Science Societies

Developing high-yielding and stress-resilient soybean varieties

Progress and prospects for U.S. Mid-South farmers

By Harmeet Singh-Bakala, Francia Ravelombola, Jessica Argenta, Cheryl Adeva, Maiara de Oliveira, Grover Shannon, and Feng Lin, University of Missouri-T.E. Jake Fisher Delta, Research, Extension and Education Center, Portageville, MO

February 28, 2025

The soybean-breeding program at the University of Missouri Fisher Delta Research, Extension & Education Center is dedicated to developing high-yielding, resilient varieties to support farmers in the U.S. Mid-South. Photo by Kyle Spradley | © 2014 - Curators of the University of Missouri. Published under this license: https://creativecommons.org/licenses/by-nc/2.0/

Soybean is an important crop as a global food, oil, and feed source, yet its productivity faces threats from climate-change-driven factors. The Mid-South U.S., a major soybean-producing region, experiences unique environmental challenges that affect yield and farm profitability. The soybean-breeding program at the University of Missouri Fisher Delta Research, Extension & Education Center (MU-FDREEC) is dedicated to developing high-yielding, resilient varieties to support farmers in this region. Over the past five years, MU-FDREEC has released 24 new soybean varieties, including conventional, herbicide-tolerant, and specialty types (high oleic acid). Collaborations with farmers, industry partners and research institutions have led to improvements in disease resistance, seed quality and yield, benefiting soybean producers nationwide. Looking ahead, the program is focused on enhancing climate resilience, optimizing photosynthetic efficiency, and incorporating genomic technologies. These efforts aim to provide Mid-South farmers with improved soybean varieties that boost productivity, profitability, and sustainability.

Earn 0.5 CEUs in Crop Management by taking the quiz for the article.

Soybean is the most widely cultivated legume crop and ranks among the top five crops in the world (Martignone et al., 2023) with a total production of 395 million metric tons in 2023–2024 (USDA, 2024). It provides a significant amount of protein and edible oil for human consumption and is a key source of protein for animal feed. However, soybean production is increasingly challenged by climate-change-related factors such as extreme temperature, water stress, diseases, and insect pests (Landau et al., 2022; Song et al., 2016; Bandara et al., 2020). These will intensify in the coming decades as global temperatures and CO_2 continue to rise (Dijk et al., 2021), threatening food security and farm profitability (Ray et al., 2013).

To sustain and enhance soybean productivity, breeding programs must focus not only on enhancing current yield levels, but also on improving soybean resilience to biotic and abiotic stresses. It is important to focus on agricultural research, farmer support, and development efforts to mitigate future food shortages and climatic challenges. The U.S. is the second largest producer of soybean after Brazil, accounting for ~30% of global supply with an annual production of 113 million metric tons (USDA, 2024). Its Mid-South region grows approximately 12 million acres (14% cultivation area) of soybean, contributing to about 15% the country's total production (USDA, 2024; Rogers et al., 2015). However, undesirable weather and occurrence of diseases/pests during the growing season poses a significant threat to soybean productivity as it limits the yield potential of soybean varieties (Evans & Fisher, 1999).

Research efforts at the University of Missouri Fisher Delta Research, Extension & Education Center (MU-FDREEC) have been instrumental in developing improving soybean varieties tailored to region's unique environmental challenges, contributing to more resilient and productive cropping systems. The MU-FDREEC soybean breeding program aims to develop improved soybean varieties and enhance germplasm for improved productivity, adaptability, and profitability of Mid-South farmers. This article explores the contribution of the MU-FDREEC breeding program, highlighting its role in developing high-yielding, broadly adapted soybean varieties with improved seed quality, multiple disease resistance, and tolerance to environmental stresses.

The Missouri Fisher Delta Research, Extension & Education Center (MU-FDREEC) facilities have cold storage for seeds and germplasm. Photo by Kyle Spradley | © 2014 - Curators of the University of Missouri. Published under this license.

Why high yield and resilience matter in soybean

Soybean contributes to ~60% of global oilseed production (Martignone et al., 2023). Over the past 80 years, soybean on-farm yield has steadily increased thanks to the dedicated efforts of breeders and agronomists, who have developed and deployed improved soybean varieties (Specht et al., 2014; Boehm et al., 2019). These new varieties offer better yield potential, desirable agronomic characteristics, and resistance to various diseases and pests (Carter et al., 2004).

To better understand and enhance soybean yield potential, breeders regularly determine their progress by studying genetic improvements in yield over time (Boehm et al., 2019). They focus on selecting varieties that can perform well in different environments. Each year, breeding programs aim to boost soybean productivity by selecting plants with favorable traits including higher yield, resistance to lodging, ability to withstand environmental stresses- drought, weeds and diseases (Rogers et al., 2015).

Beyond yield improvement, varieties with stress resilience offers significant economic benefits by reducing the need for costly inputs—pesticides, herbicides, and irrigation. This not only lowers production costs, but also enhances farm profitability and promotes long-term sustainability. By providing farmers with resilient and productive soybean varieties, breeding efforts contribute to a more stable and sustainable agricultural system capable of meeting the growing global demand for soybean.

Soybean-breeding program achievements

The MU-FDREEC soybean-breeding program plays a crucial role in advancing soybean production in the Mid-South through innovation and research. This program focuses on developing high-yielding soybean varieties with improved disease resistance and enhanced quality to support farmers' profitability. In the last five years, MU-FDREEC was able to successfully release 24 new soybean varieties with high yield, resilience, and additional traits (Table 1). Significant contributions by MU-FDREEC have also made in developing a range of soybean varieties, including conventional, Roundup Ready, Liberty, high-protein, high-oleic, and low-linolenic acid content (Table 2). More recently, the program is focusing on releasing XtendFlex and Enlist herbicide traits. One of its most notable achievements is the development of SOYLEIC, a non-GMO, high-oleic soybean trait that eliminates trans fats while maintaining functional properties of soybean oil. These varieties are now commercially produced across 20 states in the U.S.

Table 1. Yield potential of soybean varieties with enhanced tolerance to diseases that have been recently released (2020–2024) by the University of Missouri Fisher Delta Research, Extension & Education Center soybean-breeding program.

Variety[a]	Year of release	Maturity group	Growth habit	Avg. yield (bu/acre)	Disease resistance[cd]
S16-14730	2020	4 LATE	I	64.7	SC
S16-11644	2020	4 LATE	SD	65.6	SCN, SRKN, BSR
S16-7922	2020	4 LATE	SD	66.6	SCN, SRKN, SC, BSR
S16-11651	2020	5 EARLY	I	67.7	SCN, SRKN, BSR
S16-15170	2020	5 EARLY	I	67.3	SC, BSR
S16-3747RR2	2020	5 EARLY	D	66.3	SCN, SRKN, BSR

Table 1. Yield potential of soybean varieties with enhanced tolerance to diseases that havebeen recently released (2020–2024) by the University of Missouri Fisher Delta Research,Extension & Education Center soybean-breeding program.

Variety[a]	Year of release	Maturitygroup[b]	Growth habit	Avg. yield (bu/acre)	Disease resistance[cd]
S16-5540GT-HO	2020	4 LATE	SD	68.9	SCN, SRKN, RN, BSR
S16-16814GT	2020	4 LATE	D	57.0	SCN, SRKN, FLS
S17-2243	2021	4 LATE	SD	61.3	SCN, SC
S16-14801	2021	5 EARLY	D	68.6	SCN, SRKN, SC, BSR
S16-5503GT	2021	4 LATE	SD	65.1	SCN, SRKN, RN, BSR
S16-8290HP	2022	5 EARLY	SD	62.9	SCN, SRKN, SC, BSR
S17-17168HP	2022	4 LATE	SD	59.0	SCN, SRKN, SC, BSR
S09-13185HP	2022	5 LATE	D	63.3	SCN, SC, BSR
S17-2193	2022	4 LATE	I	64.9	SCN, RN, SC
S16-7840	2022	5 EARLY	D	65.0	SCN, SRKN, RN, SC, BSR
S16-9090	2022	5 EARLY	SD	64.5	SRKN, RN
S16-14869	2022	5 EARLY	SD	64.4	SCN, SRKN, RN, SC, BSR

Table 1. Yield potential of soybean varieties with enhanced tolerance to diseases that havebeen recently released (2020–2024) by the University of Missouri Fisher Delta Research,Extension& Education Center soybean-breeding program.

Variety[a]	Year of release	Maturitygroup [b]	Growth habit	Avg. yield (bu/acre)	Disease resistance[cd]
S19-19741GT HOLL	2022	4 LATE	I	66.7	SCN, RN, SC, BSR
S19-18135LL55	2022	5 EARLY	SD	72.7	SCN, RN, PRR, SC, BSR
S18-6013	2023	5 EARLY	SD	69.2	SCN, SRKN, SC, BSR
S19-10701	2024	4 LATE	I	61.3	SRKN, RN, SC, BSR
S19-19764HOLL	2024	5 EARLY	I	61.7	RN, SC, PRR, BSR
S19-12537	2024	5 EARLY	I	65.6	SCN, SRKN, RN, SC, BSR

Table 1. Yield potential of soybean varieties with enhanced tolerance to diseases that havebeen recently released (2020–2024) by the University of Missouri Fisher Delta Research,Extension& Education Center soybean-breeding program.

Variety[a]	Year of release	Maturitygroup[b]	Growth habit	Avg. yield (bu/acre)	Disease resistance[cd]

[a] GT, glyphosate tolerant; RR2, Roundup Ready 2 Yield; LL55, LibertyLink.

[b] D, determinate; SD, semi-determinate; I, indeterminate.

[c] SCN, soybean cyst nematode; SRKN, southern root-knot nematode; RN, reniform nematode; SC, stem canker; PRR, Phytophthora root rot; FLS, frogeye leaf spot; BSR, brown spot rot.

[d] All disease responses showing results from genetic markers (except for RN—field tolerance confirmed). Responses confirmed with gene-specific markers: SCN (genes *Rhg1a*, *Rhg1b*, *Rhg4*), PRR (*Rps1a*, *Rps1c*, *Rps1d*, *Rpsk1*), FLS (*Rcs3*), SC (*Rdc3*), and BSR and RKN—confirmed with non-gene-specific markers.

Table 2. Environmental tolerance and seed-related traits of recently released varieties (2020–2024) by University of Missouri Fisher Delta Research, Extension & Education Center soybean-breeding program.

Variety[a]	Year of release	Type[b]	Salt tolerance[c]	Iron chlorosis tolerance[c]	Seed-related traits
S16-14730	2020	Conv	Includer	Tolerant	-
S16-11644	2020	Conv	Excluder	Tolerant	-
S16-7922	2020	Conv	Excluder	Sensitive	-
S16-11651	2020	Conv	Excluder	Tolerant	-
S16-15170	2020	Conv	Excluder	Tolerant	-
S16-3747RR2	2020	RR2	Excluder	Tolerant	-

Table 2. Environmental tolerance and seed-related traits of recently released varieties (2020–2024) by University of Missouri Fisher Delta Research, Extension & Education Center soybean-breeding program.

Variety[a]	Year of release	Type[b]	Salt tolerance[c]	Iron chlorosis tolerance[c]	Seed-related traits
S16-5540GT	2020	GT	Excluder	Sensitive	–
S16-16814GT-HO	2020	GT/HO	Includer	Tolerant	High oleic acid[d]
S17-2243	2021	Conv	Excluder	Tolerant	–
S16-14801	2021	Conv	Excluder	Sensitive	–
S16-5503GT	2021	GT	Excluder	Sensitive	–
S16-8290HP	2022	Conv	Excluder	Sensitive	High protein
S17-17168HP	2022	Conv	Excluder	Sensitive	High protein
S09-13185HP	2022	Conv	Excluder	Tolerant	High protein
S17-2193	2022	Conv	Excluder	Tolerant	–
S16-7840	2022	Conv	Excluder	Sensitive	–
S16-9090	2022	Conv	Excluder	Tolerant	–
S16-14869	2022	Conv	Excluder	Sensitive	–
S19-19741GT-HOLL	2022	GT/HOLL	Excluder	Tolerant	High oleic acid, low linolenic acid[d]
S19-18135LL55	2022	LL55	Excluder	Sensitive	–
S18-6013	2023	Conv	Includer	Sensitive	–
S19-10701	2024	Conv	Excluder	Tolerant	–

Table 2. Environmental tolerance and seed-related traits of recently released varieties (2020–2024) by University of Missouri Fisher Delta Research, Extension & Education Center soybean-breeding program.

Variety[a]	Year of release	Type[b]	Salt tolerance[c]	Iron chlorosis tolerance[c]	Seed-related traits
S19-19764HOLL	2024	Conv	Excluder	Sensitive	High oleic acid, low linolenic acid[d]
S19-12537	2024	Conv	Includer	Tolerant	–

[a] HO, high oleic acid (> 75%); LL, low linolenic acid (< 3%); HOLL, combined high oleic acid and low linolenic acid; HP, high protein (> 36.5%); GT, glyphosate tolerant.

[b] Conv, conventional; RR2, Roundup Ready 2.

[c] Salt and iron tolerance—just genetic marker screening.

[d] Genetic and wet lab confirmation.

In addition to enhancing seed composition and breeding methodologies, the program has achieved great progress in combating key diseases, which are a major threat to soybean production. In collaborations with various institutions across the U.S., MU-FDREEC has identified new genes to improve soybean varieties resistant to these diseases such as soybean cyst and root-knot nematodes, benefiting farmers worldwide. Over the past two decades, the MU-FDREEC soybean-breeding program has grown into one of the top public breeding programs, supplying germplasm and technology to major seed companies for variety development. The program's sustained commitment to collaboration with farmers, industry partners, and the USDA, ensures that cutting-edge research is translated into real-world benefits, driving agricultural sustainability and economic growth.

Role of research in developing superior varieties

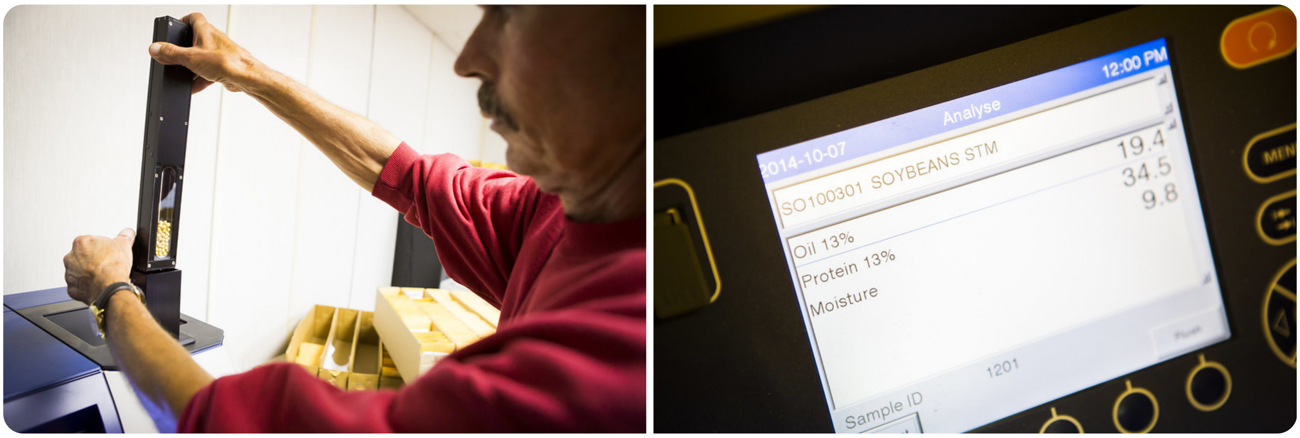
Research plays a vital role in developing improved soybean varieties by enabling breeders to make informed decisions that balance multiple important traits. While selecting for higher yield over time, breeders also consider other agronomic traits such as lodging resistance, maturity, and pod load. These traits can be indirectly affected by yield selection. Additionally, yield improvement efforts often impact end use quality traits such as protein and oil content, which are known to have an inverse relationship with yield (Boehm et al., 2019). To enhance the breeding program's effectiveness, integrating herbicide incorporation strategies, such as Enlist and XtendFlex, is essential. These technologies not only support weed management, but also contribute to the development of soybean varieties with enhanced herbicide tolerance, ensuring improved agronomic performance and adaptability in diverse growing environments.

At MU-FDREEC, researchers use advanced breeding methods to accelerate development of improved soybean varieties. One such tool is marker-assisted selection, a method that helps breeders to select plants with superior genetic profiles without the need for extensive field evaluations, improving selection accuracy and reducing breeding time. The use of greenhouses for off-season crossings and winter nurseries in Costa Rica allows rapid generation advancement, enabling the development of new varieties in shorter time. To enhance selection efficiency, the program has recently integrated unmanned aerial vehicles (UAVs) and advanced technologies into the soybean-breeding pipeline, addressing the major bottleneck of phenotyping (Figure 1). Traditional methods are slow and labor-intensive, while UAVs rapidly capture high resolution data across multiple field locations providing valuable insights into plant health, stress response and growth patterns. This accelerates the selection of superior varieties. UAVs are also used for precise herbicide application, improving field management and reducing labor costs. By combining traditional breeding expertise with modern technology, MU-FDREEC continues to develop high yielding, resilient soybean varieties with improved seed quality.

Figure 1. Advanced technologies used at the Missouri Fisher Delta Research, Extension & Education Center (MU-FDREEC) for enhancing variety selection accuracy: (top) UAV, MutlispeQ, and GASMET; and (bottom) aerial images from a drone showing FDREEC field trials.

Practical benefits for Mid-South farmers

The improved soybean varieties developed through research at MU-FDREEC offer significant practical benefits to the farmers in the Mid-South region. With built-in resistance to major diseases and pests in the region, farmers can lower their dependence on pesticides, leading to cost savings and more sustainable farming practices. Improved seed quality traits, such as high oil and protein and a superior fatty acid profile, enhance the marketability of soybean, ensuring better returns for farmers. Several varieties have desired herbicide traits for weed control, including technologies such as Liberty Link and Roundup Ready. Moreover, traits like lodging resistance and optimized plant architecture contribute to easier harvestability and efficient field management. By adopting these advanced soybean varieties, farmers can maximize field productivity, improve profitability, and be more sustainable.



Improved seed quality traits, such as high oil and protein and a superior fatty acid profile, enhance the marketability of soybean, ensuring better returns for farmers. Photo by Kyle Spradley | © 2014 - Curators of the University of Missouri. Published under this license.

Future directions in soybean breeding

At MU-FDREEC, future soybean-breeding efforts focus on improving yield potential by optimizing photosynthetic efficiency (Koester et al., 2014; Vogel et al., 2021), enhancing resilience to climate change, by developing varieties that can withstand extreme weather events and evolving pests and diseases. Research also aims to improve seed nutritional value to meet growing global demand for high quality food and feed and develop varieties suited for sustainable and regenerative agricultural practices that promote soil health and reduce environmental impacts. By incorporating advanced breeding technologies, such as genomic selection, marker-assisted selection, and precision phenotyping with UAV drones, breeders can efficiently analyze large populations and accelerate the development of high-yielding, stress-tolerant soybean varieties to meet the evolving needs of farmers and agricultural industry.

References

Bandara, A. Y., Weerasooriya, D. K., Bradley, C. A., Allen, T. W., & Esker, P. D. (2020). Dissecting the economic impact of soybean diseases in the United States over two decades. *PloS One*, *15*(4), e0231141. https://doi.org/10.1371/journal.pone.0231141

Boehm, J. D., Jr., Abdel-Haleem, H., Schapaugh, W. T., Jr., Rainey, K., Pantalone, V. R., Shannon, G., ... & Li, Z. (2019). Genetic improvement of US soybean in maturity groups V, VI, and VII. *Crop Science*, *59*, 1838–1852. https://doi.org/10.2135/cropsci2018.10.0627

Cober, E. R., & Voldeng, H. D. (1999). Developing high-protein, high-yield soybean populations and lines. *Crop Science*, *40*, 39–42. https://doi.org/10.2135/cropsci2000.40139x

Dijk, M. V., Morley, T., Rau, M. L., & Saghai, Y. (2021). A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050. *Nature Food*, *2*, 494–501. https://doi.org/10.1038/s43016-021-00322-9

Foyer, C. H., Lam, H.-M., Nguyen, H.T., Siddique, K.H.M., Varshney, R.K., Colmer, T.D., ... & Considine, M.J. (2016). Neglecting legumes has compromised human health and sustainable food production. *Nature Plants*, *2*, 16112. http://dx.doi.org/10.1038/nplants.2016.112

Koester, R. P., Skoneczka, J. A., Cary, T. R., Diers, B. W., & Ainsworth, E. A. (2014). Historical gains in soybean (*Glycine max* Merr.) seed yield are driven by linear increases in light interception, energy conversion, and partitioning efficiencies. *Journal of Experimental Botany*, *65*, 3311–3321. https://doi.org/10.1093/jxb/eru187

Landau, C. A., Hager, A. G., & Williams II, M. M. (2022). Deteriorating weed control and variable weather portends greater soybean yield losses in the future. *Science of The Total Environment*, *830*, 154764. https://doi.org/10.1016/j.scitotenv.2022.154764

Martignone, G. M. B., Ghosh, B., Papadas, D., & Behrendt, K. (2023). The rise of soybean in international commodity markets: A quantile investigation. *Heliyon*, *10*(15), e34669. https://doi.org/10.1016/j.heliyon.2024.e34669

Ray, D. K., Mueller, N. D., West, P. C., & Foley, J. A. (2013). Yield trends are insufficient to double crop production by 2050. *PloS One*, *8*, e66428. https://doi.org/10.1371/journal.pone.0066428

Rogers, J., Chen, P., Shi, A., Zhang, B., Scaboo, A., Smith, F., & Zing, A. (2015). Agronomic performance and genetic progress of selected historical soybean varieties in the southern USA. *Plant Breeding*, *134*, 85–93. https://doi.org/10.1111/pbr.12222

Song, L., Prince, S., Valliyodan, B., Joshi, T., Maldonado dos Santos, J.V., Wang, J., … & Nguyen, H.T. (2016). Genome-wide transcriptome analysis of soybean primary root under varying water-deficit conditions. *BMC Genomics*, *17*, 57. https://doi.org/10.1186/s12864-016-2378-y

Specht, J. E., Diers, B. W., Nelson, R. L., de Toledo, J. F. F., Torrion, J. A., & Grassini, P. (2014). Soybean. In S. Smith et al. (Eds.), *Yield gains in major U.S. field crops* (pp. 311–356). CSSA Spec. Publ. 33. ASA, CSSA, and SSSA. https://doi.org/10.2135/cssaspecpub33.c12

USDA. (2024). *Crop production summary*. https://downloads.usda.library.cornell.edu/usdaesmis/files/k3569432s/ns065v292/8910md644/cropan24.pdf

Vogel, J. T., Liu, W., Olhoft, P., Crafts-Brandner, S. J., Pennycooke, J. C., & Christiansen, N. (2021). Soybean yield formation physiology—A foundation for precision breeding based improvement. *Frontiers in Plant Science*, *12*, 719706.

https://doi.org/10.3389/fpls.2021.719706

Wilson, R. F. (2008). Soybean: Market-driven research needs. In G. Stacey (Ed.), *Genetics and genomics of soybean* (pp. 3–15). Springer. https://doi.org/10.1007/978-0-387-72299-3_1

Self-study CEU quiz

Earn 0.5 CEUs in Crop Management by taking the quiz for the article at https://web.sciencesocieties.org/Learning-Center/Courses. For your convenience, the quiz is printed below. The CEU can be purchased individually, or you can access as part of your Online Classroom Subscription.

1. **What country is the largest producer of soybean in the world?**

   a. The United States.

   b. India.

   c. Brazil.

   d. China.

2. **Which of the following is a soybean trait developed by the University of Missouri-FDREEC soybean-breeding program that eliminates trans fats**

while maintaining functional properties of soybean oil?

a. SOYLEIC.

b. MSSB.

c. SRKN.

d. XtendFlex.

3. **Unmanned aerial vehicles allow soybean breeders to direct more precise herbicide application.**

   a. True.

   b. False.

4. **Which of the following varieties released by the University of Missouri-FDREEC soybean-breeding program is resistant to soybean cyst nematode?**

   a. S16-14730.

   b. S16-15170.

   c. S16-9090.

   d. S19-12537.

5. **Which of the following varieties released by the University of Missouri-FDREEC soybean-breeding program is/are both high protein and tolerant to iron chlorosis?**

a. S09-13185HP.

b. S16-14801.

c. S16-5503GT.

d. Both a and c.
