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| Please use this form to clearly and concisely report on project progress. The information included should reflect quantifiable results that can be used to evaluate and measure project success. Comments should be limited to the designated boxes. Technical reports, no longer than 4 pages, may be attached to this summary report. | |
| Project Number: | **1820-172-0118-C (formerly 1820-172-0130)** |
| Project Title: | **Yield potential of commercial varieties under drought- identifying and overcoming weaknesses through public breeding advances (Year 1)** |
| Organization: | USDA-ARS |
| Principal Investigator Name: | **Thomas E. Carter, Jr.** |
| Report Period: | June 16, 2017 to September 15, 2018 |
| Project Status: | |
| Farmers need help with drought: 1) Farmers need documented performance data for commercial varieties under drought. 2) Farmers need new drought-tolerant breeding stock, so that commercial breeding programs can use them to develop better drought-tolerant varieties. 3) Farmers need basic research to support new drought-tolerant variety release.  This new project started October 1. (Updates in red)  **September 15 Report:**  As of September 15, the main item to report is that we had a wet summer on the Atlantic coast (topped off by hurricane Florence in North and South Carolina). The widespread rain somewhat limited collection of wilting notes in the field. However, we experienced sufficient drying in late August and early September, that we were successful in taking wilting notes at Sandhills, NC and Florence SC (just after the Southern Soybean Breeders tour in Georgia). Missouri, Kansas and Arkansas were also wet, but had sufficient breaks in rain to take useful canopy wilting notes in KS and MO. USB –Smith Bucklin manager Jackie Weiss visited North Carolina on August 22-24 and met with drought project PI and Co-PIs (Locke, Burkey, and Fallen). Traveling with the team, she visited the Sandhills Research Station near Pinehurst, NC to survey drought research. In other work, the Drought Team gave three drought-related presentations (two from Burkey and one from Fallen) and published two papers (one on root architecture (Nguyen) and the other describing a germplasm release from Arkansas). The germplasm release is only the third drought tolerant germplasm release in soybean (see Manjarrez et al. below). We also noted many new desirable slow wilting genotypes that are mentioned in the highlights.    **Publications from this Quarter:**  Manjarrez-Sandoval, Pedro, Pengyin Chen, Leandro Mozzoni\*, Liliana Florez-Palacios, Moldir Orazaly, Chengjun Wu, Thomas R. Sinclair, Thomas E. Carter Jr., Larry C. Purcell, and C. Andy King. 2018. Registration of the Soybean Germplasm Lines R10-2436 and R10-2710 with Drought Tolerance Traits and High Yield under Moderate Water Stress. J. Plant Registrations (In Press – 09/09/2018).  Prince S.J., B. Valliyodan, H. Ye, M. Yang, S. Tai, W. Hu, M. Murphy, L.A. Durnell, L. Song, T. Joshi, Y. Liu, J.V. de Velde, K. Vandepoele, G.J. Shannon, H.T. Nguyen. 2018. Understanding genetic control of root system architecture in soybean: Insights into the genetic basis of lateral root number. Plant Cell and Environment doi:10.1111/pce.13333  **Previous Publications on current grant (Oct 1. – June 15).**  Heng Ye, Manish Roorkiwal, Babu Valliyodan, Lijuan Zhou, Pengyin Chen, Rajeev Varshney, Henry T. Nguyen. Genetic diversity of root system architecture in response to drought stress in grain legumes (2018). Journal of Experimental Botany, 69 (13): 3267–3277.  Heng Ye, Babu Valliyodan, Li Song, J. Grover Shannon, Pengyin Chen and Henry T. Nguyen. “Advances in the drought and heat resistance of soybean” in book “Achieving sustainable cultivation of soybeans” (2018). BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE.  Bagherzadi, Laleh, T.R. Sinclair, M. Zwieneicki, F. Secchi, W. Hoffman**, T.Carter,** and T.Rufty. 2017. Assessing water-related plant traits to explain slow wilting PI 471938. J. Crop Improvement. 31:400-417.  Mandeep Riar, P. Cerezini, A. Manandhar, T. R. Sinclair, Z. Li, and **T. E. Carter,** Jr. 2017. Expression of Drought-Tolerant N2 Fixation in Heterogeneous Inbred Families derived from PI 471938 and Hutcheson Soybean. Crop Sci. 58:364-369.  Kaler, S., J.D. Ray, W.T**. Schapaugh,** C.A. King, and L.C. Purcell. 2017. Genome‑wide association mapping of canopy wilting in diverse soybean genotypes. Theor. Appl. Genet. 130:2203–2217. DOI 10.1007/s00122-017-2951-z.  Clinton J. Steketee, William T. Schapaugh, Thomas E. Carter Jr., and **Zenglu Li.** 2018. Genome-wide Association Analysis and Linkage Mapping Reveal Genomic Regions Controlling Canopy Wilting in Soybean.*Frontiers in Plant Science (In review)*  Miles Ingwers, Clinton J. Steketee, Sushil K. Yadav, and **Zenglu Li.** 2018. Carbon isotope composition is correlated with above-ground biomass accumulation and foliar nitrogen concentration under low and high soil moisture availability in soybean. Environmental and Experimental Botany (Submitted)  Heng Ye, Manish Roorkiwal, Babu Valliyodan, Lijuan Zhou, Pengyin Chen, Rajeev Varshney, **Henry T. Nguyen**. 2018. Genetic diversity of root system architecture in response to drought stress in grain legumes. Journal of Experimental Botany (In Press)  **Presentations from this Quarter.**  **Ben Fallen.** The SC Soybean Board held their July meeting at the Pee Dee Research and Extension Center in Florence, SC. This is Dr. Fallen’s main drought research station in S.C. Dr. Fallen conducted a tour of drought research plots and highlighted drought research approaches.  **Kent O. Burkey.** “Genetic variation in ozone response of Fiskeby soybeans”; August 27, 2018; Soy2018, The 17th Biennial Conference on the Molecular and Cellular Biology of the Soybean, Athens Ga.  **Kent O. Burkey.** Hosted Dr. Amand Mbuya, Administrator of National Agricultural Study and Research Institute from the Democratic Republic of Congo, discussed abiotic stress tolerance, and provided a tour of our Inwood Road field site for the study of stress in soybean. July 18, Raleigh, NC;  **Previous Presentations on current grant (Oct. 1 – June 15)**  Clinton J. Steketee, Thomas R. Sinclair, Mandeep K. Riar, William T. Schapaugh, Thomas E. Carter Jr, and **Zenglu Li.** Unraveling the genetic architecture for drought tolerance related traits in soybean using genome-wide association analyses. May, 2018, UGA IPBGG Retreat, Callaway, GA  **Carter,** T.E. Invited presentation: ‘More Crop for the Drop- Developing Drought Tolerant Soybeans’. 19th Annual Customer/Partner Dialogue Workshop, USDA-ARS Coastal Plains Soil, Water, and Plant Research Center, Florence, SC, March 15th, 2018  Steketee, C.J., W.T. Schapaugh, T.E. Carter Jr., and **Z. Li.** ‘Discovery of genomic regions and germplasm to improve drought tolerance in soybean’. Soybean Breeder’s Workshop. Feb. 2018. St. Louis, MO. (Poster)  Steketee, C.J., W.T. Schapaugh, T.E. Carter Jr., and **Z. Li** ‘Identification of genomic regions and germplasm to improve drought tolerance in soybean’. GA/FL Small Grains/Soybean Expo. Jan. 2018. Perry, GA. (Poster)  **Fallen**, Ben. Invited Presentation: “Breeding for Drought Tolerate Varieties.” South Carolina Crop Improvement Association Board Meeting. Columbia, SC. 02/22/18  **Fallen**, Ben. Invited presentation: “Evaluating and Improving Drought Tolerance Across the Carolinas.” South Carolina Young Farmer and Agribusiness Association, South Carolina Promotion Board and the South Soybean Board Meeting. Charleston, SC. 01/20/18.  Henry T. **Nguyen**. ‘Development of Climate Resilient Soybeans’ Plant & Animal Genome XXVI, San Diego, CA, USA. January 13-17, 2018,  Henry T. **Nguyen**. ‘Natural Variation and Genetic Regulation of Root Architecture and Plasticity in Soybean’. International Symposium on Crop Roots and Rhizosphere Interactions, Yangling, China. October 9-13, 2017.  **Research Highlights for this quarter:**  **New Discovery of slow -wilting Southern Breeding Lines developed from Swedish Fiskeby Soybean—new genetic resources in the war on drought.** USDA researchers Carter and Burkey in North Carolina have been on the trail of stress tolerant Fiskeby soybean varieties for several years. These Swedish Fiskeby types carry resistance to multiple abiotic stresses, including drought, and have been the subject of extensive breeding and physiological research in previous projects. This summer at the Sandhills Research Station, we identified twelve slow-wilting progeny (breeding lines) derived from Fiskeby III and Fiskeby V. These are the first slow-wilting progeny derived from Fiskeby varieties in the Southern USA and provide valuable new genetic resources for applied drought tolerance research. All 12 were substantially slower wilting than the adapted parent Holladay, a maturity group (MG) V variety. Fiskeby III and Fiskeby V are MG 0 and earlier. These lines were developed by the bulk breeding method.  **New Discovery** **of New Southern Slow-Wilting Breeding Lines derived from three Chinese Soybeans PI 587696, PI 587563B, and PI 567596 – more new genetic resources in the war on drought.** USDA researcher Carter in North Carolina identified the PIs above as slow wilting in earlier research funded by USB and used them in applied breeding efforts. This summer at the Sandhills Research Station, he identified 19 slow wilting progeny from these exotic Chinese introductions. These are the first slow wilting progeny derived from these introductions in the Southern USA. They provide valuable new genetic resources for applied drought tolerance breeding. All 19 were substantially slower wilting than the adapted parent NC-Roy. These breeding lines were developed by the bulk breeding method.  **Commercial Varieties Successfully rated for canopy wilting in KS, MO NC, and SC.**  Commercial varieties were rated in SC and NC in early September for canopy wilting, and earlier in the summer at KS and MO in replicated trials. Public materials included as checks in these trials generally looked more desirable than commercial materials in terms of wilting score. However, some commercial varieties also exhibited the slow-wilting trait. Results will be reported along with yield data, in later reports.  **Eight New Slow-Wilting adapted genotypes developed in South Carolina, Missouri, and Arkansas**. New adapted breeding lines were identified from the South Carolina (2) Missouri (2) and Arkansas (3) breeding programs. Agustina, a variety recently released by South Carolina, was also identified as slow wilting. The origin of the slow wilting trait in Augustine is not clear. The breeding lines are derived primarily from PI 416937 and PI 471938. These new highly-adapted materials are potential breeding stocks for commercial breeding.    **Six USDA breeding lines validated as slow wilting in North Carolina.** Canopy wilting evaluation at the Sandhills Research Station confirmed that six adapted USDA breeding lines are slow wilting. These lines trace their pedigree not only to the well known and widely used PIs 471938 (from Nepal) and PI 416937 (from Japan) and domestic breeding line NTCPR94-5157, but also to new genetic resources PIs 407948 (from Korea), and PI 471931(from Nepal) and adapted breeding line. These new materials constitute new highly-adapted breeding resources for commercial breeding.  **Research Highlights for previous quarter:**  **New germplasm identified. Nguyen, MO.** Collaborative research efforts at the University of Missouri and the Kansas State University identified 12 new slow wilting lines from MGs III to V. These lines have good agronomic performance (low lodging, low shattering and acceptable yield). Yield advantages of these lines under drought condition are being confirmed at multiple locations (MO, KS and AR).  **Benefit of slow-wilting trait on yield under drought confirmed**. **Nguyen, MO.** Collaborative research efforts at the University of Missouri and the Kansas State University confirmed the slow wilting trait can protect yield by14% by comparing 46 recombinant inbreed lines with contrasting canopy wilting phenotypes.  **A new gene controlling root length density was cloned.** **Nguyen, MO.** Collaborative research efforts at the University of Missouri and the Kansas State University cloned a novel gene promoting root length density. This gene can protect yield by 18% under light drought stress and by 40% under severe drought stress. Currently, this gene is being incorporated into an elite line by marker assisted backcrossing.  Phase 1. Farmers need documented performance data for  commercial varieties under drought.  **Task 1a. Annual screening of commercial varieties in maturity groups III through VIII for yield and slow wilting under stress.**  **Chen June 2018** 1*) Evaluation of**commercial varieties in Missouri for slow wilting*: A set of 89 commercial varieties developed by different seed companies will be evaluated for canopy wilting at our drought site with very sandy soil in Clarkton. The entries have been planted in single 7-ft row plots in 3 replications in rainfed (dryland) condition and wilting data will be collected when drought occurs.  **2)** *Selected Missouri commercial varieties for yield and wilting evaluation*: 34 MG 4 and 14 MG 5 commercial varieties (approx. 2 entries selected from each company) have been planted in 2-row plots with 3 replications under dryland condition for wilting and yield evaluation in Clarkton. The same tests have also been planted under irrigated condition for yield evaluation on Lee Farm. Yield retention index will be calculated using irrigated and non-irrigated yield data.  **Chen September 2018**  *Evaluation of**commercial varieties in Missouri for slow wilting*: 89 commercial varieties were evaluated for canopy wilting at our drought site on very sandy soils near Clarkton, MO. Six of these 89- Agrigold G5288RX, AGS GS51X17S, Credenz CZ 4820 LL, FS HiSoy 43X60, Terral Seed 4857X and S14-9051R (all from different companies) exhibited a favorable wilting tolerance score of ‘1’ on a scale of 1 to 5.  *Selected Missouri commercial varieties for yield and wilting evaluation*:  34 Maturity Group (MG) 4 and 14 MG 5 varieties (from 11 companies) were evaluated for canopy wilting data in replicated trials and these data will be reported along with other agronomic evaluations in the December 2018 report.  **Carter June 2018.** *Screening Commercial Varieties for wilting trait in North Carolina.* On May 31, we planted a total of 150 commercial varieties plus checks in 4-rep tests at the drought-prone Sandhills Research station in NC. These varieties span early group V to late Group VI. Emergence was good.  **Carter September 2018.** In early September (ahead of the arrival of hurricane Florence), all 150 commercial varieties were rated successfully for wilting at the Sandhills research station. Data are being compiled.  **Schapaugh June 2018.** *Screening Commercial Varieties for wilting trait in Kansas*. We planted 75 commercial varieties (plus checks) spanning maturity groups 3, 4 and 5 on May 24 at our drought site in Salina. These trials included varieties from 14 companies.  **Schapaugh September 2018.** *Screening Commercial Varieties for wilting trait in Kansas.* We took advantage of this environmental stress and evaluated wilting response in commercial yield trials at five locations (including Salina). The number of commercial entries ranged from 29 near Pittsburg, to 75 near Salina. Depending upon the location we captured from 1 to 4 wilting ratings at each location, at growth stages ranging from R2 to R5.8. In addition to the commercial entries, we had Uniform Test trials at four of the five locations, and took wilting ratings on the maturity groups 3, 4, 4s and 5 trials near Onaga, Ottawa, McCune and Pittsburg,  **Mozzoni June 2018.** *Screening Commercial Varieties for wilting trait in Arkansas.* We are screening 56 MG IV and 45 MG IV commercial varieties in Stuttgart, AR in three replications. These materials were selected on the basis of their inclusion in the 2018 Arkansas State Variety Test. Yield and wilting data will be recorded.  **Mozzoni September 2018.**  We had a very dry June and early July, with weather turning more favorable for crop development in late July and August. We were able to collect wilting data only once in early August, and we are currently analyzing it. Overall symptoms were mild. Preliminary analysis of commercial varieties is indicating a very high environmental component of variance for this year’s trials (Coefficient of variation of 28% and LSD of 14 points for MG4 test, and a CV of 21%, and LSD of 12 percent points for MG5 test. We observed a min of 15%, mean 25%, max 35% wilting for entries in MG4, and a min of 20%, mean of 28% and max 37% wilting for entries in MG5). All this is to say that there is very little separation among lines this year. This is disappointing and could be the result of the unusual environment (drought was pronounced early in vegetative stages), coupled with a new, less experienced rater performing field scorings in 2018.    **Fallen June 2018.** *Screening Commercial Varieties for wilting trait in South Carolina.* It has been a very wet May in South Carolina and little planting occurred until June. For 2018, the commercial drought screening in Florence, SC includes four replicated tests based on maturity group. They are: **Maturity Groups 5 Early** (17 varieties); **Maturity Group 5 Late** (17 varieties); **Maturity Group 6** (29 varieties); and **Maturity Group 7&8** (21 varieties). These varieties are included in the 2018 official variety test conducted by Clemson University.  **Fallen September 2018.**  Many farmers in SC planted their soybean crop late this year due to wet conditions in May. Then in June, SC experienced 19 days without any measurable rainfall, making soybean planting especially difficult until late June, when most of the soybeans were ultimately planted. Then rain became abundant until August 20. By late August and early September, we experienced late season drought stress and a heat index in the triple digits so that, in the end,we collected good notes for drought screening at Florence, SC.  This year, we were able to take wilting notes on all plots on each of two days. The commercial stress test was rated for wilting on August 27th and September 3rd. Visually, differences between the lines were obvious. These data is in the process of being transferred to a computer, and we plan to combine them with the yield and other agronomic data after harvest. Because this material is also being grown under irrigation, the conclusions we are able to make should be very insightful. The most interesting observation from the commercial wilting tests this year was how poor some commercial varieties looked under stress as compared to irrigation. The new variety maturity group VI variety NC-Dilday appeared unusually susceptible to drought.   |  | | --- | | **Phase 2. *Farmers need new drought-tolerant breeding stock.***  **Task 2a.** **Yield testing and release of new publicly-developed drought-resistant breeding lines.** |   **Task 2a.** **Yield testing and release of new publicly-developed drought-resistant breeding lines. Task 2b.** **Impact of the Slow-Wilting trait and other drought tolerance traits on seed yield under drought stress and high yielding conditions.**  **Mozzoni June 2018.** *The drought-tolerance breeding pipeline in Arkansas.* A total of 10 advanced drought tolerant breeding lines are being evaluated in droughted and irrigated companion tests at five Arkansas locations in replicated yield trials. These lines are also being tested under drought conditions at Sandhills, NC and Salina, KS in replicated trials.  A total of 32 lines are being tested in the non-replicated preliminary yield trial for drought project at four AR locations (Stuttgart, Rohwer, Marianna, and Keiser). These lines were selected from 2017 progeny rows based on their field performance. Progeny rows were planted at Stuttgart, AR and selections will be made during fall. In addition, we are advancing 9 F4, 8 F3, 12 F2, and 6 F1 breeding populations for drought project. New cross combinations to incorporate drought traits with high yield are planned for the summer.  **Mozzoni September 2018.**  A total of 15 new hybrid populations were initiated this summer  to incorporate drought traits into high yielding genetic backgrounds.  **Fallen June 2018.** *The drought-tolerance breeding pipeline in South Carolina.* This year we are hybridizing three diverse drought tolerate germplasm lines developed by Team Drought. An array of drought-tolerant F2 through F4 nursery populations are packaged and ready to plant. We plan to plant ~2,000 progeny rows related to drought tolerance in 2018. We also have three preliminary yield trials of new ‘in-house’ drought materials developed by our SC program. Additionally, we are testing collaborative trials developed by USB team members Dr. Schapaugh in Kansas and Dr. Carter in North Carolina. In total, we are testing 250 lines and 1,000 plots for yield under drought.  **Fallen September 2018.**  All plots were planted by the end of June. We were able to take wilting notes on all material in late August and again in early September. Plots exhibited a wide range in wilting (very little to moderate to moderately severe), and we were able to identify easily some very fast wilting lines, that were consistent across tests and locations. Some of the newly developed SC breeding materials developed for drought tolerance, appeared slow wilting in both SC and NC. This parentage of this material was USDA N8002 (slow wilting) x a high yielding line from Missouri. In addition, we were able to record wilting scores for some material developed by Tommy Carter in NC and Bill Schapaugh in KS. Again, some very promising lines displayed very little to no drought stress. Overall, the season indicated that some of the new breeding materials being developed may do very well under drought conditions.  **Carter June 2018.** *The drought-tolerance breeding pipeline in North Carolina.*  At the drought prone Sandhills Research Station in NC, we are testing 360 ‘in house’ breeding lines plus checks in 1520 plots for seed yield and the slow wilting trait. We are also testing an additional 45 genotypes in 180 plots for USB collaborators Fallen and Mozzoni. In addition to yield plots, we are also growing smaller replicated ‘wilt only’ observation plots (3 row wide and 6 feet long) for USB collaborators Chen, Li, and Schapaugh (a total of 219 genotypes in 867 plots). An extensive nursery of F2 plants, F4 plants, and F4-derived progeny rows are also being grown this summer. Elite drought tolerant lies will be hybridized in our ‘crossing block’ in late July.  **Carter September 2018.** After a wet summer, the Sandhills research station developed substantial drought in several fields in early September, allowing us to take canopy wilting notes on approximately 70% of our 40 acres of plot work. The remaining plots were inundated by hurricane Florence before sufficient wilting could develop for note taking. Collaborative tests from Kansas and Missouri were too advanced in terms of maturity to obtain accurate estimates of canopy wilting. However, Collaborative trials from SC and AR, were successfully along with 1 of 2 tests from GA. Regarding breeding lines from SC, SC17-DRC-23 and SC17-DRC-23, were identified as slow wilters. Both lines had the new slow-wilting USDA variety N8002 in their pedigrees. The newly released variety from SC, Agustina was identified as slow wilting in the commercial Group VII trials. In the Arkansas collaborative trials, 3 adapted Arkansas breeding lines were identified as very slow wilting- R15-7510, R16-3989, and R16-3998. In the Missouri collaborative trials, two adapted breeding lines were identified as slow wilting- S14-1604 and S15-1043C. S14-6404 was also identified as slow wilting in trials in MO in 2018. In the GA collaborative trials, 12 plant introductions (PIs) were confirmed as slow wilting. These PIs are primarily from China. Evaluation of USDA breeding lines at Sandhills in 2018 confirmed the slow-wilting nature of 6 adapted breeding lines (N05-7380, N06-7363, N09-138980, N10-7277, N10-7412, and N11-10295) which in the aggregate trace to PIs 416937, 471931, 471938, 407948 and adapted breeding line NTCPR94-5157.  **Schapaugh June 2018.** *The drought-tolerance breeding pipeline in Kansas.*  Over 2000 Kansas State-developed breeding lines are being tested in replicated plots from three to five locations to evaluate response to drought. In addition, fifteen, F4 populations from drought tolerant germplasm were planted in May. Our F2 drought populations are being harvested in Puerto Rico, and will be planted as F3s in June. About 3000 F4:5 lines from populations developed using drought tolerant germplasm were planted in May in progeny rows. Our drought prone site near Salina was planted on 24 May 2018. Over 680 genotypes are being evaluated at this site in replicated experiments. About 380 experimental lines and plant introductions are being evaluated for wilting only to assist USB team members (Carter – 140 entries; Li – 160 entries; Schapaugh – 30 entries; Fallen – 15 entries; Nguyen and Chen – 24 entries; and Mozzoni – 15 entries). We are also evaluating a recombinant inbred population with 200 entries for Nguyen and Chen.  **Schapaugh September 2018.** *The drought-tolerance breeding pipeline in Kansas.*  Our F3 drought populations were planted in June for generation advance and initiated the development of about 10 new F1 populations in our crossing block. In July and early August, all our dryland trials experienced significant drought and heat stress, not only at our drought prone site near Salina, in central KS, but also at our locations in Northeast, East Central and Southeast, KS. We took advantage of hot, dry conditions at the end of August at Salina and on 8/31 and 9/1 we took about 2500 wilting ratings on the genotypes provided by the team members (Carter, Li, Schapaugh, Fallen, Nguyen and Chen, and Mozzoni).  **Li June 2018**. *The drought-tolerance breeding pipeline in Georgia.*  We have developed nine near-isogenic lines (NILs), which carry various QTL for slow canopy wilting and fibrous root traits derived from PI 416937. These lines will planted in Athens, GA for QTL confirmation, evaluation and seed increase this year. In 2017, we evaluated an RIL population for root architecture using a peanut inverter and imaging system. The data are still being analyzed. We also plan to develop four populations in this summer using four top slow-wilting lines that we identified from our previous study. The populations will be used for mapping new canopy willing QTL and developing enhanced germplasm.  **Li September 2018**. *The drought-tolerance breeding pipeline in Georgia.*  The nine near-isogenic lines (NILs) derived from PI 416937 which carry various QTL for canopy wilting and fibrous root traits are currently under evaluation for confirmation of QTLs, agronomic performance, and seed increase at Athens. Top performing lines in these tests may be advanced to regional testing for potential release as commercial drought resistant cultivars. Selected NILs will be genotyped with 50k SNP chips. In this quarter, the efforts have been toward upkeep of research plots and preparing for harvest. In 2017, we evaluated a RIL population for root architecture using a peanut inverter and imaging system. The data are still being analyzed.  **Chen June 2018**. *The drought-tolerance breeding pipeline in Missouri.*  *i) Yield evaluation of newly released and promising lines*: We are evaluating 15 maturity group (MG) 4 and 11 MG-5 high yielding lines along with checks for slow wilting and yield under rainfed (dryland) conditions at Clarkton. The tests were planted in 4-row plots in 3 replications. The same tests have also been planted at our irrigated field on Lee Farm. A drought yield index will be estimated using the non-irrigated and irrigated yields. *ii) Progeny row testing:* F4:5 progenies from 7 drought breeding populations with approximately 150 lines each will be planted soon in single plant progeny rows under irrigated conditions at Lee Farm for visual selection at maturity. The selected rows (lines) will be evaluated for slow wilting and yield in 2019. *iii) New crossing plan*: 10-15 new crosses will be initiated in which high yielding elite breeding lines and mated to breeding lines which exhibit slow wilting and/or superior yield under drought. *iv) Yield evaluation of contrasting wilting lines and PIs*: A set of 52 contrasting accessions (28 RILs, 4NILs, 12 PIs, 4 breeding lines and 4 checks) will be evaluated for canopy wilting and yield. The test has been planted in 2-row plots with 3 replications under rainfed and irrigated conditions. The most highly contrasting slow-wilting and fast-wilting lines will be selected and be tested for yield under both rainfed and irrigated conditions in 2019. A relation between slow wilting trait and yield under drought stress will be evaluated.  **Chen September 2018**. *The drought-tolerance breeding pipeline in Missouri.*  *Yield evaluation of newly released and promising lines*:  Sets of 15 MG IV and 11 MG V breeding lines along with checks for each MG for slow wilting and yield evaluation have been planted in rainfed (Clarkton) ) and irrigated conditions ) Lee farm) in replicated trials. Wilting scores were recorded on the dryland plots. In the group IV set, only 4 entries- S14-1625, S14-6205, RIL #118 and PI 458515 (drought tolerant check)- showed a favorable wilting score. In the Group V test, only 5 entries, S14-4034, S11-20124C, RIL#1360, S14-1604, and PI 567383 (Tolerant check) exhibited slow wilting. S14-1604 was confirmed as slow wilting in North Carolina trials in 2018 as well. Comparative yield and drought yield index will be presented in the December 2018 report. Comparative yield and drought yield index will be presented in later reports.  *Progeny row testing:* F4:5 breeding lines from 5 drought-related breeding populations (approximately 150 lines per population) were planted in single plant rows under irrigated conditions at the Lee Farm for visual selection at maturity. The selected breeding lines will be evaluated for slow wilting and yield in 2019.  *New crossing plan*: 12 new hybridizations have been made between high-yielding elite breeding lines and accessions which exhibited slow- wilting and/or good yield under drought. The list of the successful crosses will be presented in the December 2018 report.  *Yield evaluation of contrasting wilting lines and PIs*:  A set of 52 contrasting accessions (28 RILs, 4NILs, 12 PIs, 4 breeding lines and 4 checks) were planted under rainfed and irrigated conditions in replicated trials and rated for canopy wilting in the rainfed plots. Of 13 previously identified slow wilting RILs, only 6 RILs, (RIL027, RIL042,RIL097, RIL099, RIL122 and RIL145) showed a favorable wiling score of 1.0 to 1.7. Of 15 previously identified fast wilting RILs, only 6 (RIL026, RIL050, RIL078, RIL136, RIL223 and RIL227) exhibited unfavorable wilting scores from 3.3 to 4.7. Those RILs which were consistent over years for slow/fast wilting will be tested again for wilting and yield under both rainfed and irrigated condition in 2019. The yield data of RILs and PIs will be presented in December 2018 report.  **Nguyen June 2018**. *Incorporation of slow wilting trait into elite background:* We are incorporating major slow wilting genes and also a root length density gene into the best elite lines by marker-assisted selection. We are making BC2F1 crosses for slow wilting genes and BC4F1crosses for the root length density gene this summer.*Confirmation of slow wilting benefit for yield under drought.* Forty-six contrasting RILs were selected from two populations. Yield trials at Salina, KS and Clarkton, MO of 2017 showed that the slow wilting trait can improve yield by 14% under drought (rainfed) conditions. In 2018, these yield trials are being repeated at two locations to confirm the beneficial effects of slow wilting.  **Nguyen September 2018**.  Incorporation of slow wilting trait into elite background: two major slow wilting genes and root length density gene are being incorporated into the adapted lines by marker-assisted selection. BC2 and BC4 backcrossing were conducted this summer to develop the F1 for transferring the slow wilting and root length density gene, respectively, in the field this summer. *Confirmation of slow wilting benefit for yield under drought.* Forty-six contrasting RILs (fast *vs* slow wilting) were selected from two populations for yield trials at Salina, KS and Clarkton, MO under irrigated and rainfed conditions. The test is ongoing and the results for the impacts of SW trait on drought tolerance will be updated in the next quarterly-report.  **Locke June 2018:** *Impact of genotype and drought on seed composition and yield in North Carolina.* In 2017, we harvested 12 genotypes grown in replicated wet/dry plots at the Sandhills Research Station in NC. We found that there is high genotypic variability in yield and seed protein responses to drought, and these responses did not correlate with particular yield or protein traits under irrigation. This experiment is being repeated in 2018 using high yield, high protein, and high oil genotypes. All plots will be harvested for yield, and seed composition will be measured with NIR.  **Locke September 2018:** Stress was mild and we were not able to get wilting ratings ahead of hurricane Florence. However, we successfully irrigated the control plots several times through the growing season. All plots will be harvested and then analyzed for seed composition this fall.    **Phase 3. Farmers need basic work to support new drought-tolerant**  **variety release.**  **Task 3. Conduct basic work to support cultivar and gemplasm release**.  **Li June 2018**. *Molecular tagging of drought genes.* We visually scored canopy wilting for 130 RILs derived from Hutcheson and PI 471938 genotyped with the SoySNP6K iSelect BeadChip in repeated field experiments during drought stress in 2017 by collaborating with Drs. Schapaugh (Kansas State Univ.) and Carter (USDA-ARS). Substantial variation in canopy wilting was observed among these RILs. In addition, Two QTL were identified from PI 471938 in the RIL population for canopy wilting using composite interval mapping. The RIL population along with 24 slow wilting germplasm will be evaluated again in 2018 at three locations by collaborating with Drs. Schapaugh (Kansas State Univ.) and Carter (USDA-ARS).  **Li September 2018**. *Molecular tagging of drought genes.* The Hutcheson x PI 471938 recombinant inbred line (RIL) population and 24 additional slow wilting germplasm lines and PI accessions are currently under evaluation for drought tolerant traits at three locations in GA, KS and NC through collaboration with Dr. Bill Schapaugh (Kansas State University) and Dr. Tommy Carter (USDA-ARS). The lines were phenotyped using visual ground evaluation at all locations, with additional data being collected using a UAV to capture aerial images throughout the growing season at the GA location. This will be used to confirm previously identified QTLs using the genotypic data collected previously form the SoySNP6K iSelect BeadChip and composite interval mapping.  The creation of four new slow wilting mapping population was started this summer by hybridizing previously identified slowwilting germplasm to elite cultivars. These populations will be further developed to for use in identifying for new canopy wilting QTL that can be used to enhance germplasm.  **Locke June 2018:** *Impact of slow-wilting trait on yield and physiological responses*. To measure the impact of the ‘slow-wilting’ trait on soil moisture, photosynthesis and transpiration in the field, we planted an experiment at the Sandhills Research Station in NC on May 30 for intensive environmental and physiological measurements. Slow-wilting genotype N06-7194, which descends from PI 416937, and fast-wilting genotype NC Roy were planted in four replicates of irrigated and non-irrigated conditions. Soil moisture sensors will be installed to monitor soil water depletion in each plot at three depths, and canopy-level transpiration will be continuously monitored using infrared radiometers. Leaf-level responses of photosynthesis and transpiration to drought will be measured during dry-down periods using gas exchange. Pre-sunrise and mid-day leaf water potential will also be measured.  **Locke September 2018:** Diurnal, leaf-level responses of photosynthesis and transpiration to drought were measured on five dates during dry-down periods using gas exchange. Pre-sunrise and mid-day leaf water potential were also measured. In 2018 our differential irrigation treatment was imposed from 10 August to 14 September (ended by hurricane Florence). Additionally, low-cost cameras built from Raspberry Pi components were mounted above plots and programmed to photograph the canopy from above every 30 minutes during daylight hours. Our goal is to use machine learning to train a computer to automatically rate canopy images for wilting, which could eventually increase the throughput for canopy wilting ratings. This work is in very preliminary stages.    **Nguyen June 2018**. *Identify new drought tolerance genetic resources*: Previously, a diverse set of exotic plant introductions (PIs) (540 lines at MG III to V) were screened for slow wilting trait at Salina, KS in collaboration with Kansas State University. A total of 12 PIs (four lines from each MG), were selected for their stable performance, a low slow wilting score, and better agronomic traits. These 12 lines together with 8 sensitive checks were planted at Salina (KS), Clarkton (MO), and Stuttgart (AR) in yield plots under both non-stress (irrigated) and drought (rainfed) conditions. The lines with best yield under drought/non-stress will be selected as new germplasm lines for drought tolerance breeding. *Identify new drought tolerance genes by GWAS*: A diverse set of exotic plant introductions (PIs) (540 lines from MG III to V) were screened for slow wilting trait for three years at Salina, KS in collaboration with Kansas State University. Whole-genome re-sequencing was conducted in this set and a high-density SNP matrix (>5 million SNPs) is being validated. Once the SNP matrix becomes available, genome-wide-association-study (GWAS) will be performed to identify loci or genes associated with slow wilting trait. *Identify new drought tolerance genes by linkage mapping:* A mapping population (202 RILs) derived from the cross of S05-11482 × PI 458515 (confirmed slow wilting parent) was developed during the previous USB-supported project. This population was planted at two locations (Salina, KS and Clarkton, MO) in single row (7-ft) plots with 2 replications this summer. Phenotyping for the slow wilting trait will be performed. A genotyping plan will be set up after examination of the phenotyping data of 1st year.  **Nguyen September 2018**.  Identify new drought tolerance genetic resources: A new set of of 12 PIs at MG III to V, were selected for their stable performance of slow wilting and better agronomic traits (low lodging, low shattering, acceptable yield of >30bu/a). These 12 lines together with 8 sensitive checks were planted at Salina (KS), Clarkton (MO), and Stuttgart (AR) in yield plots under both non-stress (irrigated) and drought (rainfed) conditions. The results will be updated in the next quarterly-report.  Identify new drought tolerance genes by GWAS: The diverse set of exotic plant introductions (PIs) (540 lines at MG III to V) were screened for slow wilting trait for three years at Salina, KS in collaboration with Kansas State University. However, the data from 2017 was affected by dicamba drift. We will be repeating this test for the lines at MG IV and V again at Clarkton (MO) in 2018.  Identify new drought tolerance genes by linkage mapping: A mapping population (202 RILs) derived from the cross of S05-11482 × PI 458515 (confirmed slow wilting parent) was developed during the previous USB-supported project. Phenotyping for the slow wiltingtrait were conducted from R2 to R5 stage. The KS location had a problem of dicamba drift; however, we managed to evaluate the slow wilting trait once in the early September. Good segregation of the slow wilting trait were observed in the progenies and detailed data analysis will be updated in the next quarterly-report.  Confirm the previously identified major slow wilting genes: A set of near-isogenic lines for two major SW genes on Chr. 6 and 10 (*qSW\_Gm06* and *10*) were developed from a heterogeneous inbred line. These lines only differ in the presence or absence of the two major slow wilting genes. The preliminary evaluation in the field confirmed that these two genes can improve SW phenotype under water-limited conditions and stacking the two genes together can further slightly improve SW phenotype. We will increase and perform yield test next year**.**  **Chen June 2018**. *i) Field phenotyping of mapping population***:** A set of 202 RILs derived from the mapping population S05-11482 x PI 458515) will be phenotyped for canopy wilting. The lines have been planted in rainfed field in single 7-ft row plots with 2 replications in Clarkton. The objective is to map new slow wilting QTLs. ii) *Phenotyping exotic soybeans from genome sequencing set for slow wilting:* About 255 MG4 and 84 MG5 exotic soybean accessions have been planted in single 7-ft row plots in 2 reps under rainfed conditions. The accessions will be phenotyped for slow wilting. The objective is to identify new slow wilting germplasm and conduct GWAS analysis to identify new slow wilting QTLs. *iii) Effect of irrigation on yield of drought tolerant soybeans***:** Two drought tolerant MG5 soybean lines (R10-2436 & R10-2710) with sustained N2 fixation capacity will be compared with two commercial checks under 3 levels of irrigation – 0 irrigation, 50% of the full irrigation and 100% (full) irrigation. Seed yield, wilting, maturity, plant height and lodging will be ascertained. This part of research is in collaboration with Dr. Earl Vories, an USDA irrigation engineer at the Delta Center.  **Chen September 2018. *i)*** *Field phenotyping of mapping population***:** A set of 202 RILs derived from the mapping population S05-11482 x PI 458515 (a sow wilting accession) was scored for canopy wilting and data were sent to Dr. Henry Nguyen’s lab to conduct QTL mapping analysis. ***ii)*** *Phenotyping exotic soybeans from genome sequencing set for slow wilting :* About 339 MG4 and 84 MG5 exotic soybean accessions were evaluated for canopy wilting under rainfed field. Out of 339 accessions, only 8 PIs showed a favorable wilting score of “1” and 12 PIs exhibited a score of 1.5 on a scale of 1 to 5. The wilting score data were sent to Dr. Henry Nguyen’s lab for compilation and genetic analysis. The PIs exhibiting a wilting score of “1” were PI 567648C, PI 092651, PI 091132-3, PI 567675, PI 424079, PI 416768, PI 632747 and PI 594661. These PIs may be useful in our future hybridization program. **iii)** *Effect of irrigation on yield of drought tolerant soybeans****:*** Two drought tolerant MG5 soybean lines (R10-2436 & R10-2710) exhibiting sustained N2 fixation capacity, along with two commercial checks were planted under 2 levels of irrigation – 0 irrigation and 100% (full) irrigation. Drought stress in this trial was mild over the growing season. Data on seed yield, wilting, maturity, plant height and lodging will be collected. This part of research is in collaboration with Dr. Earl Vories, an USDA irrigation engineer at the Delta Center.  **Burkey June 2018**. *Increased water use efficiency derived from Fiskeby soybean types.* Recent research has revealed that the Swedish variety Fiskeby III has an improved water use efficiency, called intrinsic water use efficiency. We have developed numerous MG 5 lines by hybridizing the USDA variety Holladay with Fiskeby III and Fiskeby V. 100 of the Fiskeby V-derived lines were evaluated for yield in 2017, and the top 20 are being –re-evaluated for slow wilting at the Sandhills Research Station in replicated plots in 2018. In addition, we are evaluating 100 lines derived from Fiskeby III for the slow wilting trait at Sandhills. Any lines which exhibit the slow wilting trait will be examined for water use effficiency as well. All lines derived from the Fiskeby materials are also being yield tested at other NC sites. These preliminary studies should pave the way for a more detailed study of the enhanced water use efficiency trait.  **Burkey September 2018**. *Increased water use efficiency derived from Fiskeby soybean types.* Validation studies show that the water use efficiency of Fiskeby III and Fiskeby V under greenhouse conditions is higher than several other plant introductions (Fiskeby 840-2-7, Fiskeby 840-7-3, and Traff) developed by the breeding program in Fiskeby, Sweden. Fiskeby 840-7-3 exhibited the lowest water use efficiency of the Fiskeby types tested. This finding correlates with differences in ozone tolerance for these genotypes, linking water use efficiency and ozone tolerance through a mechanism involving leaf conductance. This greenhouse study confirmed that Fiskeby III and Fiskeby V are good sources of the water use efficiency trait. In other field work, 120 breeding lines (maturity group V) derived from either Fiskby III or Fiskeby V were evaluated for the slow wilting trait at Sandhills in replicated trials, just prior to the arrival of hurricane Florence. Approximately 7 of the 120 appeared to be slow wilting. Because Fiskeby III and Fiskeby V are slow wilting as well as water use efficient, we are using wilting scores to identify progeny likely to carry the water use efficiency trait. These slow wilting breeding lines will be evaluated for wilting, water use efficiency, and agronomic traits in follow up trials. | |