2012 UC Davis Grain Legume Improvement and Statewide Support Activities

Report

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I. UC Davis Program Objectives

The grain Legume improvement program at UC Davis gives continuity to the breeding program conducted by Steve Temple. The focus has been put on three species: *Phaseolus lunatus, Cicerarietinum,* and *Phaseolus vulgaris*. During 2012 experiments were grown in different locations in central and San Joaquin Valley with the main goal of evaluate advanced genotypes that were previously crossed and advanced for several generations by Steve Temple and collaborators.
New germplasm of garbanzo as well as baby and large limas were planted in observation trials at UC Davis with the main goal of observe adaptation, increase seed and make preliminary selection of parental lines that will be included in new crosses to increase the genetic base of each breeding program.

The legume program is focused in the following research objectives:

<u>Lima beans</u> (baby and large lima): Increase resistance to Lygus and nematodes, and preferentially combination of both. Increase resistance against mites in large limas. Increaseyield and improve seed quality, specially seed size and color.

<u>Garbanzos</u>: Current emphasis is on seed quality (color, size, and seed coat roughness), yield, and resistance to Ascochyta, white mold, and viruses. As feasible, adaptation to other regions or season (Spring).

<u>Common beans</u>: Steve Temple had developed improved lines for several common bean types, including yellow (UC Canario 707) and Flor de Mayo (UCD 9623). Depending on demand from the industry additional breeding can be performed to either enhance existing varieties in different market places or initiate improvement of different types. Currently, the program is focusing on further improving Cranberry types, especially to decrease shattering. Further progress can be achieved by selecting for improved plant type (taller, more erect) and a more vigorous root system.

The following report provides a summary of the results obtained in 2012 by crop in different stages of the pipeline by crop. These results were possible only with significant assistant from bean growers, collaborators at West Site Research and extension Center (WSREC) and students from the bean program at UC Davis. We are especially grateful to Chuck Cox who provided field space and crop management at Westley. We extend our acknowledgments to Jim Jackson, Fred Steward and Rafael Solorio for their valuable contribution in field execution and crop management at UC Davis and WSREC.

II. Garbanzo Breeding

A. Garbanzo Yield Trial

A large yield test that combines 26 garbanzo lines and 4 checks was planted in Nov 2012 at UC Davis and December 2012 at WSREC. The trial included a second year of evaluation of 18 UC Davis lines tested during 2011 and a first year of evaluation of 8 UC Davis lines that performed well in the observation trial of 2011 at UC Davis. Four public or private garbanzo varieties were included as checks in both locations. Germination counts, yield results as well as growth habit and plant vigor scores are shown in the results tables that follow.

Because of limited rainfall after planting at UC Davis, there was delayed and partial germination in most of the lines, as shown by **Figure 1**. Statistically significant variation was observed for the number of emerged seedlings per 120 seeds planted in each plot, from a minimum of 29 (UCD1116) to a maximum of 92 (UCD1121). With the exception of line UCD0903, all entries had a narrow range of germination rates. UCD0903 showed a broader range of germination rates among the four replicates, possibly due to its greater sensitivity to moisture and/or low temperature.

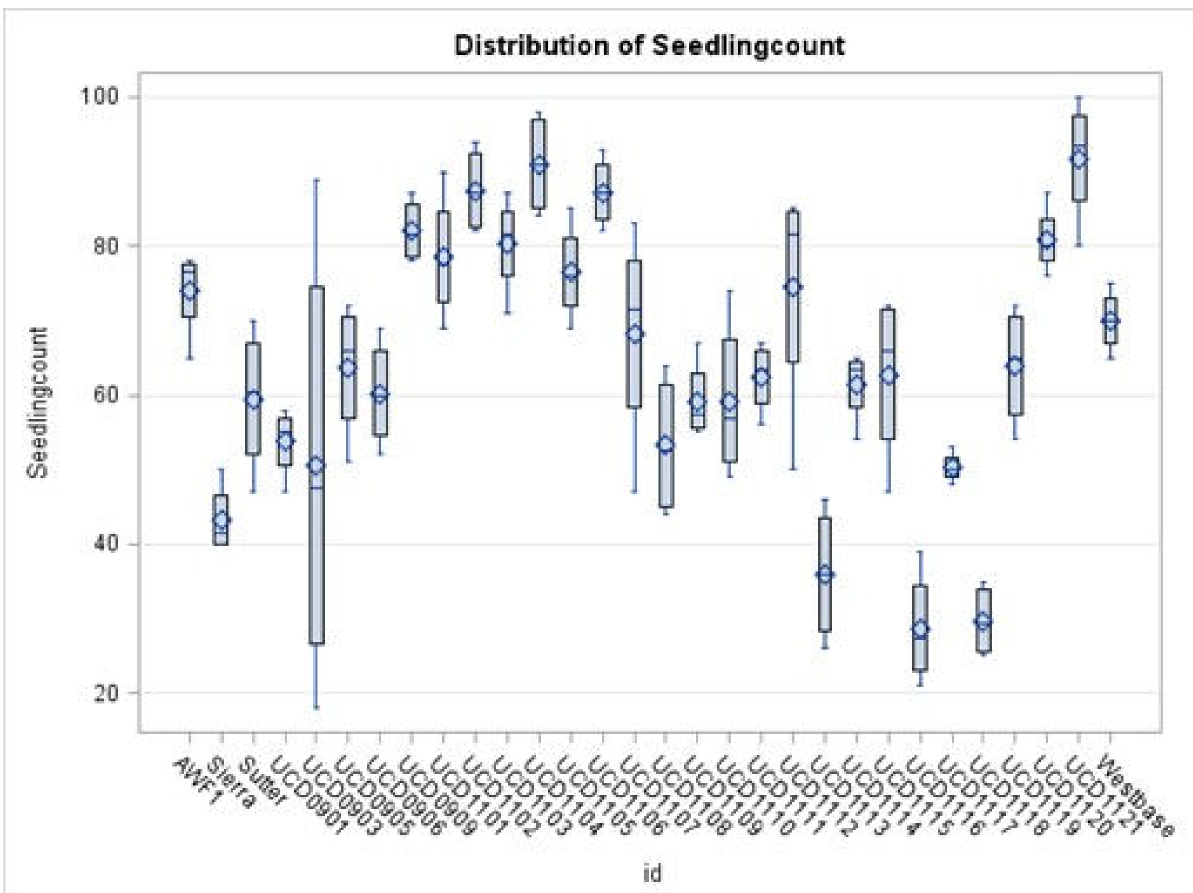


Figure 1. Seedling count (no. of seedlings emerged out of 120 seeds planted) in garbanzo field trial at UC Davis. DOP: Nov. 18, 2011; date of observation: Jan. 6, 2012. Four replications. Statistically significant variation for seed counts: * (P < 0.001). Coefficient of variation: 15%**

The UC Davis planting recovered, nevertheless, primarily because of the inherent flexibility in growth habit of legume plants. When presented with more space, legume plants (including garbanzos, limas, and commons) will branch more and occupy the space. Hence, this experiment ultimately gave interpretable results.

For yield-related traits, statistically significant differences among entries were observed for all the traits evaluated indicating a strong genetic component for the variation among the lines (**Table 1**). From the 30 genotypes included in the trial, several lines yielded as well as the commercial checks (Sutter and WB7) and two lines (UCD1107 and UCD1110) performed significantly better than the commercial checks AWF1 and Sierra (single-leaf type). UCD1107 yielded 100 lbs above the commercial check Sutter that remains the standard of the industry in Sacramento Valley. A significant difference in terms of plant vigor was also observed among entries ranking from 2 (high vigor) to 4 (poor vigor). Further research is being conducted on these materials to analyze the genetic and environmental component of the differential response to the genotypes. Evaluations of the same lines will be conducted in 2013 under field conditions (including a seed treatment component) and under growth chamber conditions to better understand the genetic component of vigor and its relationship with final yield(**Table 2**).

Table 1. Mean Squares from the Analysis of Variance for four traits in 30 genotypes evaluated at UC Davis in 2012.

Source	df	MS YIELD		MS GRWHBT		MS PTVIGOUR	
BLOC	3	1298062	***	0.222		0.289	
ENTRY	29	346668.5	***	0.616	***	1.34	***
Residual	87	70990.96		0.13		0.254	
Grand Mean		1325.333		1.967		2.867	
R-Squared		0.6931		0.6205		0.6422	
C.V.		20.10%		18.35%		17.59%	
LSD		496.16		0.6721		0.93	
Herit.		0.493		0.482		0.516	

Good plant establishment and higher yield (2172.5 lbs/A) was achieved at the West Side Research and Extension Center (WSREC) and significant differences (**Table** 3) were observed among genotypes for plant vigor, growth habit and yield **(Table 4**). It is noteworthy that four experimental lines yielded statistically better than all the checks, including the best yielding check Sutter, which in the trial ranked 17 for yield among all the entries. The line UCD1110, one of the best yielding lines at WSREC also showed a very good performance at UC Davis ranking second in yield. The general adaptability for different environments may give the line UCD1110 a competitive advantage against other commercial lines that perform well in some conditions but lack performance under contrasting environments. Results at WSRC are very promising in terms

Table 2. Means for Yield, Plant Vigor and Growth Habit of 30 Garbanzo Genotypes Evaluated at UC Davis in 2012.

NAME	YIELD	C.V.	Group[1]	VIGOR[2]	CV	Group[1]	GH[3]	CV	GROUP[1]
UCD1107	1835	19.5 rt	a	3.00	0	abcde	2.25	22.2	bc
UCD1110	1740	31.7 t	ab	3.00	0	abcde	2.00	0	abc
Sutter-q	1735	30.3 t	ab	3.25	15.4	bcde	1.75	28.6	abc
WB7- s	1685	28.6 t	abc	2.25	22.2	ab	2.00	0	abc
UCD1120	1665	22.1 t	abcd	2.50	23.1	abc	2.25	22.2	bc
UCD1101	1660	19.6 t	abcd	2.50	23.1	abc	2.50	23.1	c
UCD1103	1620	35.7 t	abcde	2.50	23.1	abc	2.00	0	abc
UCD1102	1525	16.2	abcdef	2.00	0	a	1.75	28.6	abc
UCD1121	1505	21.9	abcdefg	2.25	22.2	ab	2.25	22.2	bc
UCD1105	1485	13.3	abcdefg	2.25	22.2	ab	2.00	0	abc
UCD0901	1470	34.4	abcdefg	3.00	27.2	abcde	2.00	0	abc
UCD1119	1430	4.8	abcdefg	2.75	18.2	abcd	2.00	0	abc
UCD1104	1425	34.5	abcdefg	3.00	0	abcde	2.00	0	abc
UCD1109	1425	33.2	abcdefg	2.75	18.2	abcd	2.00	0	abc
UCD0909	1295	28.4	abcdefgh	2.00	0	a	1.25	40	a
AWF1-r	1295	8.6	abcdefgh	2.25	22.2	ab	1.50	38.5	ab
UCD0903	1290	32.2	abcdefgh	3.75	13.3	de	2.00	0	abc
UCD1108	1290	4.8	abcdefgh	3.00	27.2	abcde	3.50	16.5	d
UCD1118	1250	16.4	abcdefgh	4.00	0	e	2.00	0	abc
UCD1113	1250	35	abcdefgh	4.00	0	e	2.00	0	abc
UCD1106	1150	28.3 qs	bcdefgh	2.25	22.2	ab	1.25	40	a
UCD0906	1095	19.4 qs	cdefgh	3.00	0	abcde	2.00	0	abc
UCD1112	1090	21.8 qs	cdefgh	3.00	27.2	abcde	2.00	0	abc
Sierra-t	1080	14.9 qs	defgh	3.75	13.3	de	2.00	0	abc
UCD0905	1035	14.2 qs	efgh	2.50	23.1	abc	1.75	28.6	abc
UCD1115	1010	8.8 qs	fgh	3.00	27.2	abcde	1.75	28.6	abc
UCD1111	995	9.3 qs	fgh	2.75	18.2	abcd	1.75	28.6	abc
UCD1114	910	18.7 qs	gh	2.50	23.1	abc	2.00	0	abc
UCD1116	785	17.1 qrs	h	3.75	13.3	de	1.75	28.6	abc
UCD1117	735	22.6 qrs	h	3.50	16.5	cde	1.75	28.6	abc

[1] Group= Mean separation by Duncan's Multiple Range Test at p=0.0, Means followed by the same letter are not statistically different. [2] Plant Vigor=Measured in a scale of 1 to 5, being 1 very high vigor and 5 very low vigor. [3] Growth Habit or plant type (GH), measured in a scale of 1 to 5, being 1 upright and 5 prostrate.

of yield with 4 entries yielding at least 700 pounds above the best check Sutter. The growth habit for the 10 best yielding lines ranked from erect (1.5) to semi spreading (3), being in general more spreading than the check AWF1 but still similar to the growth habit of prevalent varieties Sutter and Sierra.

Yield for the UCD09 series, which has been tested for two consecutive years, was very similar to the checks. The line UCD0909 stands out with a yield of 2330 lbs/A, 240 lbs above the best check, Sutter, and has a very erect growth habit and good plant vigor. While the yield of UCD0909 was promising, seed quality didnot overcome the quality of Sutter. Yield of the same line evaluated at the UC Davis trial was significantly lower than best check Sutter (**Table 2**). Even though other garbanzo lines from the 09 series didnot yield significantly higher than the best check, Sutter, their performance in terms of seed quality was very superior compare to the checks. As observed in **Figure 2**, from the 09 group, the single leaf types: UCD 0903 and UCD 0905 stand out with a large seed size (65 and 62 respectively) and a very high canning quality (89 and 96% respectively), making them very good candidates for large-plot testing, especially for the canning market. In the 09 series, the line UCD 0901 stands out with a good yield, good seed quality for canning and a bigger seed size compare to Sutter.

Table 3. Mean Squares from the Analysis of Variance for Three Traits in 30 Garbanzo Lines Evaluated at WSREC in 2012.

Source	df	MS YIELD		MS GRWHBT		MS PTVIGOUR	
BLOC	3	166599		0.144		0.322	
ENTRY	29	1126771	***	1.057	***	0.875	***
Residual	87	135741		0.162		0.184	
Grand Mean		2172.5		2.417		2.383	
R-Squared		0.7375		0.6886		0.6216	
C.V.		16.96%		16.64%		18.01%	
LSD		617.42		0.6739		0.7194	
Herit.		0.646		0.581		0.484	

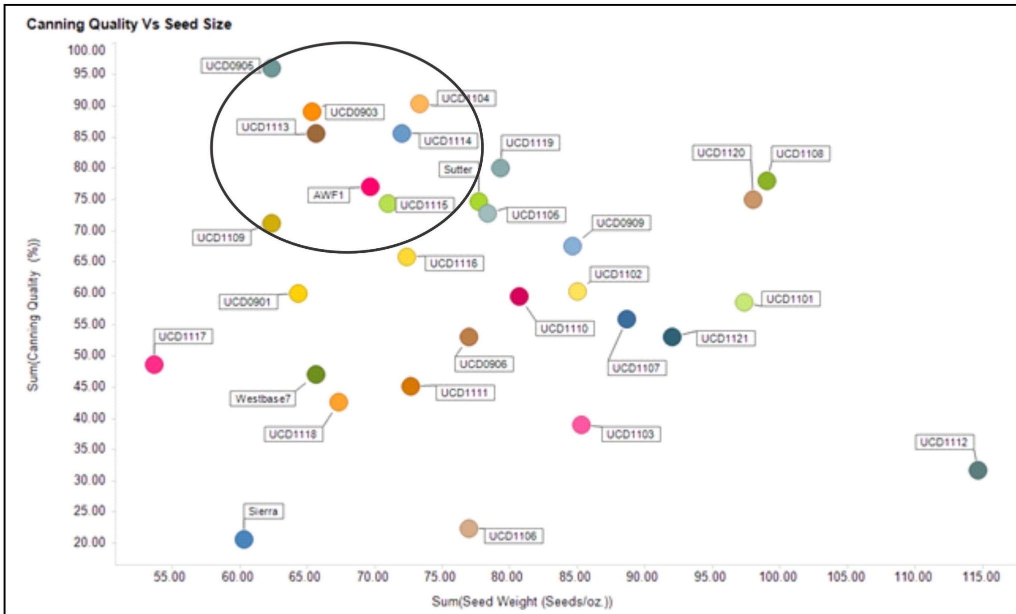


Figure 2. Seed size and seed canning quality evaluated in 30 garbanzo lines in the Yield test conducted at WSREC and Davis CA, in 2012.

Table 4. Means for Yield, Plant Vigor and Growth Habit of 30 Garbanzo Genotypes Evaluated at the West Site Research and Extension Center (WSREC), Five Points, CA, 2012.

NAME	YIELD	CV	GROUP[1]	GHABIT[2]	C.V.	LSD	VIGOR[3]	C.V.	LSD
UCD1121	3465qrst	14.1	a	3	0	d	2.25	22.2	bc
UCD1101	3295qrst	14.2	ab	3	0	d	2	0	b
UCD1120	3155qrst	33	abc	2.5	23.1	bcd	2	0	b
UCD1110	2815qrst	11.9	abcd	2.75	18.2	cd	3	0	cde
UCD1102	2570rst	16.9	bcd	2.75	18.2	cd	2.5	23.1	bcd
UCD1111	2395 t	15.8	cd	2.5	23.1	bcd	2.5	23.1	bcd
UCD1103	2380 t	17.4	cd	1.75	28.6	ab	2	0	b
UCD1118	2365 t	13.6	cd	3	0	d	2.75	18.2	bcde
UCD1119	2340 t	13.4	cd	2.5	23.1	bcd	2.5	23.1	bcd
UCD0909	2330 t	7.7	cd	1.5	38.5	a	1.75	28.6	a
UCD1112	2305 t	4.5	d	2.75	18.2	cd	2	0	b
UCD1104	2265 t	14.5	d	2.25	22.2	abcd	2	0	b
UCD1115	2260 t	17.2	d	2.75	18.2	cd	2	0	b
UCD1107	2255 t	18.9	d	3	0	d	2	0	b
UCD1105	2220 t	11.1	d	2.75	18.2	cd	2.25	22.2	bc
UCD0901	2130 t	6.5	d	3	0	d	3	0	cde
Sutter-q	2090 t	23	d	2.25	22.2	abcd	2.75	34.8	bcde
UCD1108	2010 t	8.5	d	3	0	d	2	0	b
UCD1114	1965 t	11.1	e	2	0	abc	1.75	28.6	a
UCD1106	1895 t	4	e	1.5	38.5	a	2	0	b
UCD0906	1880 t	21	e	1.75	28.6	ab	2.25	22.2	bc
UCD1113	1860 t	7.7	e	2	0	abc	2.25	22.2	bc
AWF1-r	1855 t	15.7	e	1.5	38.5	a	2	0	b
Westbase7-s	1835 t	11.3	e	2.5	23.1	bcd	2.75	18.2	bcde
UCD0905	1830 t	10.7	e	2	0	abc	2.25	22.2	bc
UCD1109	1825 t	21.2	e	2	0	abc	2.25	22.2	bc
UCD1117	1810 t	24.1	e	3	0	d	3	27.2	cde
UCD1116	1380	9.2	e	3	0	d	3	0	cde
UCD0903	1310	25.4	e	2	0	abc	3.25	15.4	de
Sierra-t	1085	22.4	e	2.25	22.2	abcd	3.5	16.5	e

[1] Group= Mean separation by Duncan's Multiple Range Test at p=0.01 Means followed by the same letter are not statistically different. [2]GHABIT: Plant type, from 1 upright to 3 spreading. [3]Vigor: 1 strong to 5 weak.

Field trials containing the best candidates from the 09 series: UCD 0901, UCD0903 and UCD 0905 have been planted in Dec, 2012 at WSREC and in January 2013 at UC Davis. The trial also includes lines from the UCD 11 series that showed the best performance in 2012: UCD 1101, UCD 1104, UCD 1108, UCD1109 and UCD1121. Further evaluation of these lines will be performed to gather more information about yield potential, seed quality, canning quality and other traits of economic interest. The program is expected to get sufficient seed increase from the trials with the objective of planting the best candidate lines in large strip trials in farmers' fields in the fall of 2013.

Yield test analysis across locations

As in previous years, a change in relative performance of genotypes was observed across sites. Under these circumstances, the interaction genotype by environment was studied with the objective of explore the stability of the garbanzo lines under contrasting environments. The analysis combined data from the trials at WSREC and UC Davis in 2011 and 2012. Results of the analysis of variance are shown in **Table 5** and **Figures2and 3**.As expected, the analysis shows a very high effect of the environment; with yields at WSREC that almost doubled those at UC Davis. These results can be expected considering that WSREC represents the environmental

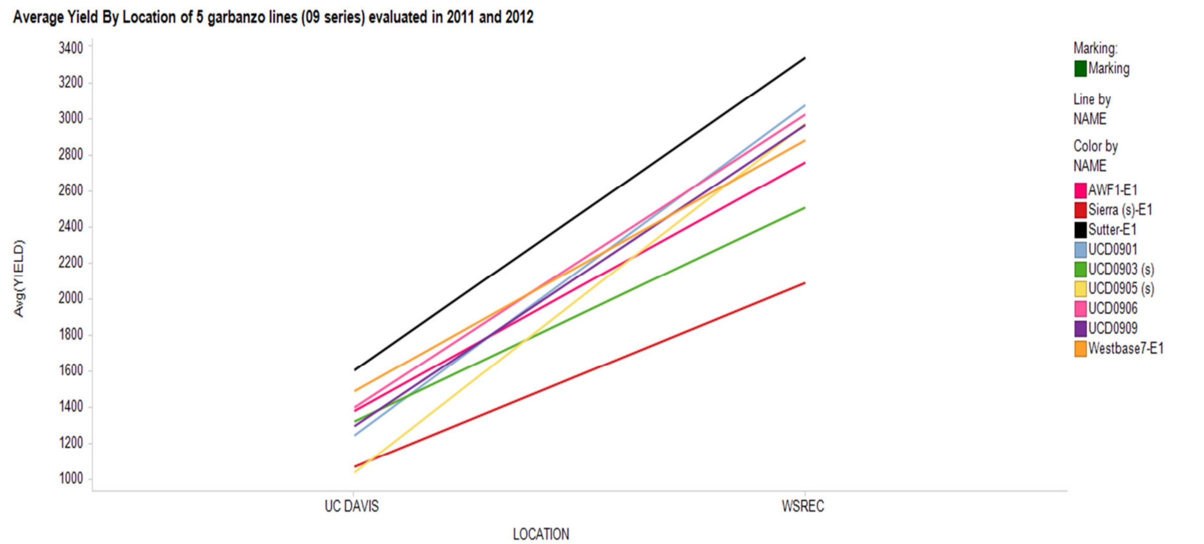


Figure 3. Average yield (Lbs/A) by location of 5 garbanzo lines (09 series) evaluated in yield trials in 2011 and 2012.

and agronomic conditions of the San Joaquin Valle where yields have being traditionally higher and more consistent in comparison to the Sacramento Valley, where cooler and wetter environment have produced uneven and unpredictable results.

The analysis (**Table 5**) shows a very highly significant effect of location (Environment),followed by Genotype and the interaction Genotype by Environment (E>G>GxE). The strong effect environment influence and the significant genotype x environment interactionsuggestphenotypic performance is influenced significantly by the testing site (WSREC or UCDavis) and therefore, the testing and varietal selection should continue in sites representing the contrasting environments of San Joaquin Valle and Sacramento Valley. On the other hand, the significant interaction of genotype x environment suggest that some lines may express better their yield potential under certain environment conditions. To illustrate the case, mean yield by line was plotted by location in **Figures3 and 4**. A crossover interaction is observed for some of the experimental lines, especially for UCD 0905, which was a low-yielding line at UC Davis but expressed a higher yield potential at WSREC. It is interesting to observe the high stability of the checks Sutter and Sierra, which also showed higher and lower yields compare to the lines from the 09 series.

Table 5. Analysis of variance across locations for yield of 30 genotypes of garbanzo tested at UC Davis and WSREC in 2012.

Source	df	SS	MS	F-value	Pr>
Total	239	108170918.3			
LOC	1	43061481.7	43061481.7	416.59	0.0000
ENTRY	29	30794668.3	1061885.1	10.27	0.0000
LOC *ENTRY	29	11935068.3	411554.1	3.98	0.0000
BLOC (LOC)	6	4393983.3	732330.6	7.08	0.0000
Residual	174	17985716.67	103366.188		

Grand mean=	1748.92	C.V.=	18.38%
R-square=	0.8337	LSD for entry=	418.66
Heritability=	0.612	Significance at 1%	

As mentioned before, yield potential is much higher within the UCD 11 series for both environments, as is observed in **Figure4**, where the checks Sutter and Sierra yielded below the average. It is interesting to see that the best line UCD 1101 showed both high yield and higher stability across sites, making it a very good candidate for a garbanzo variety across different environments although further testing need to be done to confirm this advantage.

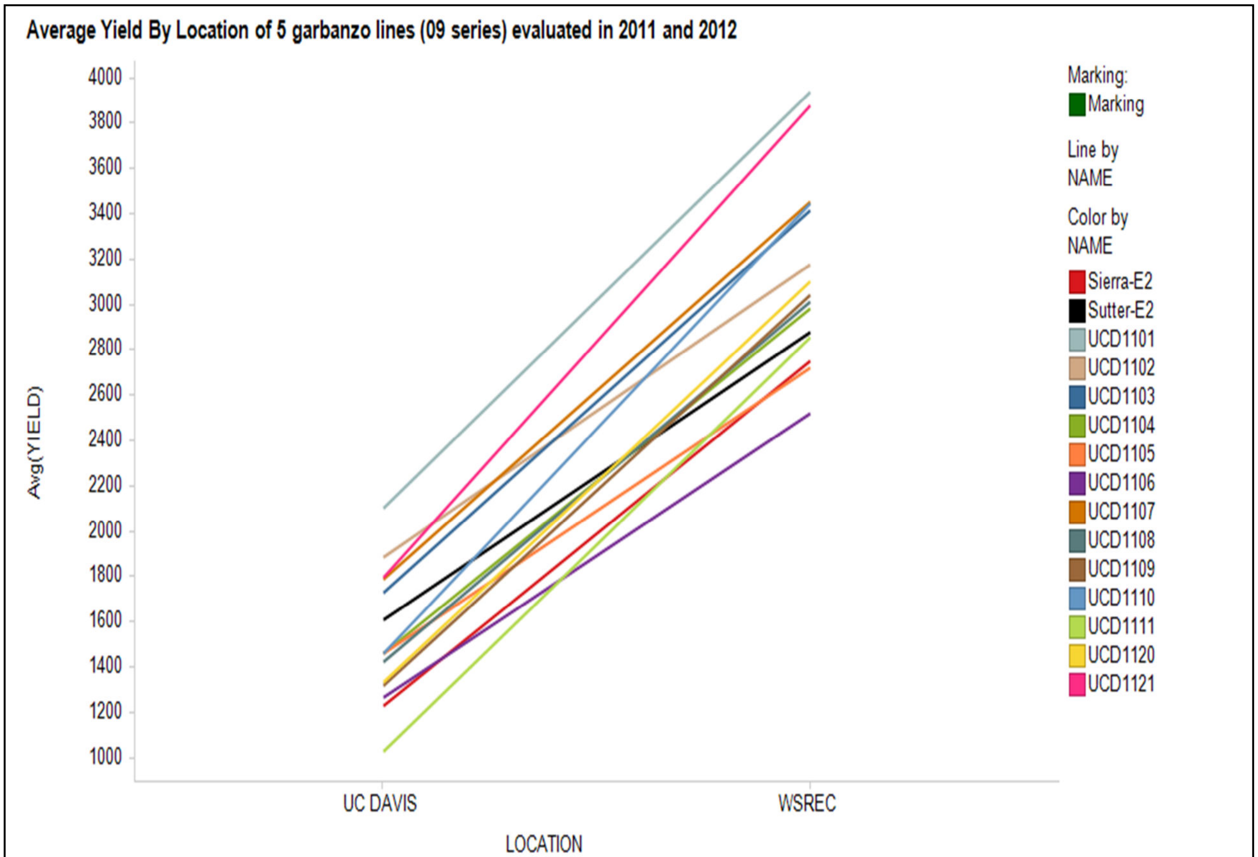


Figure 4. Average yield (Lbs/A) by location of 5 garbanzo lines (11 series) evaluated in yield trials in 2011 and 2012.

Table 6. Mean yield across locations and grain quality data for 30 garbanzo genotypes evaluated at UC Davis and WSREC in 2012.

NAME	ENTRY	YIELD	*	C.V.	RANK	GROUP[1]	Seed Weight (Seeds/oz)	Canning Quality (%)
UCD1121	30	2485.0	qrst	44.9	1	a	92.0	53
UCD1101	6	2477.5	qrst	38.4	2	a	97.3	58.6
UCD1120	29	2410.0	qrst	44.6	3	ab	98.0	75
UCD1110	15	2277.5	rst	31.3	4	abc	80.7	59.5
UCD1102	7	2047.5	rt	31.6	5	abcd	85.0	60.25
UCD1107	12	2045.0	rt	20.9	6	abcd	88.7	55.9
UCD1103	8	2000.0	rt	30.9	7	abcde	85.3	39.05
Sutter	25q	1912.5	t	26.3	8	bcde	77.7	74.65
UCD1119	24	1885.0	t	28.1	9	cde	79.3	80
UCD1105	10	1852.5	t	24	10	cde	78.3	72.8
UCD1104	9	1845.0	t	32.1	11	cde	73.3	90.35
UCD0909	4	1812.5	t	33.9	12	cde	84.7	67.5
UCD1118	23	1807.5	t	35.8	13	cde	67.3	42.6
UCD0901	1	1800.0	t	27.4	14	cde	64.3	60
Westbase7	27s	1760.0	t	20.1	15	de	65.7	47
UCD1112	17	1697.5	t	39.5	16	de	114.7	31.7
UCD1111	16	1695.0	t	46.6	17	de	72.7	45.1
UCD1108	13	1650.0	t	24.4	18	de	99.0	77.95
UCD1115	20	1635.0	t	43.9	19	de	71.0	74.3
UCD1109	14	1625.0	t	27.9	20	de	62.3	71.15
AWF1	26r	1575.0	t	23	21	de	69.7	77
UCD1113	18	1555.0	t	28.6	22	de	65.7	85.55
UCD1106	11	1522.5	t	29.8	23	e	77.0	22.4
UCD0906	2	1487.5	q	34.4	24	f	77.0	53
UCD1114	19	1437.5	q	41.2	25	f	72.0	85.6
UCD0905	5	1432.5	q	31.7	26	f	62.3	96
UCD0903	3	1300.0	qs	26.8	27	f	65.3	89
UCD1117	22	1272.5	qs	51.2	28	f	53.7	48.55
Sierra	28t	1082.5	qrs	17.7	29	f	60.3	20.65
UCD1116	21	1082.5	qrs	31.4	30	f	72.3	65.9

**Means followed by a letter (q,r…), differ by a 2-sided LSD, from the means of check entries denoted by the same letter. [1] Group= Mean separation by Duncan's Multiple Range Test at p=0.0, Means followed by the same letter are not statistically different.*

B. Garbanzo Germplasm evaluation

Photo 1. Garbanzo core collection (n = 504) planted at UC Davis (DOP: March 10, 2012; Photo: May 18, 2012)

A group of 504 garbanzo lines representing the garbanzo "core collection" of the USDA Plant Introduction Station at Pullman, WA, were provided to the UC Davis Bean Improvement Program in 2012. This collection contains chosen accessions of desi and kabuli types representing the genetic diversity of the entire gene-bank collection, therefore, it contains a large variation for important traits like growth habit, maturity, seed type and yield. To evaluate this available diversity for use in the crop improvement, the 504 lines were planted during spring of 2012 in small plots at UC Davis. The objective was to evaluate the adaptability and seed production of these materials under California/local conditions (**Photo 1**). At the end of the season seed was collected from most of the materials, only 7 lines either didn't germinate or produce any seed at all. A large phenotypic variation was observed for seed type, whit 71% being desi type, 28.4% kabuli and 0.6% a mix of both. A large variation was also observed for the traits of interest, growth habits from prostrate to erect were observed as well as different maturity times, seed color, size and seed production by plot. **Figure 3** shows a large variation for seed size (1000 seed weight) and seed produced by plot. A large percentage of the lines with an average seed size of 3 and 4 yielded from 10 to 700 g, some kabuli types with very large seed size (4 and 5) also reached very good yield, from 20 to 530 g/plot. These lines represent a great opportunity for the breeding program and may become potential parents for future crosses to increase not only genetic diversity for yield and seed size but also for other economic traits.

C. Breeding for Fresh-type Chickpea

One of the research topics of the legume program is to pursue the development of new markets for grain legumes for California. A potential opportunity is the selection of varieties for a fresh (or green) harvest chickpea (similar to "edamame" soybean). Even though there is currently no chickpea varieties developed specifically for this purpose, there is demand in the market for consumption of fresh-type chickpeas (**Photo 2**). By analogy with soybean, such a variety would have larger seeds, thinner seedcoats, a more intense green color especially at earlier seed developmental stages, and higher sugar content.

Photo 2.Fresh-style garbanzos being offered in the market.

Photo 3. Six of the 7 lines with green seed color identified in the USDA garbanzo Core Collection and selected as parents for the crossing program at UC Davis

Seven lines with green seed color were identified in the core collection evaluation (**Photo 3**). The green color varies from pallid green to very strong green, the kabuli seed type (#2 in picture) with a pallid green color and had a very large seed size, however the seed production of the line (130gr) was below the average (289gr). 5 of the desi types with a smaller seed size yielded above the average, with yields ranging from 200 to 445 gr. The 7 lines evaluated in the core collection will be included in a crossing program with the commercial line Sutter and Sierra in 2013 as part of the research project of one of the PhD students in the bean group at UC Davis.

III. Lima Bean Breeding

A. Advanced Yield trials

An advanced yield test including 29 large lima bean lines was planted at the Cox-Perez Ranch in Westley during the summer of 2012. The trial represented a second year of evaluation of limas that had been evaluatedevaluated for yield and resistance to the nematodes*M. incognita* and *M. javanica*(with the assistance of P. Roberts, UCR) at the Kearney Agriculture Center in previous years. The lines tested in the replicated yield trial at Westley are putative hybrids of either UC 92 or the nematode-resistant selection "459-1".The trial was planted in a very good field; weather conditions and very good management practices allowed a significant increase in yield (4627lbs/A), compared to that obtained in 2011 (3200 lbs/A). The C.V. of 9.9% indicates a very high quality experiment (**Table 7**). Statistically significant differences were observed for yield among entries (**Table 8**). The experiment suggested a fairly high level of homogeneity among entries (the majority of the lines belonged to the same statistical class: abc. Nevertheless, several superior lines were identified: 11(11)16, 12(11)275-276, 11(11)24, and11(11)15. Together with superior lines from the 2011 trials, these lines should be introduced into larger, strip trials in several locations to more accurately estimate their yield potential. In parallel, these lines will be assayed with P. Roberts (UCR) for their nematode resistance.

Table 7. Analysis of variance for Yield of 32 lima bean genotypes evaluated at Westley, CA in 2012.

Source	df	SS	MS	F-value	Pr>
Total	119	36374132.01			
BLOC	3	5701015.533	1900339	9.08	0
ENTRY	30	12670491.83	422349.7	2.02	0.0063
Residual	86	18002624.65	209332.8		
Grand Mean=	4627.432		R-Square=	0.5051	
C.V=	9.89%		Heritability=	0.203	
LSD=	922.698		Significance at	1%	

Table 8. Mean Yield of 31 Lima Bean Genotypes Evaluated at Westley, CA, in 2012.

Name	Entry	Mean	C.V.		Rank	Group[1]
11(11)16	19	5163.75	6.1	q	1	a
12(11)275-276	28	5115	5.7		2	a
11(11)24	26	5027.5	7.5		3	ab
11(11)15	10	5021.25	6.2		4	ab
12(11)201-203-209-210	20	4983.75	14.2		5	abc
12(11)229-230	23	4971.25	7.2		6	abc
11(11)1	21	4967.5	5.6		7	abc
11(11)13	27	4952.5	11		8	abc
12(11)277-278	29	4863.75	4.9		9	abc
11(11)3	9	4847.5	9		10	abc
12(11)237-238	24	4828.75	15.3		11	abc
11(11)10	25	4730	18.1		12	abc
11(11)7	16	4720	14.2		13	abc
11(11)21	15	4697.5	16.8		14	abc
11(11)17	11	4683.75	16.4		15	abc
11(11)28	14	4645	18.5		16	abc
11(11)5	18	4641.25	8.2		17	abc
11(11)8	3	4623.75	11.1		18	abc
11(11)26	22	4482.5	8.1		19	abc
12(11)133-134	12	4478.75	16		20	abc
11(11)4	17	4476.25	9.6		21	abc
11(11)29	6	4455	6.5		22	abc
Dompe 95	**31r**	4408.75	3.5		23	abc
11(11)11	2	4387.5	16.3		24	abc
11(11)18	8	4325.58	9.8		25	abc
UC 92	**30q**	4310	2.3		26	abc
12(11)67-68	7	4265.58	6		27	abc
11(11)20	4	4178.25	7.7		28	abc
11(11)12	13	4151	10		29	abc
11(11)19	5	4081.25	8.1		30	bc
11(11)9	1	3966.25	5.2		31	c

B. Evaluation of Lima Bean Germplasm

A sample of some 250 lima bean lines was obtained from the Genetic Resources Unit at the International Center for Tropical Agriculture (CIAT) in Cali, Colombia. This center houses the world collection for *Phaseolus* beans. This sample represented the broadest diversity possible for lima beans. It was planted in late June at UC Davis only (**Photo 4**). A smaller sample was obtained from Dr. James Beaver at the University of Puerto Rico, resulting from explorations conducted in the Caribbean islands. The observation nursery for both samples turned out to be a disappointment as they consisted mostly (CIAT) or entirely (PR) of entries that were highly sensitive to photoperiod: they are adapted to short days (long nights) and, therefore, expressed delays in flowering well into the Fall 2012. About ten percent of the CIAT collection did flower, however, at a normal date (late July or August) and were harvested for further evaluation in 2013 (**Photo 5**).

C. Identification of a Marker to Check for Hybridity in Lima Bean Crosses (Funding from the California Crop Improvement Association)

Because California lima bean varieties are very similar in their appearance, it is often difficult if the progenies of crosses are actually hybrid instead of selfings from the female parent. Morphological traits, such as pigmentation or plant type are not helpful with few exceptions. Molecular markers allow us to determine hybridity with more certainty and earlier in the progeny's cycle. Based on this need in the breeding program, we searched for a polymorphic marker to genotype lima bean progeny from crosses involving UC 92 and UC Haskell. Such a marker would allow us to visually test for heterozygosity by simple lab techniques involving PCR and agarose gel electrophoresis. Once hybridity in the F_1 has been determined, further selfing generations (without further marker tests) can lead to recombinant inbred populations for genetic analysis and can be used again during the development of backcross populations for future breeding work.

Twenty Simple Sequence Repeat (SSR) markers were tested, which were known to be polymorphic in common bean (*Phaseolus vulgaris L.*) based on previous work (Yu et al. 2000, Gaitán-Solís et al. 2002, Blair et al. 2003, Kwak and Gepts 2009). All 20 sets of primers were tested on both Lima bean (*Phaseolus lunatus*) inbred parents, UC Haskell and UC 92, to see if any would give a co-dominant polymorphic banding pattern. Plant DNA was extracted using Qiagen genomic DNA purification kit (cat. no.#69104). PCR conditions for all reactions were the same except for their annealing temperatures which varied from 47°C to 52°C. Reagent concentration was as recommended by New England Biolabs for Taq DNA Polymerase with ThermoPol Buffer (cat. no.#M06267). Most markers produced amplicons with both parents, but did not show size variation on the agarose gel. Pv-ctt001 was chosen as the marker to use because it showed the greatest difference in PCR product length. This was verified by testing Pv-ctt001 on 14 more Lima bean tissue extracts and it showed a consistent banding pattern for all UC 92 and UC Haskell parents, both between ~750 bp and ~1 kb, but with UC Haskell ~100 bp larger. Pv-ctt001 was then used to test F1 progeny to see if crosses were successful and produced heterozygote offspring which would show markers from both parents or inadvertent selfs, which would only show the marker for the female parent. The DNA standard used for these reactions

Photo 4. Lima bean germplasm collection introduced from a) the gene bank at CIAT (Cali, Colombia), left in the photo; and b) Dr. J. Beaver, University of Puerto Rico, right in the photo. Most accessions were viny types and, eventually, showed high levels of photoperiod sensitivity, delaying their flowering well in to Fall 2012.

Photo 5. Seeds of recent lima bean introductions harvested in Fall 2012 at UC Davis.

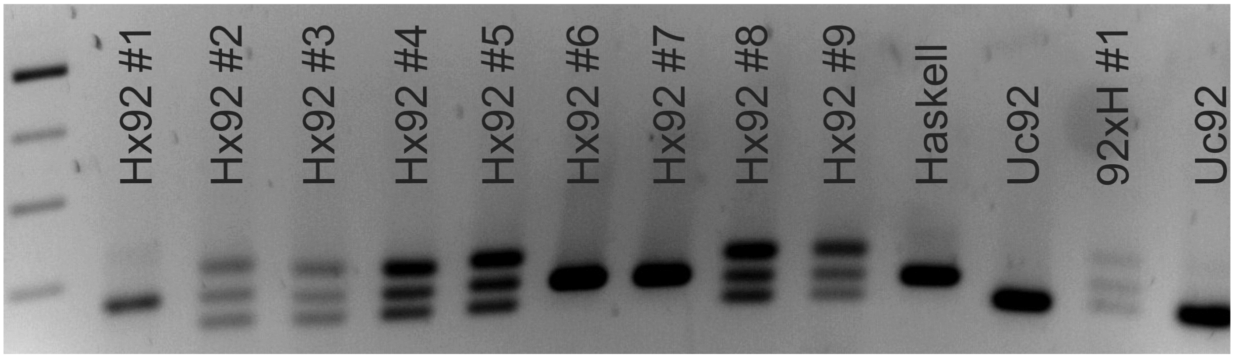


Figure 5.Molecular marker to distinguish selfs from hybrids in the progeny of crosses between UC 92 and UC Haskell. Each lane is a separate individual. Individuals Hx92 #2, #3, #4, #5, #8, #9, and 92xH #1 are hybrids (3-banded pattern), whereas Hx92 #1, #6, and #7 resulted from selfing in the female parent.

was All Purpose Hi-Lo DNA Marker by bionexus. The amplicons of interest run between the 750 b.p. and 1 kb bands. The heterozygotes show a triplet banding pattern rather than the expected doublet of the combined parents. This third band, which is slightly larger than both of the expected amplicons is referred to as a stutter band, which is due to DNA slippage during PCR amplification because of the highly repetitive simple sequence in the SSR marker. This is a common result of using SSR markers (**Figure 5**).

Table 9. Seed stocks for the UC Haskell/UC 92 cross for the development of genetic and breeding populations

Cross	**Number of seeds**
UC Haskell x UC 92 BC$_1$	44
UC 92 x UC Haskell BC1	53
UC Haskell x UC 92 F1 (not genotyped)	51
UC 92 x UC Haskell F1 (not genotyped)	41

Twelve F1 plants for crosses in each direction were grown. Nine of the twelve, 75%, of the UC Haskell (♀) x UC 92 (♂) progeny tested were heterozygous. Five of twelve, 42%, of the UC 92 (♀) x UC Haskell (♂) progeny tested were heterozygous for the Pv-ctt001 marker. Based on the success rates of these crosses and the total number of seeds I collected which will be genotyped upon planting need, I expect to have 42 UC Haskell x UC 92 F$_1$ seeds and 17 UC 92 by UC Haskell F$_1$ seeds as backups. Genotyped heterozygous plants were used as males for backcrosses to inbred parents as well as for production of F$_2$ seeds which are currently growing (**Table 9**).

Table 10. PCR conditions for the analysis of marker Pv-ctt001

PCR Conditions	°C	Sec.	cycles
Initial Denature	95	30	1
Denature	95	30	35
Annealing	47	45	
Extension	68	60	
Final Extension	68	300	1

Yu et al. 2000

For the sake of completeness, other conditions for the analysis of the Pv-ctt001 marker are given here (**Table 10**). The actual microsatellite sequence is (CTT)$_3$(T)$_3$ (CTT)$_6$. The forward primer is **TGTAAACGACGGCCAGTATGC**GAGGGTGTTCACTATT GTCACTGC ; and the reverse primer is TTCATGGATGGTGGAGGAACAG .

IV. Common Bean Breeding

A. Cooperative Dry Bean Nursery-2012

The Cooperative Dry Bean Nursery is an initiative of the North American bean breeders. Each breeder propose 2-3 varieties for addition to the roster of the CDBN for the ongoing year. In turn, these varieties are then planted in the respective locations of the contributors. For 2012, the locations were California, Colorado, Idaho, Maryland, Michigan, Montana, Nebraska, New York, North Dakota, Washington, and Wyoming State Experiment Stations and Agricultural Research Centers- as part of the Regional W2150 Multi-State Projectand the University of Guelph, Canada, andAgriculture Research Service – USDA at Prosser, Washington.

At UC Davis, the trial gave excellent results. The average yield was 2880 Lbs/A with a coefficient of variation was 12% (**Table 11**). The two entries representing UC Davis were UC 0801 (cranberry type) and UC 9634 (pink type), with yields of 2,983 Lbs/A and 3,381 Lbs/A, respectively. Overall, the three pink varieties included in the nursery showed high yield and yield stability (**Table 12**).

Table 11. Mean Squares from the Analysis of Variance for yield (Lbs/A) and days to flowering (DF) of 20 common bean genotypes evaluated at UC Davis in 2012 as part of the 2012 Cooperative Dry Bean Nursery (CDBN).

Source	df	MS YIELD		MS DF	
BLOC	3	82115.62		1.73	
Variety	19	664064.87	***	11.01	***
Residual	57	120767.60		2.36	
Grand Mean		2879.75		45.17	
R-Squared		0.65		0.79	
C.V.		12.07%		3.40%	
Herit.		0.53		0.71	
LSD		654.84		2.89	

B. Drought Tolerance Nursery

Drs. C. Urrea (U. of Nebraska) and T. Porch (USDA-ARS, Puerto Rico) provided a nursery of selected common bean lines that had been bred for tolerance to drought. Some additional materials were added to this nursery, including known sources of drought tolerance and UC Davis-developed lines. The type of drought stress applied was a terminal type, with withholding of the last irrigations, i.e., primarily during pod development primarily.

Table 12. Yield (Lbs/A) and days to flowering (DF) of 20 common bean varieties evaluated at UC Davis as part of the 2012 Cooperative Dry Bean Nursery (CDBN)

Line	Source	Grain Type	YIELD	Group[1]	DF[2]	Group
PT9-6	Miklas-USDA-ARS	Pinto	3455.0	a	48.3	e
PK9-4	Miklas-USDA-ARS	Pink	3425.0	a	45.5	abcde
UCD9634	Gepts-UCD	Pink	3381.3	a	44.3	abcd
Othello	Miklas-USDA-ARS	Pinto	3351.3	a	41.5	a
Long´s Peak	Brick-CSU	Pinto	3337.5	a	43.8	abcd
ISB-11	ISB-Bean	Pinto	3227.5	ab	46.8	cde
Rosetta	Kelly-MSU	Pink	3006.3	abc	47.0	cde
ND020351-R	Osorno-NDSU	Pinto	2991.3	abc	47.8	de
UCD0801	Gepts-UCD	Cranberry	2982.5	abc	46.0	bcde
Rexeter	Smith-Guelph	Navy	2966.3	abc	48.5	f
ISB-24	ISB-Bean	Pinto	2856.3	abcd	43.8	abcd
SR10-20	Miklas-USDA-ARS	Red	2832.5	abcd	43.8	abcd
CGN9-1	Miklas-USDA-ARS	G. Northern	2793.8	abcd	46.0	bcde
ISB-16	ISB-Dean	Pinto	2787.5	abcd	42.8	abc
Coyne	Urrea-NE	G. Northern	2537.5	bcd	43.3	abc
ISB-18	ISB-Bean	Pinto	2468.8	bcd	42.3	ab
T-39	Miklas-USDA-ARS	Black	2361.3	cd	51.3	f
Rio Rojo	Osorno-NDSU	Red	2357.5	cd	45.0	abcde
CELRK	Check-UCD	LRK	2291.3	cd	41.5	a
Majesty	Ruppert AAFC	DRK	2185.0	d	44.8	abcde

[1] Group= Mean separation by Duncan's Multiple Range Test at p=0.01. [2] Means followed by the same letter are not statistically different. [2]DF= days to flowering measured by the number of days from planting to when approximately 50% plants in a plot have at least one opened flower.

Results showed a good quality trial (CV ~ 14%) (**Table 13**) with statistically significant differences between the irrigated and non-irrigated treatments and among varieties (**Table 14**). Although successful at imposing a drought stress, the stress could have been stronger to allow us to better distinguish different varieties. Nevertheless, there were some very good materials, with yields statistically above known drought tolerance sources, such as BAT 477 and SEA 5. Another observation was that there was good correlation with and without drought stress (**Fig. 6**).

Table 13. Mean Squares from the Analysis of Variance for yield (Lbs/A) of 26 common bean genotypes evaluated under terminal drought at UC Davis in 2012 (Split plot design: MP: Main Plot; SP: Sub-plot)

Source	df	SS	MS	F-value	Pr>
Model	57	32007070.30	561527.55	6.78	<.0001
Error	104	8614531.70	82832.04		
Total	161	40621602.00			
BLOC	2	411960.48	205980.24	2.49	0.0881
MP (Irrigation)	1	2476054.22	2476054.22	29.89	<0.0001
MP *BLOC	2	97837.15	48918.57	0.59	0.5559
SP (Genotype)	26	27574593.67	1060561.29	12.80	<0.0001
MP *SP	26	1446624.78	55639.41	0.67	0.8778
Grand Mean=	2000.111		R-squared=	0.7879	
C.V.=	**14.38%**		LSD for MP=	123.1062	

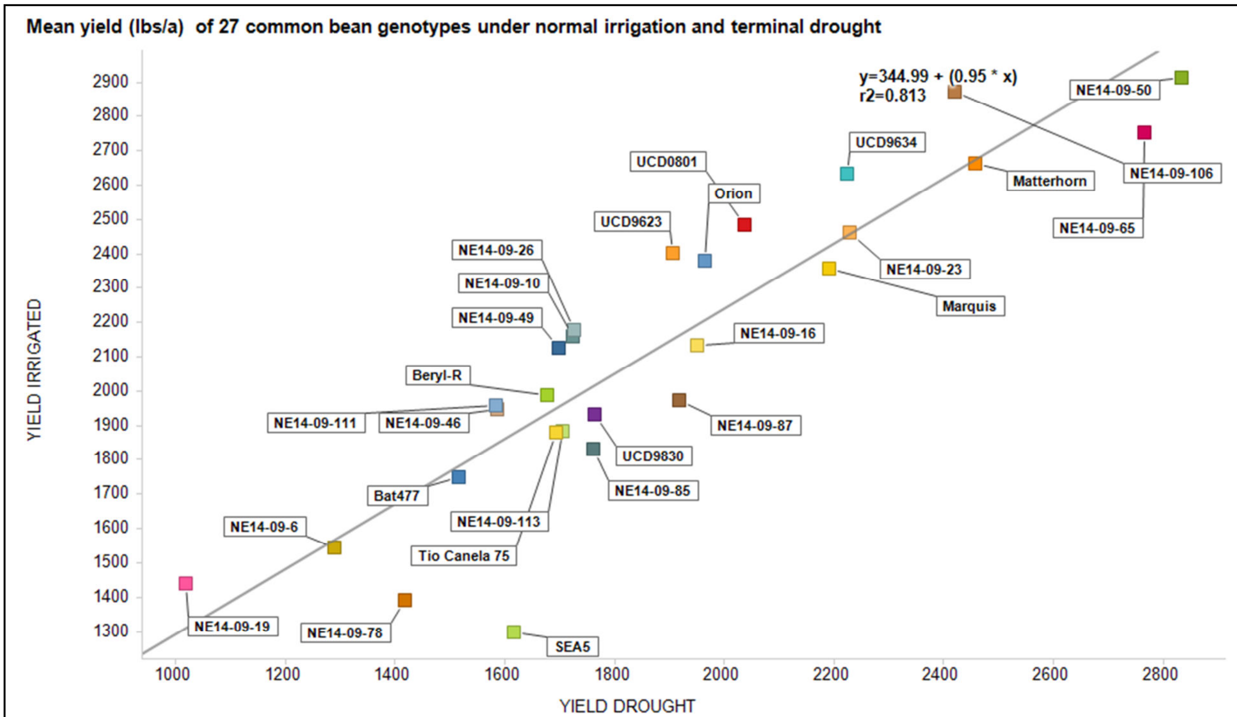


Figure 6.High level of correlation between performance under drought stress and irrigated yields.

Table 14. Mean yield (Lb/A) of 27 genotypes of common bean evaluated under terminal drought conditions at UC Davis in 2012.

Name	Entry	Mean	C.V.	Rank	Mean Sep.
NE14-09-50	8	2873.33	10.1	1	a
NE14-09-65	9	2760	12.9	2	ab
NE14-09-106	13	2646.67	14.3	3	abc
Matterhorn	17	2560	9.9	4	abcd
UCD9634	24	2428.33	16.3	5	abcde
NE14-09-23	4	2345.83	15.6	6	abcdef
Marquis	18	2274.17	6	7	bcdef
UCD0881	26	2260.83	22.3	8	bcdef
Orion	19	2171.67	15.8	9	cdef
UCD9623	25	2153.33	15.4	10	cdef
NE14-09-16	3	2041.67	9.1	11	def
NE14-09-26	5	1952.5	18.4	12	ef
NE14-09-10	2	1942.5	21.6	13	ef
NE14-09-49	7	1912.5	14.1	14	ef
UCD9830	27	1847.5	16.3	15	f
Beryl-R	20	1833.33	10.7	16	f
NE14-09-85	11	1795.83	13.1	17	g
NE14-09-113	15	1794.17	6.9	18	g
TioCanela 75	23	1786.67	12	19	g
NE14-09-111	14	1771.67	19.7	20	g
NE14-09-46	6	1765.83	18.5	21	g
NE14-09-87	12	1692.5	35.5	22	g
Bat477	22	1632.5	16.6	23	g
SEA5	21	1457.5	17.3	24	g
NE14-09-6	1	1416.67	19.4	25	g
NE14-09-78	10	1404.17	22.6	26	g
NE14-09-19	16	1229.17	25.3	27	g

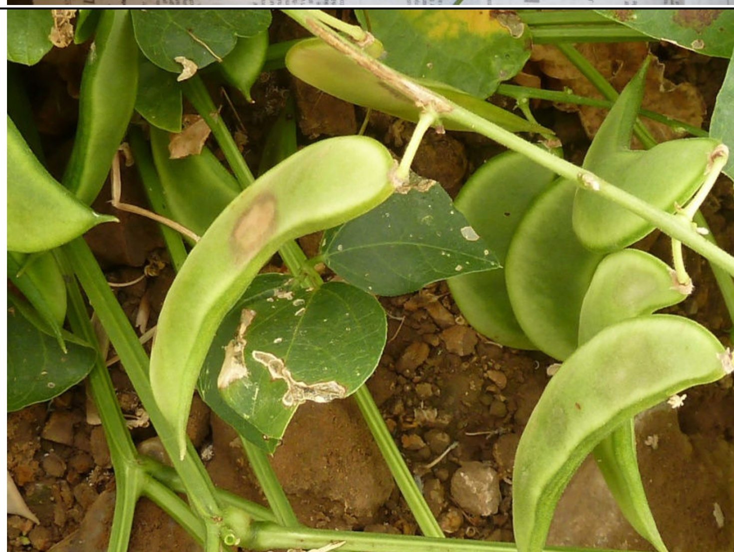
V. Additional Activities

A. Chocolate Blotch

Report on Visit to Field of Bush Baby Lima variety in Westley
By: Mayumi Acosta and Paul Gepts (Bean Breeding, UC Davis)
Date: 2012-08-14
Observations (with additional observations from UC Davis, Knights Landing locations)

The field was located northwest of Westley. The variety planted was UC Beija-Flor.

The field was very uniform and clean of weeds. The lima bean plants had reached the pod fill stage for the crown set and were still flowering in the top part.

A variety of symptoms were observed mostly on leaves. These symptoms include necrotic blotches of various shapes and sizes, distributed seemingly at random over the leaflet surfaces. There were no insects like mites, but in some cases leaf miners were observed.		
Pods showed a few symptoms.		
The symptoms observed were unlike those observed for a fungal disease called *Alternaria*, which had been proposed before as a potential causal agent. For typical symptoms of *Alternaria*, see photo to the right.		http://gardener.wikia.com/wiki/File:Bean_Brown_Spot_Alternaria_alternata.jpg

Plants with symptoms were distributed in broad gradients (from heavy symptoms to no symptoms); no foci with strong symptoms were observed as might be expected from infections by pathogens or infestations by pests. The two observations are important to find out the cause of this problem:

First, along the irrigation pipe, plants on the outside of the pipe (left in the photo) had fewer or no symptoms compared to those on the flow side of the pipe (right of the pipe in the photo). One possible explanation is that excess water (or toxic compounds in the water) may be responsible for the symptoms observed.

Second, at the opposite end of the field, we observed plants with either heavy symptoms and symptomless plants within a short distance from each other. The plants with symptoms were found near the terminal irrigation ditch but with remnant (stagnant) water from the last irrigation in that ditch, suggesting prolonged exposure to irrigation water.

In contrast, some 20' away from these plants, there were symptomless plants but in areas where the irrigation ditches were completely dry, suggesting less exposure to irrigation water.

Current hypothesis: The "chocolate" blotching may be due to a toxic compound included in the irrigation water. This raises a number of questions:

1) What is the nature of the toxic compound?
2) What is the origin of the water used for irrigation?
3) Have fertilizers or pesticides been added to the irrigation water?
4) Are the different lima bean varieties all susceptible to the same degree?
5) Is there an alternative explanation? E.g., direct or secondary involvement of a pathogen?
6) What is the effect on yield, if any, of this condition?

A plant analysis received from David Von Riesen (Westan Growers) shows an excessive level of boron. Yet the plants did not show the typical symptoms of boron toxicity: marginal chlorosis and necrosis on leaves. Thus, there should be an alternative or complementary cause (without excluding the involvement of boron). Further analyses show higher levels of boron in plants with symptoms compared to those without symptoms in the Westley field.
Isolation attempts by Mike Davis (Plant Pathology Dept.) yielded no possible fungal or bacterial infectious agents.

Other reports show this to be a more widespread problem: locations include Westley, State Rd. 152 & San Joaquin River (three cases described by Shannon Mueller), Knights Landing, and Dixon.

What needs to be done?

1) Systematic survey of lima bean fields with or without symptoms: Which source of water? Any additions to the water? This would help answer the question whether river vs. well water may be responsible, and whether any water additive could also be involved.
2) In these same fields, which varieties showed symptoms and to what extent? This would show whether there is a genetic component. So far, UC Beija-Flor, UC 92 and UC Luna have been reported.

3) Seed stocks from selected field can be planted in a greenhouse at UC Davis and checked for symptoms? This would help determine whether any seed-transmitted factor (including a pathogen) is involved.
4) There is a potential confounding symptom, namely damage by leaf miners.

B. Field Days and Other Activities

- With assistance from the farm advisors – Carol Frate, Shannon Mueller, and Rachael Long, three field days were organized. Two early in the year for the garbanzo experiments at the West Side REC (May 23, 2012) and UC Davis (May 24, 2012), and the third one at UC Davis for the common bean trials on Sept. 6. 2012.

- P. Gepts hosted Nathan Sano and Japanese visitors on Sept. 25, 2012.

- Harvests at Kearney took place with the assistance of C. Morris, with funding provided by the UC Davis Bean Breeding program (funded by CDBAB)

- Our application – with R. Long and Larry Godfrey – to the Specialty Crops Block Grant (managed by CDFA) was unsuccessful. This project would have dealt with integrated pest management of Lygus in UC Haskell (with L. Godfrey, UC Davis Dept. of Entomology), nitrogen balance management (with R. Long), and breeding for these traits (P. Gepts). CDFA does not provide comments as to why proposal are rejected. A pre-proposal has now been submitted to the CDFA SCBG to develop fresh-type garbanzo varieties.

- An application was submitted by P. Gepts to US AID to develop new common bean varieties with drought tolerance.