Summary of Breeding Efforts to Expand Genetic Diversity for Yield

Soybean Breeders' Workshop, February 2011

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This report focuses solely on using exotic germplasm for increasing yield and not for disease resistance, abiotic tolerance, or quality traits. Some of the reports that I received contained that information but I did include those data in this report. Several scientists also reported on research to map yield QTL from exotic germplasm. Although this is related to the topic, this information was not requested. Reporting on the received data would not provide an accurate account of this category of research, so that information is also not included.

The following breeders provided information on their breeding efforts to expand genetic diversity to increase yield and the second column is their estimate of percentage of their breeding program devoted to this objective.

Breeder	% breeding effort for introducing new genetic diversity for yield
Roger Boerma, University of Georgia	15 to 20
Tommy Carter, USDA-ARS, NCSU, Raleigh	90
Pengyin Chen, University of Arkansas	5
Kerry Clark, University of Missouri	20
Elroy Cober, Agriculture and Agri-Food Canada, Ottawa	3
Brian Diers, University of Illinois	15
Rouf Mian, USDA-ARS, Wooster, OH	10 to 15
Randall Nelson, USDA-ARS, University of Illinois	95
J. H. Orf, University of Minnesota	20
Vince Pantalone, University of Tennessee	10
Vaino Poysa, Agriculture Canada, Harrow, Ontario	5
Istvan Rajcan, University of Guelph	10 to15
Grover Shannon, University of Missouri Delta Center	30
Rusty Smith, USDA-ARS, Stoneville, MS	30

Below I have summarized the answers to specific questions that I obtained from the respondents. In some cases when I considered it informative, I identified people with their specific answers but in most cases I have reported summaries from a compilation of all of the information that I received.

1. **How are you choosing exotic material for parents and do you have any insights to share about successful selection? What sources of exotic germplasm are currently active in your breeding program?**

   Programs are using a variety of data sources to select parents. For the breeding objectives of increasing yield per se, selection of the plant introduction parent is almost exclusively for good agronomic traits, primarily high yield. Other selection criteria are important for programs that are combining other traits with yield. Roger Boerma has crossed with an introduction with high canopy photosynthetic capacity. Data used to select parents include Soybean Asian Variety Evaluation (SAGE) and Soybean Asian Germplasm Evaluation (SAGE) Tests, other Japanese and Chinese varieties, European varieties, experimental lines derived from exotic germplasm developed in other programs, selections based on germplasm evaluation data from the USDA Soybean Germplasm Collection, and local germplasm tests.

No one reported that any one parental selection method was highly superior to others and success has been achieved with many different parental sources. Selecting for high yield and good agronomic characteristics within other gene pools does not seem to be selecting for the same alleles as in the currently used North American gene pool but the definitive data on that is still not available.

Improved lines and heterogeneous populations with exotic pedigrees developed by some programs are important sources of diversity for several programs. Not everyone provided a detailed list of exotic lines used as parents so I will not itemized the specific accessions being used. It is significant that there were 165 PIs cited in the reports and that number is not an exhaustive list of the material being used. Among the 165 PIs, there 22 *G. soja* accessions reported being used by Tommy Carter, Roger Boerma, and Randy Nelson, and Randy Nelson has yield tested lines derived from 1 accession of *G. tomentella*. This collective breeding program is an enormous resource for soybean breeding to expand the genetic base of North American production and can make available to other breeders highly productive lines with diverse pedigrees.

2. Are you handling populations with exotic germplasm different than domestic by domestic populations and if so why and how?

The need for altered breeding methods depended on the source of exotic material and the specific breeding program. Those using released cultivars from breeding programs in other countries or experimental lines developed from exotic lines by other North American programs are generally using standard breeding procedures.

For populations directly from exotic by domestic crosses, Tommy Carter uses bulk breeding in the F_2 and then visual selection in the F_3. His conclusion is that population sizes needed for these crosses are too large to be practical for SSD, but SSD is the best method one or two generations removed from PIs.

Pengyin Chen handles populations with exotic germplasm in the same way as domestic _ domestic populations, but lowers his selection intensity. In addition, using a larger population with mass selection in early generations appeared to be effective in getting rid of the inferior types in the progeny.

Roger Boerma grows F_2 populations with 5,000 to 6,000 plants to select an adequate number of plants for yield testing that do not shatter and are resistant to bacteria pustule. Selection for non-shattering and resistance to pustule continues on a single plant basis until F_5 and finally in progeny rows. His goal is to yield test 150 to 200 lines per population.

Jim Orf also creates larger populations for domestic x exotic populations than domestic x domestic and tries to maintain larger populations through to plant rows. He also keeps a larger percentage of exotic lines and is less stringent on seed quality and protein and oil minimums for lines to remain in the breeding program.

Vaino Poysa places less selection pressure on yield and assumes that several rounds of selection and crossing with adapted lines will be needed.

Randy Nelson uses an early generation testing procedure that begins with approximately 1000 F_2 plants with 20 to 40 plants per cross selected for one row yield tests in the F_3. Selected F_3 lines are tested in replicated, bordered plots and 20 to 40 single plants are advanced to one row yield tests from the selected $F_{3:5}$ lines. Pedigrees and yield are considered in making selections.

Rouf Mian is making crosses with MG II and III elite lines from Ohio and MG IV to VII lines with exotic pedigree from Drs. Shannon, Chen, and Boerma. These crosses create opportunity to combine yield genes from north, south, and exotic sources.

Grover Shannon also creates larger populations for exotic x domestic crosses. If there is a large difference in maturity, he will not select single plants until the F_6 generation.

3. What are your biggest challenges to success?

The most common problems reported were selecting lines that are competitive with progeny from elite crosses especially in populations with a high percentage of exotic pedigree, maintaining sufficiently large populations of lines that are suitable for yield testing with acceptable agronomic traits, disease resistance and proper maturity, and not having enough resources. There was an expressed concern about how to select exotic parents and identifying derived progeny with different alleles than are already present in the currently used gene pool.

4. **Who do you view as the consumer of your improved lines and are you doing anything to actively promote these lines as either germplasm or varieties**?

Breeders in private industry, breeders at public institutions and soybean growers we all equally listed as the primary consumers of the products of these breeding programs. Many programs are focusing on developing cultivars as well as germplasm releases from exotic germplasm. Some see other scientists who are interested in the genetic and physiological basis of yield as an important clientele.

5. What, if any, additional collaborations that would be helpful for you?

Most of the needs were for additional cooperation in testing of experimental lines. In some cases specific environments are needed to evaluate for stress or disease. Some would like to partner with private industry in testing lines or to help education graduate students in breeding with exotic germplasm. There was one suggestion for a test similar to the Uniform Tests specifically for exotic derived lines. Several respondents were interested in exchanging material with other breeders and/or stressed the importance of keeping strong public programs that will develop high yielding lines from exotic germplasm. Several respondents concluded that current levels of collaboration were sufficient. If anyone is interested in testing exotic-derived lines or would like to exchange such breeding material, I would encourage you to contact any of the respondents to explore those possibilities.

6. Do you anticipate that your use of exotic germplasm for seed yield will increase, decrease or stay the same in the future?

Four respondents indicated that their effort in breeding for increased yield using exotic germplasm will increase, two said they might increase slightly, and eight will remain the same. No one indicated that they would reduce their effort in this area.

7. Below are examples of successful outcomes from the past 3 years where the respondents provided specific data on the performance on cultivars and experimental lines derived from exotic germplasm.

Roger Boerma released the MG VII cultivar "Woodruff". In tests over 45 locations in the Southern Uniform Tests Woodruff (56.7 bu/a) yielded significantly more the Benning (49.6 bu/a). Woodruff has a 25% exotic pedigree with PI 416937 as a grandparent. He has also developed two MG VII breeding lines,

G07-6012 and G07-6029, from N7103 x PI 366123, a *Glycine soja* accession. Both of these breeding lines yield within 85% of their max parent, N7103.

Pengyin Chen has released three germplasm lines with 50% PI parentage: R99-1613F (NKRA452 x PI290126B), R01-2731F (Caviness _ PI 592947), and R01-3474F (Caviness _ PI 594208). These germplasm lines have shown yield ranging from 97 to 101% of the check cultivars in regional testing. He assumes that PI 594208 and PI 592947 are contributing favorable yield alleles since both R01-3474F and R01-2731F yield at least 3 bu/ac greater than Caviness in most tests.

Randall Nelson released LG04-6000, which has 13% exotic pedigree and was derived from Jilin 15 (PI 436682). Average over 22 locations in 2007 Prelim and 2008 Uniform IV test, LG04-6000 yielded significantly (0.05) more than LD00-3309 (59.1 compared to 54.7 bu/a), the highest yielding check. At 15 locations in the 2010 Uniform IV test, LG06-5798 (LG00-3372 x LD00-3309) yielded significantly (0.05) more than LD00-3309 (57.1 compared to 53.7 bu/a). The parents of LG00-3372 are PI 561319A and PI 574477. At 11 locations in the 2010 Prelim III test, LG07-2309 (IA3023 x LG01-7728) (61.8 bu/a) equaled the yield of IA3023 (61.8 bu/a) and IA4004 (61.3 bu/a). LG01-7728 is a BC1 line with Williams 82 as the recurrent parent and the *G. soja* accession PI 479676 as the donor parent.

Jim Orf released a germplasm line M01-242025 (MN0302 x PI 495831). In addition to competitive yield it has the *Rps-1k* gene for phytophthora resistance, good iron chlorosis tolerance and slightly better than average protein and oil concentration.

Vaino Poysa has released 3 cultivars with Japanese parentage. "Tourco" has Honiku 65 in the pedigree, "Nature" has Raiden and Enrei in the pedigree and OX-101 is 25% Toyomusume and 3% Enrei.

Grover Shannon developed S07-3666 with a 50% exotic pedigree from PI 427099 and PI 445830. Over 6 environments in southeast Missouri, it yielded 63.3 and 62.9 on loam and clay, respectively, compared to AG4703 at 67.1 and 62.6 bu/a. In two years of testing on sandy soils S07-3666 yielded 48.8 bu/a compared to 40.7 bu/a for AG4703. In testing over 26 locations in the Prelim and Uniform IVS tests, S07-3666 yielded 47.7 bu/a compared to 47.6 bu/a for AG4703. S08-17361 has a 25% exotic pedigree from PIs 253665D, 283331, 391594 and 437851A. Average over 9 locations in southeast Missouri, S08-17361 yielded 69.3 bu/a compared to 56.3 bu/a for AG 4903.

Vince Pantalone released the MG V glyphosate tolerant cultivar 'USG 75T40' that ranked second highest for seed yield in the 2008 and 2009 Tennessee State Variety Test, exceeding the commercial average by 6 bu/A on the 2 year mean. One parent of this line is LG98-1445 with a 25% exotic pedigree from PI 227333 and PI 91730-1. USG 75T40 is resistant to SCN Race 2 (HG Type 1.2.5.7), and moderately resistant to SCN Race 14 (HG type 1.3.5.6.7) in greenhouse pots. It also showed an order of magnitude lower SDS DX score (2.8) compared to commercial varieties during the 2009 season where we had a high natural infestation in the state variety test that year. In a 2010 group IVE test in east and west Tennessee the top four entries were reselections from LG01-3733 ($F_{3:5}$ Rend x LG97-9301). Those top four lines averaged 44.4 bu/a compared with the best check LD00-2817P at 36.2 bu/a.

Rusty Smith is planning on releasing LG01-5087-5 from LN93-11632 x LG96-1713. LG96-1713 has a pedigree that is 75% exotic germplasm from PI 427099, PI 438151, and PI 445830. In tests at Stoneville, MS from 2006 to 2009, LG01-5087-5 yield 70.7 bu/a compared to 94B73 that yielded 70.6 bu/a.