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| Project Number:  | USB #1820-172-0118-C |
| Project Title:  | Yield potential of commercial varieties under drought- identifying and overcoming weaknesses through public breeding advances (Year 1 of 3)Project Duration: Oct. 1, 2017- Sept. 30, 2018 |
| Organization:  | USDA-ARS |
| Principal Investigator Name: | Thomas E. Carter, Jr. |
| Project Status - What key activities were undertaken and what were the key accomplishments during the life of this project? Please use this field to clearly and concisely report on project progress. The information included should reflect quantifiable results (expand upon the KPIs) that can be used to evaluate and measure project success. Technical reports, no longer than 4 pages, may be included in this section.  |
|  Farmers need help with drought. This research was designed to help the farmer in 3 phases. 1) Farmers need documented performance data for commercial varieties under drought. We will yield test commercial varieties in multiple states in maturity groups III through VIII at drought prone sites. Results will aid farmers with variety choices and guide new public-private breeding efforts to fix the drought problem, 2) Farmers need new drought-tolerant breeding stock so that commercial breeding programs can develop better drought-tolerant varieties. The nine public soybean scientists in this project have a wealth of advanced drought-tolerant materials in their breeding pipeline. New materials will be evaluated and released to commercial breeders based on yield performance under drought. 3) Farmers need basic work to support new drought-tolerant variety release. This basic work encompasses genome wide association mapping and physiological investigation of the slow canopy wilting trait. **Research Highlights:****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.**New Group V Germplasm Releases in AR:** In late 2017, the University of Arkansas released two high-yielding, drought-tolerant germplasm lines, R10-2436 and R10-2710. During six years of evaluation under moderate drought stress, R10-2436 yielded 48.2 bu/ac and R10-2710 produced 46.5 bu/ac as compared to the maturity group V check mean of 41.7 bu/ac. in Stuttgart, AR. Both lines carry the prolonged N-fixation trait as one mechanism of tolerance under drought. The registration of these two releases has been accepted by the Journal of Plant Registrations (Manjarrez et al, 2018. See pub list). **Commercial Soybean Varieties Screened for Drought Reaction in Multi-state Trials in 2018.** USB team drought members coordinated with State Variety Trials to screen more than 100 commercial varieties for drought response in NC, SC, AR, KS, and MO. It was a very wet summer overall, but 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, after the 2018 harvest is complete.**Coordination and Exchange of Public Breeding Materials for Drought Tolerance Testing in 2018.** Researchers in NC, SC, and KS opened up their drought-prone field sites for collaborative screening trials in 2018. Physiologists Kent Burkey and Anna Locke, plus soybean breeders Ben Fallen, Lenado Mozzoni, and Zenglu Li tested their materials with Tommy Carter at the Sandhills Research Station in NC. Carter and Li tested their materials at the Clemson Station at Florence with Ben Fallen. Soybean breeder Bill Schapaugh at K-State conducted drought trials at his drought prone sites for most of the other team members including Carter, Li, Nguyen, and Chen.**New Asian Slow Wilting Germplasm Identified in GA.** Researchers at the University of Georgia (in collaboration with Kansas State Univ. and USDA-ARS at Raleigh) identified 10 new Asian soybean types possessing the slow canopy-wilting trait. 200 exotic soybean types were evaluated over four rainfed environments to identify the new genetic materials. The new sources of the slow-wilting trait identified through this research (primarily Chinese accessions) expand our capability to improve drought tolerance in soybean varieties. Results were submitted as a refereed journal article to Frontiers of Science (Steketee et al, 2018. See pub list)**New slow wilting breeding lines identified in Kansas and Missouri.** 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). **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 super-early maturing 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 new slow-wilting progeny (breeding lines) derived from Swedish varieties Fiskeby III and Fiskeby V. These southern maturity breeding lines are the first slow-wilting progeny derived from Fiskeby varieties and provide valuable new genetic resources for applied drought tolerance research. At the Sandshills Research Station in NC, 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.**Discovery** **of New Southern Slow-Wilting Breeding Lines derived from three Chinese Soybeans PI 587696, PI 587563B, and PI 567596 – 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.**USDA in NC develops slow-wilting breeding lines from Korean PI 407948 and Nepali PI 471931 - new genetic resources in the war on drought.** Canopy wilting evaluation at the Sandhills Research Station confirmed that six new adapted USDA breeding lines are slow wilting. These lines trace their pedigree not only to the well known and widely used PI 471938 (from Nepal) and PI 416937 (from Japan) and domestic breeding line NTCPR94-5157, but also to two new genetic resources PIs 407948 (from Korea), and PI 471931(from Nepal). These new materials constitute important new highly-adapted breeding resources for commercial breeding.**Eight New Slow-Wilting adapted breeding stocks 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. **The physiology team initiates an in-depth investigation of the relation between slow-wilting responses and field environmental conditions.** Scientist Anna Locke (USDA-ARS in NC) showed that growers could see more or less benefit of the “slow-wilting” genotypes, depending on the severity and duration of drought. Furthermore, response of slow-wilting genotypes in the field environment is not identical to responses found in greenhouse and growth chamber studies. These findings emphasizes the need for further investment in field-based physiology research, to correctly understand and efficiently use drought-related traits in the development of drought tolerant soybean cultivars. **Benefit of slow-wilting trait on yield under drought confirmed**. Collaborative research efforts at the University of Missouri and the Kansas State University confirmed that the slow wilting trait can increase yield 14% under moderate drought stress by comparing 46 recombinant inbreed lines which had contrasting canopy wilting phenotypes. **A new gene controlling root length density was cloned.** Collaborative research efforts at the University of Missouri and the Kansas State University cloned a novel gene promoting root length density. Preliminary results suggest that this gene may increase yield by 18% under moderate drought stress and by 40% under severe drought stress. Currently, this gene is being incorporated into an elite line by marker assisted backcrossing.  |
| Did this project meet the intended Key Performance Indicators (KPIs)? List each KPI and describe progress made (or not made) toward addressing it, including metrics where appropriate.  |
| * At least one commercial breeder visits our commercial drought performance trials to personally evaluate commercial varieties during the 2018 growing season, assuming that drought and canopy wilting develop. We did not obtain sufficient wilting over the wet summer to warrant visits by commercial breeders.
* At least 5 farmers visit at least one of our commercial drought performance trials to personally evaluate commercial varieties during the 2018 growing season, assuming that drought and canopy wilting occur. We did not obtain sufficient wilting over the wet summer to warrant visits by farmers.
* At least one company assists this project in evaluating new public breeding lines during the 2018 growing season. We were not able to develop signed MTAs before planting season in 2018, but will have these in place before planting in 2019.
* At least one new drought tolerant germplasm is released by the end of 2019.

See publication list. Arkansas released 2 drought tolerant germplasm lines: 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* At least one drought-tolerant commercial variety is identified and communicated to farmers in 2019, assuming that drought and canopy wilting occur. NA because project terminated before 2019.
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| Expected Outputs/Deliverables - List each deliverable identified in the project, indicate whether or not it was supplied and if not supplied, please provide an explanation as to why. |
| * Preliminary report on yield performance of commercial cultivars by the end of year 2 and an expanded report at the end of year 3. NA because project terminated before year 3
* Release of at least one new germplasm by the end of year 3.

Arkansas released 2 drought tolerant germplasm lines: 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* Quantification of the impact of the slow-wilting trait on seed yield under stress in year 3. NA because project terminated before year 3. Summer drought stress was insufficient to make this determination in 2018.
* Quantification of the impact of drought and the slow-wilting trait on seed protein content under stress by the end of year 3. NA because project terminated before year 3. Summer drought stress was insufficient to make this determination in 2018.
* Completion of a GWAS study on slow wilting by year 3. A manuscript has just been submitted on this work (Sketee et al, 2018, see pub list.)
* Backcrossing at least one generation of QTLs into elite varieties using MAS in year 3. NA because project terminated before year 3. However, the first year of backcrossing a slow wilting gene was initiated in GA.
* Quantification of phenotypic data for QTL mapping for slow-wilting by the end of year 3. NA because project terminated before year 3. However, this work was initiated in 2018.
* Complete the survey of drought tolerant breeding stock for intrinsic water-use efficiency and report results by the end of year 3. Identify high- and low- intrinsic water-use efficiency progeny from Fiskeby III by the end of year 3. NA because project terminated before year 3. However, we did accomplish he first step in this process by identifying 12 slow wilting breeding lines derived from early maturing Fiskeby III and Fiskeby V. The Fiskeby types are a source of intrinsic water use efficiency.
* Report on the drought threshold for slow-wilting trait advantage by the end of year 3. NA because project terminated before year 3. This work was initiated in NC in 2018, but summer drought stress was not sufficient to answer the question.
* Report on the relations between photosynthesis, leaf water potential, and slow wilting by the end of year 3. NA because project terminated before year 3. This work was initiated in NC in 2018, but summer drought stress was not sufficient to answer the question.
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| Describe any unforeseen events or circumstances that may have affected project timeline, costs, or deliverables (if applicable.) |
| 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.  |
| What, if any, follow-up steps are required to capture benefits for all US soybean farmers?Describe in a few sentences how the results of this project will be or should be used. |
| A new project funded by USB was initiated Oct. 1, 2018 to build on this expiring project. Field plots planted under the expiring project in the spring of 2018 are being harvested under the new project in the fall of 2018. |
| **List any relevant performance metrics not captured in KPI’s.** |
| **The drought team submitted****9 publications and made 11 presentations.****PUBLICATIONS:**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. 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 SCIENCEManjarrez-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.13333Clinton J. Steketee, William T. Schapaugh, Thomas E. Carter Jr., and Zenglu Li. 2018. Genome-Wide Association Analyses Reveal Genomic Regions Controlling Canopy Wilting in Soybean. Frontiers in Plant Science (submitted October 29, 2018)**PRESENTATIONS****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, 2018Steketee, 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.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**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;  |