UC Davis Grain Legume Improvement and Statewide Support Activities

2014-2015 Progress Report to the California Dry Bean Board

Garbanzo Breeding

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The Bean Breeding group at UC Davis is working in parallel to: 1.) Complete the testing of advanced garbanzo lines initiated by S. Temple; and to 2.) Develop new varieties of garbanzos from original crosses based on improved lines and introduced lines. Given the 50% budget reduction incurred by the Bean Breeding project overall, the total level of activity has been reduced proportionately, with emphasis placed on the release of advanced lines as varieties and the development of crosses for future releases.

Summary of 2014 Garbanzo Breeding Projects

1. Ascochyta evaluation of advanced lines.
2. Canning test by a commercial food processor of advanced garbanzo lines, with prior evaluations for yield, seed weight, canning, and seed appearance.
3. Production of breeder's seed for advanced lines to be released.
4. Initiation of the varietal release process of one simple-leaf and one compound-leaf variety.
5. Canning quality test of the chickpea core collection from the USDA.
6. Initiation of a crossing program to produce the next generation of California garbanzo varieties.

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1. Ascochyta evaluation of advanced lines

Through a collaboration with the Grain Legume Genetics and Physiology Research Unit of the USDA-ARS in Pullman, WA, we obtained evaluation data for resistance to Ascochyta Races I and II. The tests were conducted using the "mini-dome" test as described by Chen and Muehlbauer (2003) and Chen et al. (2004)[1]. The evaluation scale used ranged from 1 (no symptoms) to 9 (dead plant). Plants with scores below 4 are considered resistant.

The results showed wide-ranging levels of resistance to this pathogen, although no line stood out significantly in comparison with Sutter (compound-leaf) or Sierra (simple-leaf) cultivars. UC0901 (compound-leaf type) and UC0905 (simple-leaf type) had similar levels of resistance compared to their respective controls.

Evaluation of select garbanzo lines for Ascochyta resistance

Disease severity rating: 1 = most resistant (no disease) and 9 = dead plant

	Pathotype I							Pathotype II						
Isolate	**1**		**2**		**3**		**Ave.**	**1**		**2**		**3**		**Ave.**
Control without inoculum	1.0	1.0	1.0	1.0	1.0	1.0	**1.0**	1.0	1.0	1.0	1.0	1.0	1.0	**1.0**
AFW1	3.0	3.0	4.0	5.0	6.0	3.0	**4.0**	4.0	4.0	4.0	5.0	5.0	4.0	**4.3**
WestBase7	6.0	6.0	4.0	*	5.0	6.0	**5.4**	4.0	5.0	7.0	6.0	4.0	4.0	**5.0**
Sierra	3.0	3.0	4.0	3.0	3.0	4.0	**3.3**	4.0	4.0	5.0	*	5.0	4.0	**4.4**
UCD1109	2.0	3.0	3.0	3.0	*	*	**2.8**	5.0	*	6.0	5.0	4.0	6.0	**5.2**
UCD1121	3.0	3.0	3.0	3.0	3.0	4.0	**3.2**	4.0	4.0	3.0	3.0	4.0	4.0	**3.7**
UCD1108	2.0	2.0	2.0	2.0	2.0	*	**2.0**	3.0	4.0	4.0	3.0	4.0	3.0	**3.5**
UCD1104	3.0	2.0	2.0	2.0	2.0	2.0	**2.2**	3.0	3.0	3.0	3.0	3.0	3.0	**3.0**
UCD1101	3.0	3.0	2.0	3.0	2.0	2.0	**2.5**	3.0	3.0	3.0	3.0	4.0	4.0	**3.3**
UCD0901	**4.0**	**4.0**	**4.0**	**3.0**	**3.0**	**4.0**	**3.7**	**5.0**	**5.0**	**6.0**	**5.0**	**6.0**	**6.0**	**5.5**
UCD0903	3.0	4.0	3.0	3.0	4.0	3.0	**3.3**	5.0	5.0	6.0	*	5.0	6.0	**5.4**
UCD0905	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**4.0**	**4.0**	**4.0**	**5.0**	**4.0**	**5.0**	**4.3**
Sutter	3.0	3.0	4.0	4.0	4.0	4.0	**3.7**	4.0	4.0	5.0	4.0	5.0	5.0	**4.5**
Spanish Whit	*	*	4.0	*	3.0	5.0	**4.0**	6.0	8.0	6.0	6.0	*		**6.5**
Dwelley	3.0	3.0	3.0	3.0	3.0	3.0	**3.0**	5.0	5.0	5.0	6.0	5.0	4.0	**5.0**

The lines in blue are slated for varietal release process (see Section 4).

[1] Chen, W., Coyne, C. J., Peever, T. L., and J. Muehlbauer, F. 2004. Characterization of chickpea differentials for pathogenicity assay of ascochyta blight and identification of chickpea accessions resistant to *Didymella rabiei*. Plant Pathology 53:759-769.

Chen, W., and Muehlbauer, F. 2003. An improved technique for virulence assay of *Ascochyta rabiei* on chickpea. International Chickpea and Pigeonpea Newsletter 10:31-33.

2. Canning test by a commercial food processor of advanced lines

Advanced garbanzo lines of the UC Davis Bean Breeding program were subjected to a canning test by a commercial food processor. The test was sponsored by Kirsten Company of Lodi, CA. This test was very significant because it was conducted under commercial conditions on a large number of lines. In addition to the advanced lines, several commercial varieties were tested as checks. The results of the canning were evaluated by 10 individuals with diverse professional backgrounds. Thus, the level of confidence in this evaluation is quite high.

The test consisted of 16 samples, with 14 different lines (two of the lines were represented twice by samples from different harvest origins). Following the canning operation, the canned garbanzos were evaluated by a panel of 10 participants, including personnel from the commercial food processor (canning staff, marketing staff, and executives), warehouse/distribution representatives, and breeders.

The canned samples were judged in a blind test, in which the identity of the samples remained unknown to the panel until after the test. The samples were evaluated on a scale of 1 (bad) to 5 (excellent) for the following seven traits: color, consistency (appearance of the canning liquid), presence of cracks/splits, detachment of skins, grain size, and canned grain flavor and texture. For each trait and sample, the scores of the 10 participants were averaged. In turn, the scores of the 7 traits for each sample were averaged to obtain a single canning quality score for each sample/line included in the test. Differences among lines and samples could be subjected to a statistical test of significance when considering human testers as a replicate.

Among the different traits, statistically significant differences were observed among lines for the following traits: grain color, canning liquid consistency, cracks/splits, skin detachment, and grain size. No differences could be detected for canned grain flavor and texture.

When the seven traits were averaged for each sample, statistically significant differences among samples were observed as shown by the following tables.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	20.52551021	1.36836735	8.09	**<.0001**
Error	144	24.36855690	0.16922609		
Corrected	159	44.89406710			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Genotype	15	20.52551021	1.36836735	8.09	**<.0001**

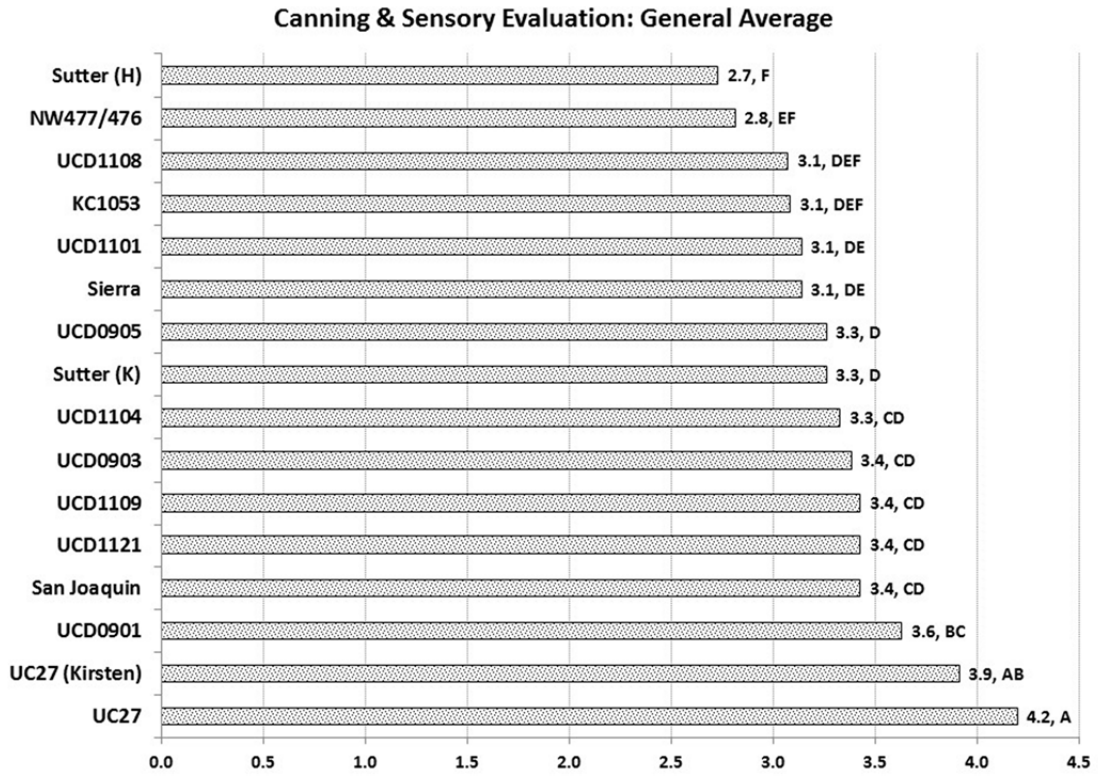

Figure 1. Comparison of averages of canning and sensory evaluations of garbanzo varieties and UCD advanced lines. The number to the right of each bar is the average evaluation score for the corresponding sample; means followed by the same letters are not significantly different from each other according to the Least Significant Difference test.

A comparison of the means showed that the best garbanzo variety for canning in this experiment is still UC27. Care should be taken, however, that all of the UCD experimental lines as well as the Sutter and Sierra check varieties, were grown in the same field location and were harvested in the same year and stored in the same location, while the other lines included in the comparison were sourced from the commercial cannery or from Kirsten Company (with field origin and harvest date unknown). Among the UC Davis experimental lines, compound-leaf type UCD0901 and simple-leaf type UCD0905 performed well, both with scores higher than (if not significantly different from) industry standards Sierra and Sutter.

This evaluation is the last piece of data that was added to the release dossier for new garbanzo varieties (see Section 4).

Figure 2. Selected varieties or advanced lines assayed for canning quality and sensory characters.

3. Production of breeder's seed of advanced lines

In order to accelerate the varietal release process, a seed increase was conducted at UC Davis Agronomy Field Headquarters in spring 2014. (An increase planted in fall 2013 failed because of lack of rains.) This increase was also used to gather required data for distinctiveness, uniformity, and stability, necessary for a Plant Variety Protection submission. The following quantities of breeder's seed were obtained:

Garbanzo yields from July 3, 2014 harvest	
line	(kg)
UCD0901	24.055
UCD0905	13.565
UCD0903	29.85
UCD1101	23.305
UCD1121	28.345
UCD1104	26.18
UCD1108	17.46
UCD1109	16.53
Sierra	10.795
Sutter	12.39

4. Varietal release

We have now accumulated essential data to propose advanced lines for varietal releases. In the last two years, I had proposed to release one simple-leaf variety (either UCD0903 or UCD0905) and two compound-leaf varieties. One of the compound-leaf varieties (either UCD0901 or UCD1109) would have been selected for seed appearance for dry pack (in addition to yield and other traits. The other compound-leaf variety would have been selected primarily based on its canning quality given that >90% of the garbanzo production of the state of California is canned.

Table. Main yield, seed weight, canning quality, visual seed observation, and *Ascochyta* resistance data for advanced garbanzo lines

		Yield												Seed weight		Canning Quality			Average expert score		*Asco-chyta* (1R-9S)	
		2010-2011		2011-2012		2012-2013		3-year Averages				General Average										
Line	Main breeding objective	Davis	WS[1]	Davis	WS	Davis	WS	Davis	Rank	WS	Rank	Yield	Rank	201	201	201	2013	2014	2012	201	2014	
		lbs/acre												(Seeds/ oz.)		(% good)		1-5 (best)	1 (best)-3		I	II
Compound-leaf type																						
UCD1101	Yield	2608	4716	1591	3158	1004	3094	1734	1	3656	1	1797	1	97	75	59	64	3.14	2.75	2.2	2.5	3.3
UCD1121	Yield	2143	4433	1442	3321	1259	2789	1615	2	3514	2	1710	2	92	78	53	54	3.43	2.4	2.4	3.2	3.7
Sutter	Check	1546	4674	1663	2003	592	3110	1267	6	3262	3	1512	3	78	65	75	59	3.26	2.4	2.2	3.7	4.5
UCD0901	St & C[2]	1089	4109	1409	2041	1489	3062	1329	4	3071	4	1468	4	64	53	60	64	3.63	1.2	1.8	3.7	5.5
UCD1104	Canning	1556	3793	1366	2171	1248	2906	1390	3	2957	5	1450	5	73	62	90	79	3.44	2.25	2.1	2.2	3.0
UCD1109	Seed type	1277	4341	1366	1749	1160	2387	1268	5	2826	6	1366	6	62	51	71	70	3.43	1.75	1.7	2.8	5.2
UCD1108	Canning	1615	4097	1236	1926	675	2383	1175	8	2802	7	1328	7	99	82	78	65	3.07	2.75	2.3	2.0	3.5
AWF1	Check	-	-	1241	1778	-	-	1241	7	2569	9	1272	8	70	-	77	-	-	1.75	1.8	4.0	4.3
Simple-leaf type																						
UCD0905	St & C	1088	4188	992	1754	865	2447	982	11	2796	8	1263	9	62	51	96	52	3.36	1.6	1.5	3.0	4.3
UCD0903	St & C	1413	3759	1236	1255	798	2313	1149	9	2442	10	1200	10	65	56	89	50	3.39	1.6	1.7	3.3	5.4
Sierra	Check	1114	3142	1035	1040	810	2483	986	10	2222	11	1073	11	60	60	21	61	3.14	1.75	1.8	3.3	4.4

[1] WS: West Side Research and Extension Center; [2] St & C: Seed type and Canning

The recent canning results by a commercial food producer, however, show that UCD0901 has both good grain and good canning quality (see Table), in addition to having yields comparable to Sutter. I am, therefore releasing UCD0901 to serve both purposes (dry pack and canning). With regard to simple-leaf types, I am releasing UC0905 based on its 18% average higher yield and canning quality comparable to that of Sierra. The Plant Sciences Varietal Release Committee has approved both releases. The varieties are tentatively called UC Pegasus (UCD0905) and UC Vega (UCD0901). The next steps will be to apply for certification (CCIA) and PVP (Innovation Access at UC Davis).

5. Canning quality in the chickpea core collection

In order to increase the genetic diversity available to develop new varieties, we obtained a sample of the chickpea core collection of the USDA in 2011. We planted this core collection in the field over two winter growing seasons (2012 and 2013) to take phenology data and increase our seed stocks of these varieties. The collection originally consisted of 504 lines, but lack of adaptation to California growing conditions has reduced this to 491 lines, still a sizable number.

We reported on our efforts to conduct a seed increase of this collection in the Annual Reports of previous years (2012-2013 and 2013-2014). After these increases, we had sufficient seeds to conduct canning tests on small quantities of seeds (20 g of seed, or 0.71 oz). After canning, the canned seeds were graded for % cracked vs. uncracked and for firmness by Manisha Thapa, a graduate student in the Plant Sciences department.

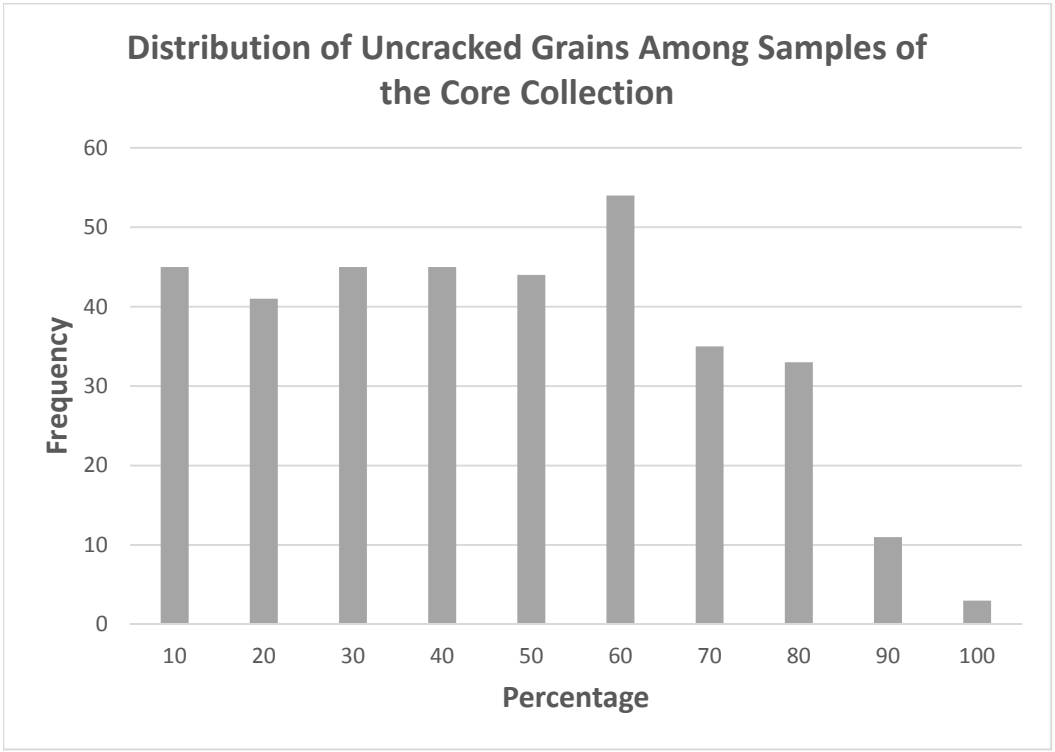

Figure 3. Frequency of grain cracking after canning among samples of the chickpea core collection of the USDA.

The analysis shows a wide distribution of cracking frequency, which is quite positive from a breeding standpoint. For the purpose of improving canning traits, a low cracking frequency is highly desireable. Further analysis will determine to what extent this trait can be recombined with higher yield, large grain size, and Ascochyta resistance, among others.

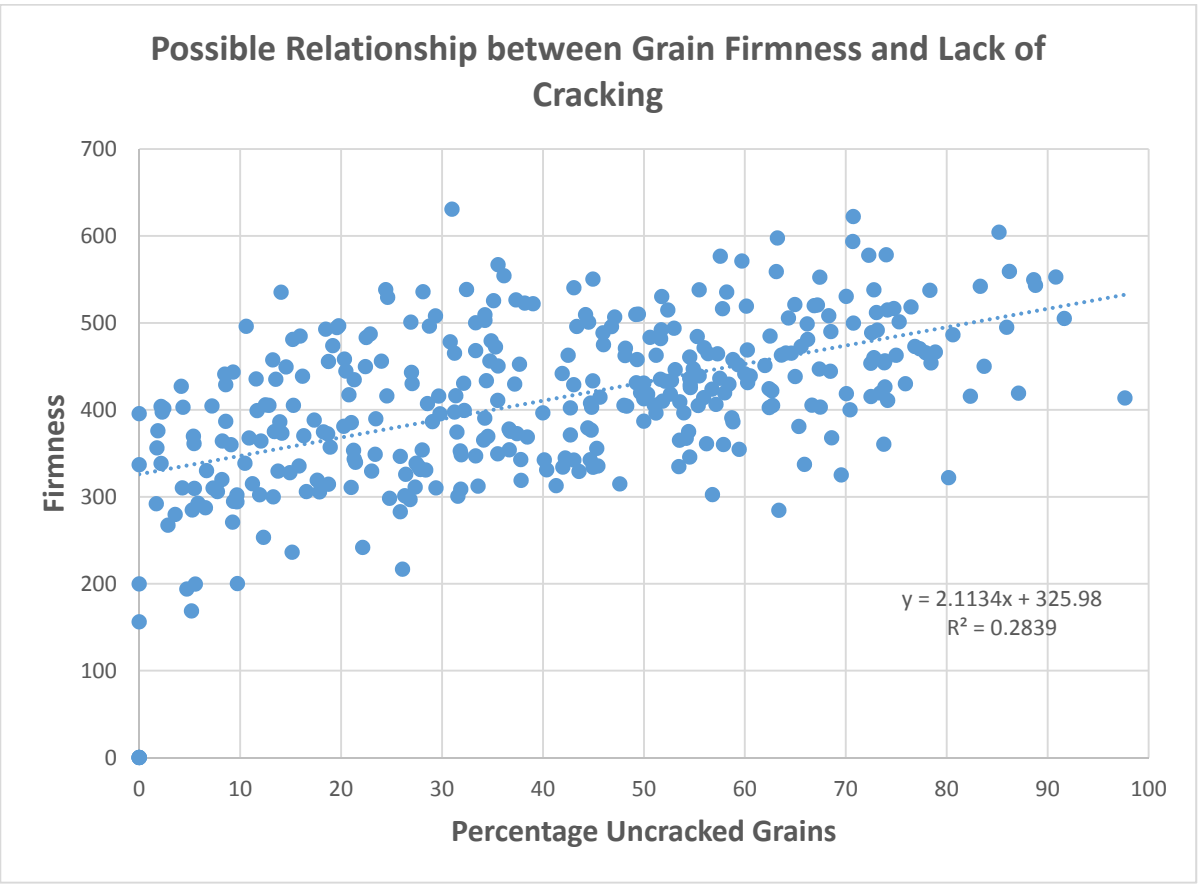

Figure 4. Relationship between physical firmness and the lack of cracking among samples of the chickpea core collection of the USDA.

6. Crossing Program

To my knowledge, there have not been any UC Davis-based garbanzo varieties, i.e., no variety resulting from crossbreeding among varieties chosen by the UC Davis bean breeding program because of their adaptation to California conditions. Instead, all varieties that have been released have resulted from introductions from outside the state or the country, which were released after testing in California.

On this basis, a crossing program was initiated that will lead to the development of new garbanzo varieties specifically designed for California growers. Based on preliminary yield and grain size data in this collection, a limited set of USDA core collection parents were selected for crossing with current varieties and advanced lines. These parents were selected from the upper right quadrant in Fig. 5 (see below).

1st round of crosses	Objective	Polymorphic marker	Number of F1 seeds	
			Harvested	After gel image (hybrids)
Sutter X UCD1121	High yield + large seed size	TA180	2	2
Sutter X UCD1101	High yield + large seed size	TA2	3	3
Sutter X PI503006	Large seed size and higher yield	TA2	1	1
Sutter X PI502998	Large seed size and higher yield	TA2	1	1
Sutter X UCD0901	High yield + large seed size	TA180	4	4
Sutter X UCD1108	Large seed size and higher yield	TA2	2	1

2nd round of crosses	Objective	Polymorphic marker	Number of F1 seeds		
			Failed	Harvested	After gel image (hybrids)
Sutter x UCD1101	High yield + large seed size	TA180	10	4	3
Sutter x UCD 1108	High yield + Canning quality	TA2	3	3	3
Sutter X UCD1109	High yield + seed quality	TA180	6	14	8
Sutter X UCD1104	High yield + Canning quality	TA180	5	4	3
Sutter X UCD1121	High yield + large seed size	TA180	7	10	8
Total			31	35	25

2nd round of crosses	Objective	Polymorphic marker	Number of F1 seeds		
			Fail	Harvested	After gel image (Hybrid)
UCD1101 X UCD0901	High yield + Large seed size	TA180	18	2	2
UCD1121 X UCD1109	High yield + Large seed size	TA2	44	0	0
UCD1104 X UCD1121	High yield + Canning quality	TA180	12	3	2
UCD1108 X UCD1101	High yield + Canning quality	TA180	12	4	4
UCD0905 X UCD1101	High yield + Simple-leaf	Leaf type, multiple leaf	27	7	7
			113 (87.5%)	16 (12.5%)	

The success of the crosses was confirmed by molecular (DNA) marker analysis. An experiment conducted by Manisha Thapa allowed her to identify markers that can unequivocally identify hybrid seeds, which is important given the lack of distinguishing morphological traits.

Primer pair	Forward	Reverse	Repeat sequence	Amplification in parents used
TA2	AAATGGAAGAAGAATAAAAACGAAAC	TTCCATTCTTTATTATCCATATCACTACA	TAA16TGA(TAA)19	Amplified and polymorphic
TAA58	CATTGCTTAAGAACCAAAATGG	CAATTTTACATCGACGTGTGC	(AAT)41	Amplified in a few parents
TA180	CATCGTGAATATTGAAGGGT	CGGTAAATAAGTTTCCCTCC	(TAA)24	Highly polymorphic
TA176	ATTTGGCTTAAACCCTCTTC	TTTATGCTTCCTCTTCTTCG	(TAA)20(GAA)9	Amplified in all but monomorphic
TA203	ATAAAGGTTTGATCCCCATT	TGTGCATTCAGATACATGCT	(TAA)43	No amplification at all

The F1 seeds harvested constitute a new and very important resource for the UC Davis bean breeding program. The F1 seeds will be planted in the greenhouse this spring to generate F2 seeds for planting in the field in the fall of 2015.