R1. These highly flood-tolerant lines will be further evaluated in subsequent flood screening trials.

Table 2. The summary of 2025 MSSB flood screening trials in Stuttgart, AR.

Test	Entry	Flooding stage	FDS mean	FDS range	Tolerant No. (FDS < 2.0)	P value
25MSSBV2	275	V2	2.6	1.0-4.3	46	<.0001
25MSSBR1	275	R1	3.0	1.0-5.0	11	<.0001
Total	550					

4. Flood tolerance evaluation for commercial cultivars in Arkansas

In 2025, fifty-one commercial soybean cultivars and advanced breeding lines from multiple industry partners and the Arkansas Soybean Breeding Program were evaluated for yield and flood tolerance under paired non-flooded and 5-day flooded conditions at the V3/V4 growth stage in Stuttgart, AR. Trial summaries are shown in Table 3. Mean yield under non-flooded conditions was 52.9 bu/ac, while mean yield under flooded conditions was 31.5 bu/ac, corresponding to an average yield loss of 40.5% due to early vegetative flooding stress.

Under flooded conditions, commercial cultivar AG50XF5 exhibited the highest flooded yield (48.4 bu/ac), strong yield retention (76.6%), and the lowest flood damage score (FDS = 1.0), indicating high flood tolerance. Several other commercial cultivars, including Progeny 4947XFS, Pioneer P50Z95E, Progeny 4842XFS, and Progeny 4824XF, also demonstrated good flood tolerance with relatively high flooded yields and low FDS values (Table 4).

In contrast, cultivar BH39A232 showed high susceptibility to flooding, with the lowest flooded yield (11.0 bu/ac), lowest yield retention (28.8%), and highest FDS (3.7). Cultivars AG47XF2 and Progeny 4734XFS also exhibited high susceptibility under flooded conditions. Several Arkansas elite breeding lines (R19C-1035, R19-45980, R23PR-00037E, and R23PR-00100E) performed well under flood stress, combining higher flooded yields with lower FDS values. Line R23PR-00100E showed the highest yield retention (82.8%) among all entries evaluated (Table 4).

Table 3. 2025 commercial soybean cultivar flood trial summary.

Test	**Treatment**	**Yield range (bu/ac)**	**Test mean (bu/ac)**	**LSD**	**Yield retention**	**Yield loss mean**	**FDS range (1-5)**
25VT-Flood	**Non-flooded**	**33.4-67.1**	**52.9**	**7.8**			
25VT-Flood	**5-day Flooded**	**11.0-48.4**	**31.5**	**11.5**	**28.8-82.8%**	**40.5%**	**1.0-3.7**

Table 4. Several flood-tolerant and susceptible cultivars and Arkansas lines performances in 2025 commercial soybean cultivar flood trial.

Line	Maturity	Non-flooded yield (bu/ac)	Flooded yield (bu/ac)	Yield retention	FDS (1-5)	Flood stress
AG50XF5	5.0	63.2	48.4	76.6%	1.0	Tolerant
Progeny 4947XFS	4.9	58.6	47.6	81.3%	1.3	Tolerant
Pioneer P50Z95E	5.0	61.1	47.0	76.9%	1.3	Tolerant
Progeny 4842XFS	4.8	67.1	44.9	66.9%	2.0	Tolerant
Progeny 4824XF	4.8	57.6	42.5	73.8%	1.7	Tolerant
R19-45980	5.3	60.8	42.1	69.2%	1.7	Tolerant
R23PR-00037E	4.9	53.6	41.0	76.5%	1.7	Tolerant
R19C-1035	4.5	62.3	40.0	64.2%	1.7	Tolerant

R23PR-00100E	4.4	45.0	37.2	82.8%	1.7	Tolerant
BH39A232	3.9	38.3	11.0	28.8%	3.7	Susceptible
AG47XF2	4.7	49.4	19.4	39.2%	2.7	Susceptible
Progeny 4734XFS	4.7	57.1	24.6	43.2%	3.3	Susceptible
Test mean		52.9	31.5	59.5%	2.2	
LSD		7.8	11.5			

5. UAV-based flood tolerance evaluation in Arkansas flood screening trials

In 2025, UAV imagery was integrated into multiple three-rep flood screening trials in Stuttgart, AR, to evaluate flood tolerance at early vegetative and mid-reproductive stages. Image data were collected daily during the 7-day flooding period, as well as at 11 days (R1) and 14 days (V2) after flooding, coinciding with visual FDS assessments.

Preliminary results showed clear separation of tolerant, moderately tolerant, and sensitive genotypes based on changes in canopy coverage during flooding and post-flood recovery (Figure 1). These UAV-based classifications were highly consistent with visual FDS ratings. Additional UAV-derived metrics, including canopy coverage, NDVI, and green leaf index (GLI), captured flooding impacts during both the stress and drainage periods (Figure 2). Clustering genotypes based on changes in these metrics revealed response patterns closely aligned with visual flood tolerance scores. These results demonstrate that UAV phenotyping provides a robust and scalable approach for quantifying flood response, monitoring canopy decline, and distinguishing tolerant and susceptible genotypes in Arkansas flood screening trials.

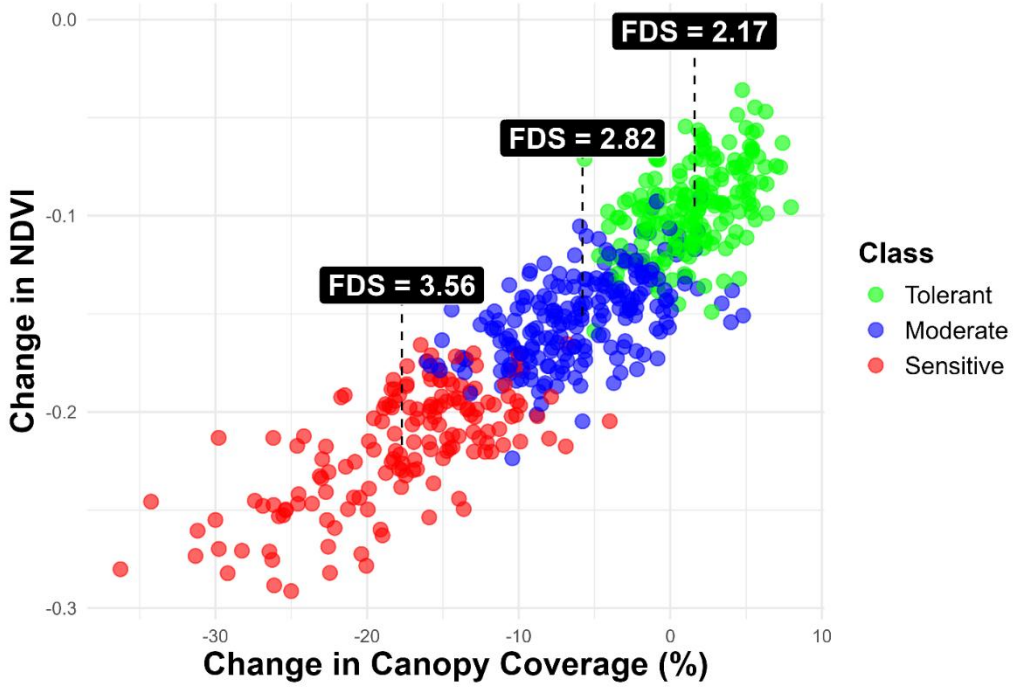

Figure 1. Clustering genotype flood responses using UAV canopy and NDVI metrics during flooding stress.

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 established 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. Both fields were captured with overhead imaging through drone technology. The Soybean Flood Official Variety Trial was harvested on October 24, 2025. Yields ranged from 10.6 bushels per acre to 73.5 bushels per acre across maturity groups

Figure 1. Flood screening in Mississippi

Louisiana State University (Moseley)

The MSSB trials and the variety tests were planted on June 12, 2025. Data from the Soybean Flood Official Variety Trial showed that most lines were very sensitive to flood FDS>2.5. data from the MSSB flood test has been shared to collaborators for combined analysis.