Final Report for Wyoming Bean Commission

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Comparison of Commercial Dry Bean Cultivars and Experimental Breeding Lines Grown under Deficit and Full Irrigation using Sprinkler Delivery

Introduction

Drought tolerance is not necessarily an important trait for dry bean grown in Wyoming if water supply is plentiful and the irrigation systems function well. Unfortunately however, there are numerous times when irrigation is delayed or times when only limited amounts of water can be applied. It is for this reason, that part of our research program is focused on not only identifying ***existing*** cultivars that perform well under deficit irrigation but also how our new ***experimental*** genotypes react. Our experimental lines are going to need some degree of drought tolerance if those genotypes are going to have market appeal beyond Wyoming. The objective of this research was to quantify the response of multiple commercial and experimental genotypes to drought.

Methods

Two experiments were located side-by-side at the University of Wyoming Research and Extension Center in Powell, Wyoming. The soil, a Garland clay loam (fine, mixed, mesic: Typic Haplarid), was prepared by roller harrow and leveled in the spring. The entire plot area did not receive any N but did receive 70 units of P, 70 units of K, 3 units of sulfate-S, 40 units elemental S, and 5 units of Zn on 27 April 2023. Chemical weed control consisted of a preplant incorporated chemical treatment of 2 pints of Sonalan, 3 pints Eptam, and 1 pint of Orro applied on 31 May 2023. Cultivation occurred during the growing season when appropriate.

The first study (hereafter called SPDT, Screening Progeny for Drought Tolerance) was divided into nine segments, one-tenth of an acre each in size. Three random segments received full irrigation throughout the season, three other random segments received slight/moderate deficit irrigation, and the other three random segments received severe deficit irrigation. These differential irrigations were only imposed beginning one-month after planting to allow uniform stand establishment, but the irrigation differentials were maintained season-long after that. A sprinkler irrigation system was used and delivered 1.0-inch per week for the full irrigation but only 0.8-inch and 0.6-inch per week was applied to the two reduced irrigation segments, respectively.

Seed were planted on 6 June in three-row plots that were 5.5 feet wide and 20 feet long using a six-row Almaco planter (one genotype/entry/line was distributed across three rows). Hereafter, all of the entries, commercial and experimental, will be referred to as "**genotype**(s)." Row spacing was 22-inch and seeding rate was approximately 90K seed per acre. The experimental design was a split plot with three replicates. The main plot was irrigation rate and the subplot was genotype. Each of the nine irrigation "sections" contained a total of 26 plots with each genotype being assigned nine distinct plots, once per "section." Genotypes with a letter-dash-number name represent our experimental genotypes (e.g., B-3, C-9, E-3, etc.) with the exception of PT9-5-6 which is now a USDA release under a new name. The study also included one small-seeded tepary-type bean (called M-10 for this trial). Overall, there were 234 plots (Fig. 1).

The second and parallel study (hereafter called the DDP) was also planted at Powell in lieu of our not conducting a trial at Sheridan (due to inability to accurately deliver differential irrigation at that location). In the DDP, 169 genotypes from the Durango Diversity Panel consisting of Great Northern, pink, pinto, and small red genotypes were planted in only one plot for each in the irrigation rates described above (substantially reduced statistical power compared to the SPDT trial). For the DDP study, one of the side objectives was to increase seed for 2024 because we were only provided enough seed of the 169 lines for three plots in 2023.

Variables and Traits Measured

For the SPDT, canopy temperature (measured with an Apogee MI-2H0 infrared radiometer on selected clear sky days), normalized difference vegetation index (NDVI measured with a hand-held Rapid Scan CS45), flowering date, leaf stomatal density on six selected lines, maturity date, conventional harvest yield, direct cut harvest yield, number of seed per pound (also presented as its reciprocal, average seed size in milligrams), number of mature pods per square foot or per square meter, number of seed per pod. This latter two variables are arrived at by individual plant sampling and hand-threshing of selected plants at maturity. Seed protein concentration (Perten DA7250 analyzer) was also measured. Actual seed per pod and number of mature pods per square foot (or square meter) are not presented but the percent change from 60% ET to 100% ET irrigation for those two variables for each genotype is presented. The tables use the units of pods per square meter, but as far as percentage change, the values would be identical regardless of units of pods per square foot, pods per square meter or per acre. For the SPDT, values for genotypes G-2 and M-10 were excluded from the most of the statistical analyses due their extremely low yields across all irrigations.

For the DDP, canopy temperature, NDVI, flowering date, maturity date, conventional harvest yield, direct cut harvest yield, number of seed per pound (also presented as its reciprocal, average seed size), leaf stomatal density, and seed protein concentration were measured.

Figure 1. Views of the two studies at Powell REC in 2023 (mid-June and mid-July).

Results and Discussion

Irrigation Differences, SPDT. Canopy temperature (averaged across all 26 lines) measured on three dates indicated that the severe deficit irrigation canopies were warmer than the moderate deficit and full irrigation plots which were similar to each other (Fig. 2 for Celsius and Fig. 3 for Fahrenheit). Plant height and yield obtained via conventional harvest was increased as irrigation amounts were increased (Figs. 4 and 5). NDVI on 23 July 2023 was not significantly affected by drought but the severe deficit irrigation did have numerically lower NDVI (0.59) than the moderate deficit irrigation (0.67) and the full irrigation (0.65) (data not shown in a separate table). A higher NDVI indicates a healthier canopy. Averaged across genotypes, the number of seed per pound decreased as irrigation rate increased (severe deficit, 1669; moderate deficit, 1592; full irrigation, 1513; data shown later) indicating that full irrigation help making the seed more plump (Tables 3 and 4).

Difference among Lines, SPDT. Averaged across the three irrigation regimes, entries with the highest NDVI were Othello, M-5, Max, and Poncho (all greater than 0.70) with M-5 being the only late-maturing type among that group of four (data not shown in a separate table).

In order to quantify drought tolerance, we have chosen to use the average yield across the three irrigations as our measure. The rationale of using all three yields is somewhat, but not completely, unique to us but is based on the idea that drought tolerance of a genotype does not just indicate good yield under drought relative to well-watered conditions but also indicates good yield across all situations (even optimal and/or water-plentiful conditions). Additionally, our categorization and calculations of drought tolerance focused almost entirely on the use of yield data from the 60% ET irrigation rate and the 100% ET irrigation rate and utilized little or no data from the 80% irrigation.

Yield differences across the three irrigations for the 26 lines showed that six genotypes were more drought tolerant (average yield greater than 2,400 pounds per acre) than the other 20 genotypes. As can be seen from Table 1, there was a trend for the early-maturing types (Max, Othello, Poncho) to outyield the later-maturing types. The inverse relationship between yield and maturity across all 26 genotypes is shown in Figure 6. Maturity dates for all three irrigation rates and all 26 genotypes are provided in Table 2.

It is premature to conclude that early-maturity equates to drought tolerance although early maturity is well known to help facilitate a crop's escape from late-season water deficits and to exhibit a more efficient use of water (yield/water applied) from a seasonal-use perspective. Late-maturing genotypes, despite having greater yield potential than early-maturing types, often have larger canopies with more leaf area, that are exposed to more days of evapotranspiration and more susceptible to greater loss and to drought. Due to this confounding with maturity (which does not occur every season), in later parts of this report, we have separated out the 26 genotypes into three groups (early-, mid-, late-maturity) in order to evaluate/compare would-be drought tolerance among the genotypes more fairly. The downside of breaking out genotypes into three maturity groups is that we have less than ten genotypes within a group which tends to weaken the genotype comparisons.

The differences among genotypes in the number of seed per pound (Table 3, the more popular units to present this variable for the seed industry) and its inverse seed size (Table 4, the weight of an average seed in milligrams used by crop physiologists) followed expected patterns.

Yield Component Analysis, SPDT. A summary of the drought tolerance of 24 of the genotypes (two genotypes were dropped due to extremely poor yield across all irrigations), as grouped by maturity, is presented Table 5 with yield cutoffs deciding each genotype's category. The three yield components that make up yield (pods per square foot or square meter, number of seed per pod, and seed size) were evaluated individually to determine if any of those traits in particular, conferred drought tolerance within the early-maturing, mid-maturity, and late-maturing types (Tables 6, 7, and 8). Across all 234 plots, actual values for pods per square meter ranged from 100 to 300 (or per square foot the range was 9 to 27 pods). Likewise, the range of values for the number of seed per pod was 3 to 5. We have not presented those raw yield component numbers elsewhere in the report.

Within the **early-maturing types** (Table 6), drought tolerance was associated with a reduced decline in yield (only 38%) associated with the deficit irrigation compared to the sensitive lines that a 60% decline (somewhat expected due to the way we assessed and quantified drought tolerance). Concomitantly, the drought-tolerant lines showed very little increase in number of pods per square meter (5%) when grown under full irrigation whereas the drought-sensitive types increased pod density per square meter by 34%. Conversely, drought-tolerance was associated with a 25% greater number of seed per pod upon full irrigation whereas drought-sensitive types only improved by 6%. Seed size (reciprocal of number of seed per pound) only increased 10% or less in response to full irrigation across the two groupings.

Within the **mid-maturing** types (Table 7), in contrast to the early-maturing types, drought tolerance was associated with a greater yield response to full irrigation than the drought-sensitive genotypes. Also, in contrast to the early-maturing genotypes, but with consistency to overall yield, the drought-tolerant genotypes responded greater to full irrigation in the number pods per square meter than drought-sensitive lines. The response of the two other yield components (seed per pod and seed size) responded similarly (15-19% increase for number of seed per pod across tolerant/sensitive and 8-13% increase for seed size across tolerant/sensitive).

Within the **late-maturing** types (Table 8), there was consistency when comparing the drought-tolerant vs. drought-sensitive types (averages) as far as the increases in overall yield (from severe deficit irrigation to full-irrigation, 46% and 53%) as well as the increases in the three yield components. There was expected variation within each group regarding yield and yield component percentage changes but the consistency within the three late-maturing drought-tolerant genotypes was surprisingly consistent.

Unlike previous years, we did not observe consistent correlations between yield and canopy temperatures in 2023. Exceptions for significant relationships between final yield and NDVI on 23 July were observed for 60% ET (Fig. 7) and 100% ET (Fig. 8). Likewise, significant relationships between final yield and canopy temperature were observed for 60% ET (Fig. 9) and 100% ET (Fig. 10).

Direct Harvest Recovery, SPDT. Each of the 234 plots were threshed using the conventional method (uprooting and feeding into the bundle thresher) as well as directly upon intact plants. Part of the reason for extremely low recovery values was a month-long delay for direct harvest vs. the earlier conventional harvest (due to weather and access to all plots as we waited for all plots in one strip to be ready prior to direct harvesting). Although recovery

percentages were lower than in previous years (38% averaged across all plots for 2023), there were trends for differences among the genotypes which was the purpose of the measurement (Table 9). As expected, upright stature was significantly affected by genotype with commercial cultivars commonly found in the Bighorn Basin showing their tradition vertical growth and average stature values greater than 8 (Table 10, Cowboy, Medicine Hat, Monterrey, Rattler, SV6139GR). However, several of our experimental genotypes (G-3, LPID-3, and NTL-1) also had upright stature ratings above 8. Upright stature is a useful trait for direct harvest as shown by the relationship between direct harvest recovery and upright stature (Fig. 11). The percentage of pods located above 4-inches are also presented in Table 9. As was the situation for upright stature, the percentage of pods positioned above 4 inches prior to direct harvest was also correlated with percent recovery (Fig. 12).

Seed protein concentration was greatest in several of breeding lines with LPID-7 having 20.3% protein (Table 11). Seed protein concentration was higher under the severe drought stress (60% ET) and averaged 18.3% vs. 17.1% at full irrigation.

Anatomical Traits SPDT. As part of a long-term experiment, and for six genotypes within the SPDT, we collected leaves for stomatal density and measured stomatal density (54 plots, 9 plots for each genotype). Stomata are the openings found on both leaf surfaces (adaxial or upper side and abaxial or lower side). We measured stomatal density on blades collected from the third uppermost trifoliolate leaves (described and shown in Fig. 13). During leaf development, stomata are created by the differentiation of epidermal cells into a pair of cells (called guard cells) that work together to form an opening during daylight hours (or a closure as happens at night) that allows CO_2 into the leaf and water vapor to exit the leaf. Botanically, one stomata is called a stoma (or maybe a stomate) and in dry bean the length of one stoma ranges from about 14 μm to 17 μm with stoma width being slightly less (around 10 μm to 15 μm). There was a non-significant trend for drought to increase stomatal density, likely due to leaf expansion being inhibited by drought which occurs after the leaf epidermal tissue has already differentiated into guard cells (the pair of cells that create one stomata) (Table 12).

Summary of Part A (SPDT)

Our results suggested that we have several progeny lines that have the potential to be competitive with many of the popular commercial lines as far as drought tolerance. The study is being repeated in 2024 and it is hoped that we will be able to narrow down which promising lines need to be advanced for testing across other dry bean producing states.

The report for Part B (DDP) continues after the tables and figures for Part A.

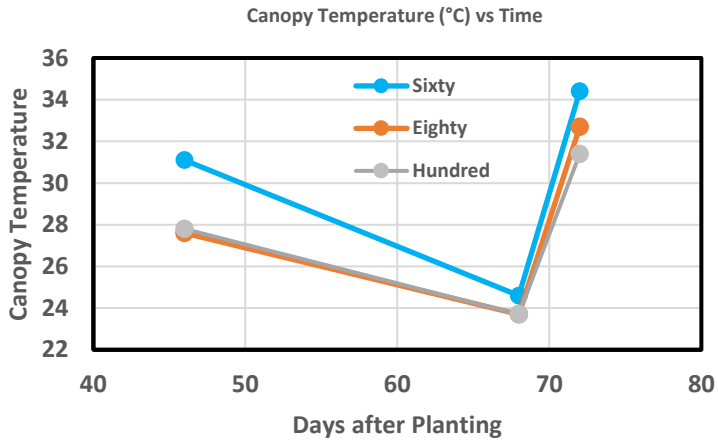

Figure 2. Canopy temperature (°C) of the three irrigation regimes (values are averaged across 26 lines.

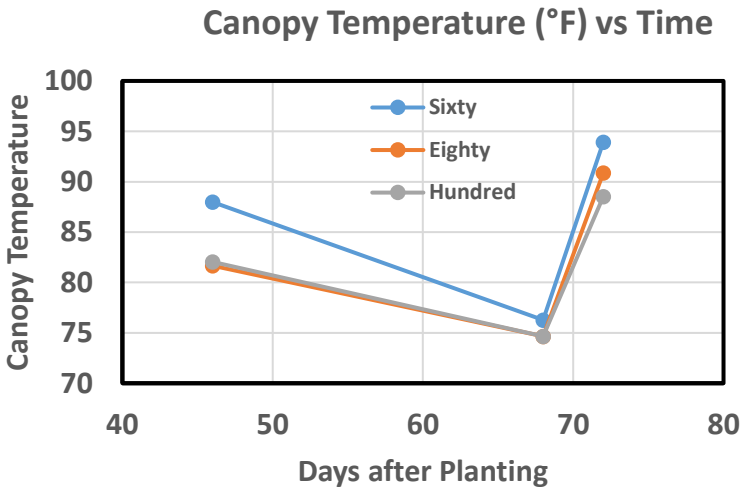

Figure 3. Canopy temperature of the three irrigation regimes (values are averaged across 26 lines.

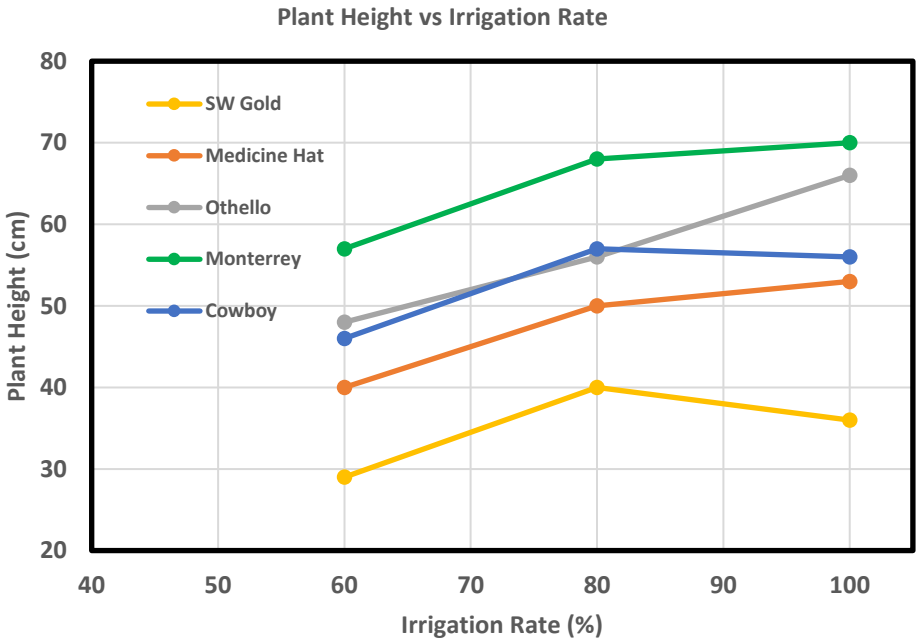

Figure 4. Effect of the different irrigation regimes on the final plant height of five selected lines in the SPDT trial in Powell 2023.

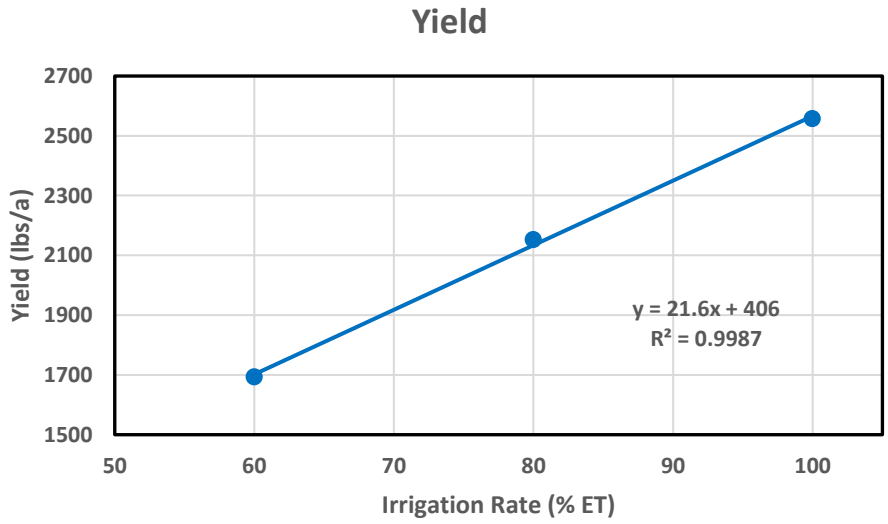

Figure 5. Effect of irrigation rate on yield (conventional harvest) averaged across the 26 SPDT entries. Each data point represents 78 plots.

Table 1. Yields (lbs/a) of the SPDT study at Powell 2023, across Three Irrigation Rates †‡§

Entry	**Irrigation Rate**			
	60% ET	80% ET	100% ET	Average
B-3	1526	2199	2484	2070
C-9	2084	2846	2599	2510
C-6	1650	2191	2295	2045
Cowboy	1686	2353	2712	2251
E-3	1406	2122	2204	1910
G-2	914	1800	1850	1521
G-3	1906	2439	2874	2405
H-3	1600	2186	2926	2237
LPID-3	1897	1679	2684	2087
LPID-7	1678	1976	2793	2149
LPID-9	1743	1689	2534	1989
M-5	1777	2224	2951	2318
Max	2097	2455	3083	2545
Medicine Hat	1952	2346	2403	2234
Monterrey	1600	2012	2569	2060
M-10	449	690	947	695
NTL-1	1876	2162	2645	2228
OLV-3	1715	2071	2618	2135
OSC-2	1665	2304	2477	2149
Othello	2326	2643	3168	2712
PT9-5-6	1796	2097	2524	2139
Poncho	2092	2430	2793	2438
Rattler	1566	2285	2450	2100
SV6193GR	1719	2476	3268	2486
Southwest Gold	1487	2165	1908	1853
Z-1	1810	2129	2718	2219
Average	1693	2152	2557	2134

† Each value (excluding the average rows/columns) is the mean across three replicates.
‡ Values were obtained from conventional harvest.
§ P-values were (Irrigation 0.049; Genotype, 0.001; Irrigation-by-Genotype, 0.135).

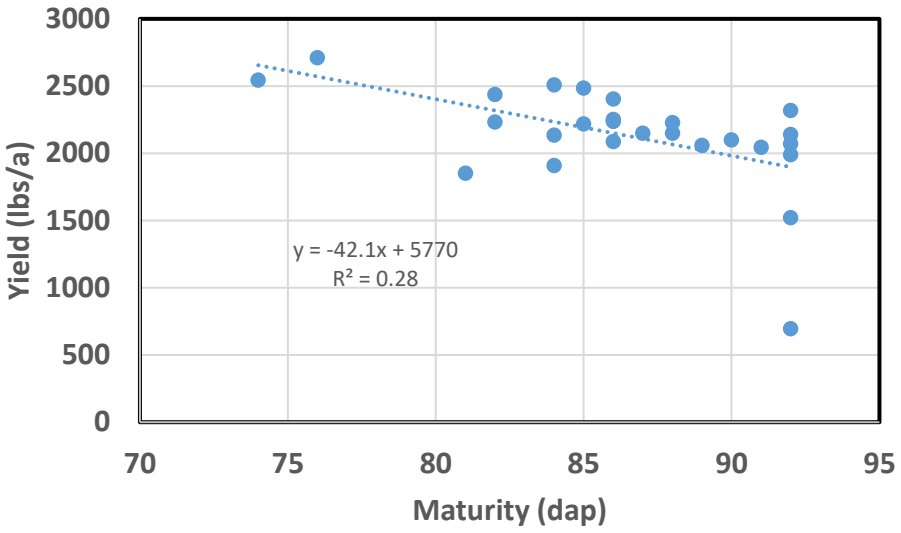

Figure 6. Relationship between yield and maturity for the 26 lines. Yields are averaged across irrigation rates. Each data point represents 9 plots.

Table 2. Maturity (dap) of the 26 genotypes in the SPDT study at Powell 2023, across three Irrigation Rates †‡§

Entry	Irrigation Rate			
	60% ET	80% ET	100% ET	Average
B-3	92	92	92	92
C-9	81	83	87	84
C-6	87	92	92	91
Cowboy	86	85	86	86
E-3	83	85	85	84
G-2	92	92	92	92
G-3	87	85	87	86
H-3	83	85	90	86
LPID-3	85	87	87	86
LPID-7	87	85	92	88
LPID-9	92	92	92	92
M-5	92	92	92	92
Max	68	77	77	74
Medicine Hat	79	83	85	82
Monterrey	89	87	90	89
M-10	92	92	92	92
NTL-1	87	87	90	88
OLV-3	83	85	85	84
OSC-2	85	85	92	87
Othello	74	76	79	76
PT9-5-6	92	92	92	92
Poncho	79	83	85	82
Rattler	87	90	92	90
SV6193GR	83	85	87	85
Southwest Gold	79	81	83	81
Z-1	81	87	87	85
Average	85	86	88	86

† Each value (excluding the average rows/columns) is the mean across three replicates.
‡ Values were obtained from conventional harvest.
§ P-values were (Irrigation 0.003; Genotype, 0.001; Irrigation-by-Genotype, 0.503).

Table 3. **Number of seeds per pound** for the 26 genotypes across Three Irrigation Rates. †‡§

Entry	**Irrigation Rate**			
	60% ET	80% ET	100% ET	Average
B-3	1768	1607	1642	1672
C-9	1786	1656	1477	1640
C-6	1624	1630	1480	1578
Cowboy	1360	1322	1295	1326
E-3	1825	1829	1723	1793
G-2	1234	1149	1083	1155
G-3	1587	1544	1420	1517
H-3	1962	1706	1528	1732
LPID-3	1313	1253	1158	1241
LPID-7	1555	1635	1417	1536
LPID-9	1431	1408	1330	1390
M-5	1332	1132	1126	1197
Max	1314	1236	1188	1246
Medicine Hat	1461	1404	1332	1399
Monterrey	1443	1373	1328	1382
M-10	4905	4465	4467	4612
NTL-1	1385	1373	1284	1347
OLV-3	1799	1863	1764	1809
OSC-2	1989	1799	1734	1840
Othello	1434	1403	1413	1417
PT9-5-6	1463	1475	1395	1444
Poncho	1321	1302	1273	1299
Rattler	1373	1297	1251	1307
SV6193GR	1423	1435	1346	1401
Southwest Gold	1905	1753	1642	1767
Z-1	1398	1337	1255	1330
Average	1669	1592	1513	1591

† Each value (excluding the average rows/columns) is the mean across three replicates.
‡ Values were obtained from conventional harvest.
§ P-values were (Irrigation 0.062; Genotype, 0.001; Irrigation-by-Genotype, 0.412).

Table 4. **Average seed size (mg)** for the 26 genotypes across Three Irrigation Rates. †

Entry	**Irrigation Rate**			
	60% ET	80% ET	100% ET	Average
B-3	258	282	277	272
C-9	254	274	308	279
C-6	281	278	308	289
Cowboy	334	344	350	343
E-3	249	249	264	254
G-2	369	395	419	294
G-3	287	295	319	300
H-3	231	267	297	265
LPID-3	246	365	394	368
LPID-7	294	279	321	298
LPID-9	318	323	341	327
M-5	340	401	403	382
Max	345	367	394	369
Medicine Hat	311	323	341	325
Monterrey	316	330	342	329
M-10	93	102	102	99
NTL-1	330	331	353	338
OLV-3	255	244	257	252
OSC-2	228	252	262	248
Othello	317	324	323	321
PT9-5-6	310	308	326	315
Poncho	343	349	358	350
Rattler	332	351	363	349
SV6193GR	319	316	337	324
Southwest Gold	239	259	276	258
Z-1	324	339	362	342
Average	293	306	323	307

† Each value (excluding the average rows/columns) is the mean across three replicates.
‡ Values were obtained from conventional harvest.
§ P-values were (Irrigation 0.049; Genotype, 0.001; Irrigation-by-Genotype, 0.135).

Table 5. Drought-tolerant genotypes as grouped within early-maturing, mid-maturing, and late-maturing genotypes found in Powell during 2023. Yields are averaged across irrigation rates (representing 9 distinct plots). Two genotypes (G-2 and H-10) were omitted from this table due to their extremely poor agronomic adaptation.

Maturity Group	**Tolerant/Sensitity Group**	**Genotype**	**Yield**
Early	Tolerant	C-9	2510
(74 - 84 dap)		Max	2545
		Othello	2712
		Poncho	2438
	Sensitive	E-3	1910
		Medicine Hat	2234
		OLV-3	2135
		Southwest Gold	1853
Mid	Tolerant	G-3	2405
(85 - 88 dap)		SV6139GR	2486
	Medium	Cowboy	2251
		H-3	2237
		NTL-1	2228
		Z-1	2219
	Sensitive	LPID-3	2087
		LPID-7	2149
		OSC-2	2149
Late	Tolerant	M-5	2318
(89 – 92)		PT9-5-6	2139
		Rattler	2100
	Sensitive	B-3	2070
		C-6	2045
		LPID-9	1989
		Monterrey	2060

Table 6. Yield component changes within the eight **early-maturing** genotypes (74 to 84 dap) at Powell in 2023. Drought tolerance or sensitivity of a genotype was determined by its average yield across three irrigation regimes (one full irrigation and two deficit irrigations). The percentage values below were calculated by taking the average of the 3 replicate plots (full irrigation) and 3 replicate plots (severe deficit irrigation) ignoring the moderate deficit irrigation values. Sprinkler irrigation was used. The average yield for each group under severe deficit and full irrigation is provided below the list of genotypes.

Drought-Tolerant Genotypes	Overall Yield Increase (%) †	Increase Pods per Square Meter (%) ‡	Increase Seeds per Pod (%) §	Increase Seed Size (%) ¶
Avg. Yield > 2400#/ac				
C9	36	1	26	8
Max	47	19	14	14
Othello	36	4	29	2
Poncho	33	-2	30	4
Group Average	**38**	**5**	**25**	**7**
Severe Deficit Yield Avg	2,150 ††			
Full Irrigation Yield Avg	2,911			
Drought-Sensitive Genotypes				
Avg. Yield (1830-2240#)/ac				
E-3	57	33	11	6
Medicine Hat	83	40	0	28
OLV-3	53	32	13	1
SW Gold	46	32	0	5
Group Average	**60**	**34**	**6**	**10**
Severe Deficit Yield Avg	1,640 ††			
Full Irrigation Yield Avg	2,347			

† Percent increase in yield (full divided by severe stress)
‡ Percent increase in pods per square meter (full divided by severe stress)
§ Percent increase in average seed number per pod (full divided by severe stress)
¶ Percent increase in average seed weight (full divided by severe stress)
†† The group percentage average may not match the percentage increase exactly due to the nature calculations involving the averaging of averages.

Table 7. Yield component changes of within nine **mid-maturity** genotypes from Powell 2023. Drought tolerance or sensitivity of a genotype was determined by its average yield across three irrigation regimes (one full irrigation and two deficit irrigations). The percentage values below were calculated by taking the average of the 3 replicate plots (full irrigation) and 3 replicate plots (severe deficit irrigation). Sprinkler irrigation was used. The average yield for each group under severe deficit and full irrigation is provided below the list of genotypes.

Drought-Tolerant Genotpyes	Overall Yield Increase (%) †	Increase Pods per Square Meter (%) ‡	Increase Seeds per Pod (%) §	Increase Seed Size (%) ¶
Yield > 2400#/ac				
G3	51	26	7	11
SV6139GR	90	38	31	5
Group Average	**70**	**32**	**19**	**8**
Severe Deficit Yield Avg	1812 ††			
Full Irrigation Yield Avg	3071			
Partly-Tolerant Genotypes				
Yield (2210-2260#)/ac				
Cowboy	61	41	9	5
H3	66	15	36	9
NTL-1	66	28	6	18
Z1	50	3	26	12
Group Average	**61**	**22**	**19**	**11**
Severe Deficit Yield Avg	1743 ††			
Full Irrigation Yield Avg	2750			
Drought-Sensitive Genotypes				
Yield (2080-2150#)/ac				
LPID-3	41	17	7	14
LPID-7	23	-7	28	9
OSC-2	46	23	10	15
Group Average	**37**	**11**	**15**	**13**
Severe Deficit Yield Avg	1747 ††			
Full Irrigation Yield Avg	2651			

† Percent increase in yield (full divided by severe stress)
‡ Percent increase in pods per square meter (full divided by severe stress)
§ Percent increase in average seed number per pod (full divided by severe stress)
¶ Percent increase in average seed weight (full divided by severe stress)
†† The group percentage average may not match the percentage increase exactly due to the nature calculations involving the averaging of averages.

Table 8. Yield component changes of within seven **late-maturing** genotypes from Powell 2023. Drought tolerance or sensitivity of a genotype was determined by its average yield across three irrigation regimes (one full irrigation and two deficit irrigations). The percentage values below were calculated by taking the average of the 3 replicate plots (full irrigation) and 3 replicate plots (severe deficit irrigation). Sprinkler irrigation was used. The average yield for each group under severe deficit and full irrigation is provided below the list of genotypes.

Drought-Tolerant Genotypes	Overall Yield Increase (%) †	Increase Pods per Square Meter (%) ‡	Increase Seeds per Pod (%) §	Increase Seed Size (%) ¶
Yield > 2100-2300#/ac				
M-5	41	31	-2	7
PT9-5-6	40	21	12	3
Rattler	56	29	11	9
Group Average	**46**	**27**	**7**	**6**
Severe Deficit Yield Avg	1713 ††			
Full Irrigation Yield Avg	2641			
Drought-Sensitive Genotypes				
Yield (1950-2060#)/ac				
B-3	63	34	1	9
C-6	39	12	13	9
LPID-9	50	30	9	5
Monterrey	60	28	16	8
Group Average	**53**	**26**	**10**	**10**
Severe Deficit Yield Avg	1630 ††			
Full Irrigation Yield Avg	2470			

† Percent increase in yield (full divided by severe stress)
‡ Percent increase in pods per square meter (full divided by severe stress)
§ Percent increase in average seed number per pod (full divided by severe stress)
¶ Percent increase in average seed weight (full divided by severe stress)
†† The group percentage average may not match the percentage increase exactly due to the nature calculations involving the averaging of averages.

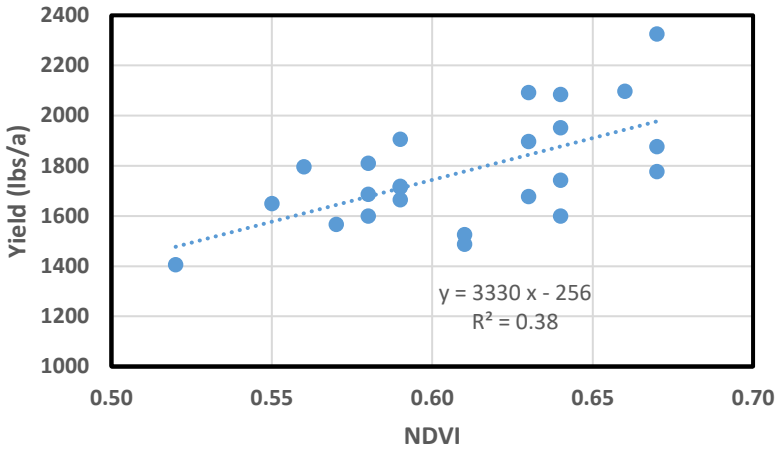

Figure 7. Relationship between final yield and NDVI on 23 July 2023 for plots grown under 60% ET (severe deficit irrigation) at Powell. Each data point is the average across three plots.

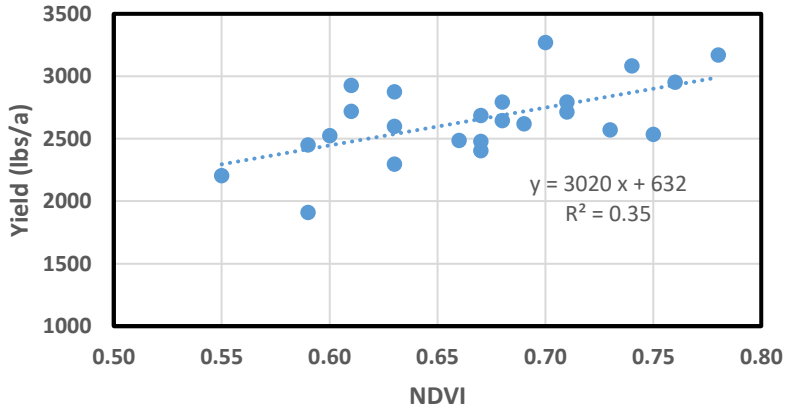

Figure 8. Relationship between final yield and NDVI on 23 July 2023 for plots grown under 100% ET (full irrigation) at Powell. Each data point is the average across three plots.

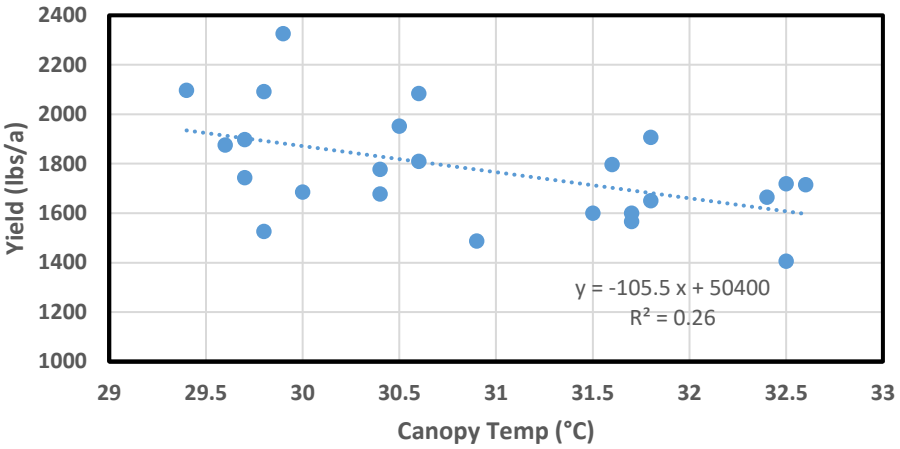

Figure 9. Relationship between final yield and canopy temperature on 22 July 2023 for plots grown under 60% ET (severe deficit irrigation) at Powell. Each data point is the average across three plots.

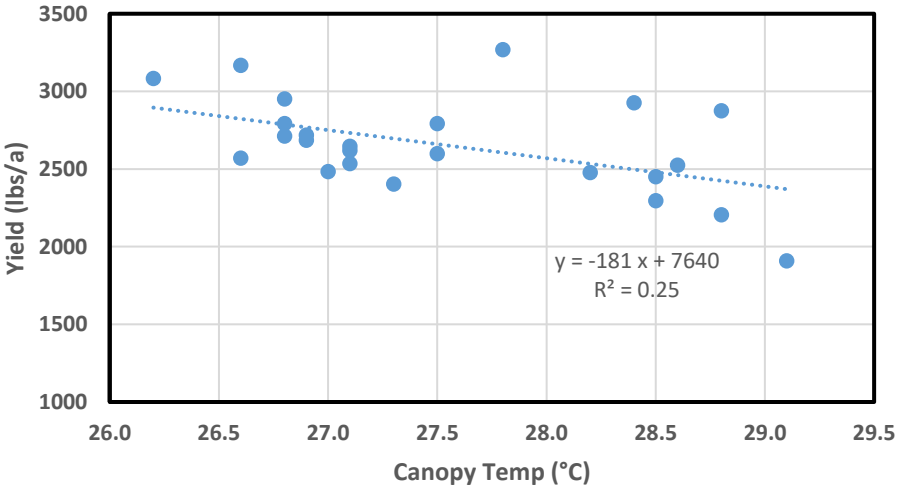

Figure 10. Relationship between final yield and canopy temperature on 22 July 2023 for plots grown under 100% ET (severe deficit irrigation) at Powell. Each data point is the average across three plots.

Table 9. Harvest recovery percentage and the percentage of pods located above 4 inches at maturity of the 26 entries in Powell. Values for both variables are averaged across the three irrigation rates because there was no water effect (P=0.254; P=0.237, respectively) drought-by-genotype interaction (P=0.386; P=0.111, respectively) on recovery. Values for recovery were 36% (severe deficit), 40% (moderate deficit), and 37% (full irrigation). Genotype effect was P=0.001.

Genotype	**Recovery**	**Pod Location**
	(Direct Harv)/(Conv Harv) × 100	% above 4-inches
B-3	33	64
C-9	37	53
C-6	34	65
owboy	53	74
E-3	34	55
G-2	34	53
G-3	37	68
H-3	39	58
LPID-3	59	69
LPID-7	44	67
LPID-9	42	74
M-5	31	40
Max	28	40
Medicine Hat	41	66
Monterrey	55	76
M-10	12	28
NTL-1	54	78
OLV-3	34	51
OSC-2	34	47
Othello	25	44
PT9-5-6	39	70
Poncho	30	40
Rattler	48	68
SV6193GR	42	66
Southwest Gold	29	53
Z-1	35	70
LSD (0.05)	13	8
Average	38	60

Table 10. Upright stature rating for the 26 genotypes across three irrigation rates. The irrigation-by-genotype effect was significant (P=0.001). Values were obtained by visual ratings at respective maturity of each plot. Values are the average of three plots.

Entry	**Upright Stature**			
	60% ET	80% ET	100% ET	Average
B-3	6.3	4.7	5.3	5.4
C-9	7.0	4.0	4.7	5.2
C-6	9.3	5.3	5.7	6.8
Cowboy	9.5	9.3	8.8	9.2
E-3	8.0	3.7	5.3	5.7
G-2	6.7	6.0	6.3	6.3
G-3	9.0	8.0	7.3	8.1
H-3	8.0	7.3	5.7	7.0
LPID-3	9.0	7.7	8.0	8.2
LPID-7	8.0	8.7	5.3	7.3
LPID-9	7.3	6.3	5.7	6.4
M-5	5.0	5.0	5.0	5.0
Max	6.1	5.6	6.0	5.9
Medicine Hat	8.7	7.3	9.3	8.4
Monterrey	8.8	9.3	8.2	8.8
M-10	5.7	4.3	4.7	4.9
NTL-1	9.0	8.0	7.0	8.0
OLV-3	8.3	6.6	5.0	6.6
OSC-2	7.3	3.7	5.0	5.3
Othello	5.3	3.3	5.7	4.8
PT9-5-6	8.0	7.7	7.3	7.7
Poncho	7.0	3.7	5.0	5.2
Rattler	9.0	8.7	7.0	8.2
SV6193GR	10.0	9.0	7.7	8.9
Southwest Gold	8.7	6.0	5.3	6.7
Z-1	9.0	6.3	7.0	7.4
LSD (0.05)	---------- 1.9 ----------			1.1
Average	7.8	6.4	6.3	7.0

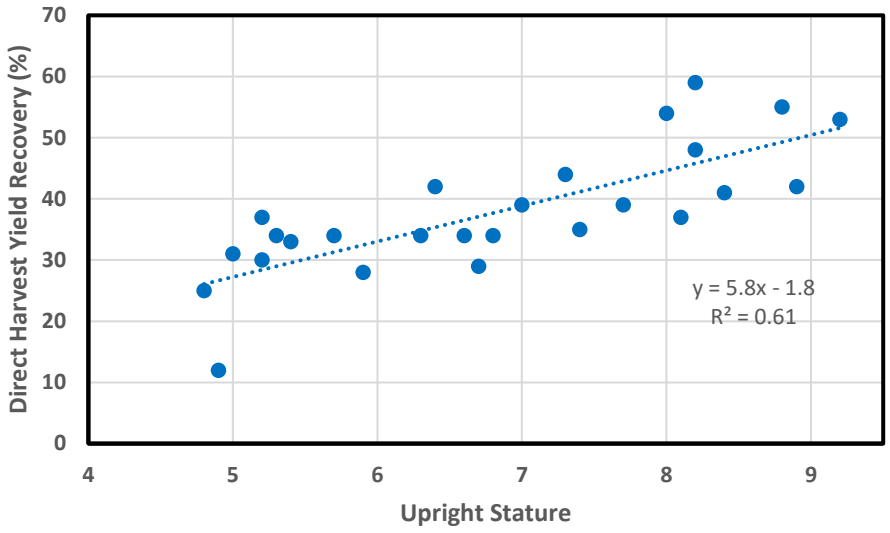

Figure 11. Relationship between direct harvest yield recovery and upright stature of 26 genotypes. Recovery and upright stature values are averaged across 9 plots (three irrigation rates and three replicates).

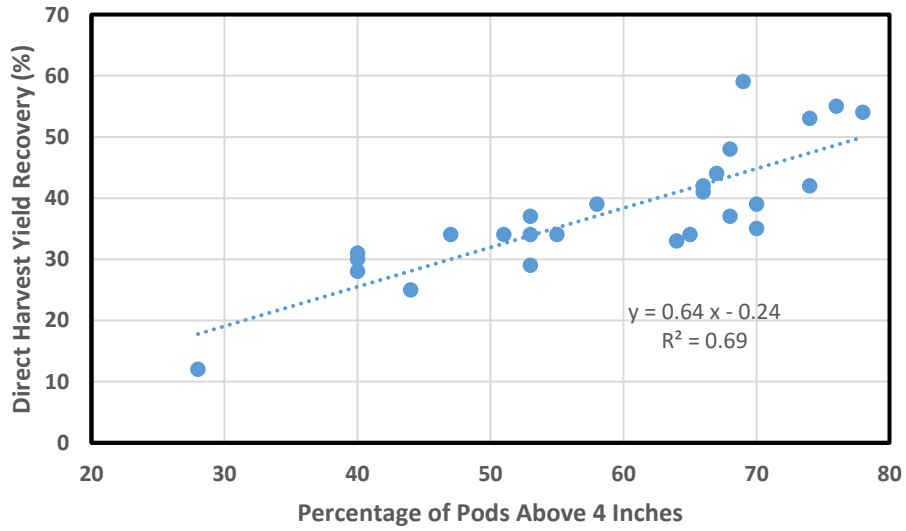

Figure 12. Relationship between direct harvest yield recovery and percentage of pods located/positioned above 4 inches of 26 genotypes. Recovery and upright stature values are averaged across 9 plots (three irrigation rates and three replicates).

Table 11. Seed protein concentration of the 26 genotypes as affected by irrigation in Powell in 2023. Seed protein was affected by a significant irrigation-by-genotype interaction. Values are the mean of three plots.

Entry	**Seed Protein Concentration**			
	60% ET	80% ET	100% ET	Average
B-3	19.4	19.3	20.2	19.6
C-9	17.6	17.3	16.6	17.2
C-6	16.8	16.1	15.7	16.2
Cowboy	18.4	17.6	17.0	17.7
E-3	20.7	19.0	17.9	19.2
G-2	18.3	15.6	15.4	16.4
G-3	16.0	16.0	15.3	15.8
H-3	18.8	18.0	16.9	17.9
LPID-3	19.3	18.9	18.5	18.9
LPID-7	20.7	20.9	19.4	20.3
LPID-9	19.8	19.9	19.3	19.7
M-5	16.8	16.6	16.4	16.6
Max	16.2	16.5	15.9	16.2
Medicine Hat	18.5	17.9	17.8	18.0
Monterrey	18.8	18.3	17.6	18.2
M-10	18.0	17.7	15.4	17.0
NTL-1	19.0	18.3	17.6	18.3
OLV-3	20.3	18.7	17.9	19.0
OSC-2	19.8	19.8	19.1	19.5
Othello	15.8	15.6	14.9	15.4
PT9-5-6	17.8	17.2	16.7	17.2
Poncho	16.6	16.7	16.6	16.6
Rattler	19.4	18.7	16.7	18.3
SV6193GR	18	17.7	16.9	17.5
Southwest Gold	18.1	17.6	16.4	17.4
Z-1	16.6	16.3	16.1	16.3
LSD (0.05)	---------- 1.2 ----------			0.7
Average	**18.3**	**17.8**	**17.1**	17.7

Table 12. Effect of drought and genotype on stomatal density of six genotypes from the SPDT trial in Powell in 2023.

Irrigation	**Adaxial (upper)**	**Abaxial (lower)**	**Ratio**
	number per square millimeter		
Severe Deficit	114	441	4.0
Moderate Deficit	111	431	4.0
Full Irrigation	101	418	4.4
Genotype			
Max	118	522	4.6
Medicine Hat	97	380	4.1
Monterrey	111	463	4.3
Othello	111	470	4.5
PT9-5-6	97	349	3.6
Poncho	118	396	3.5
LSD (0.05)	ns	46	ns

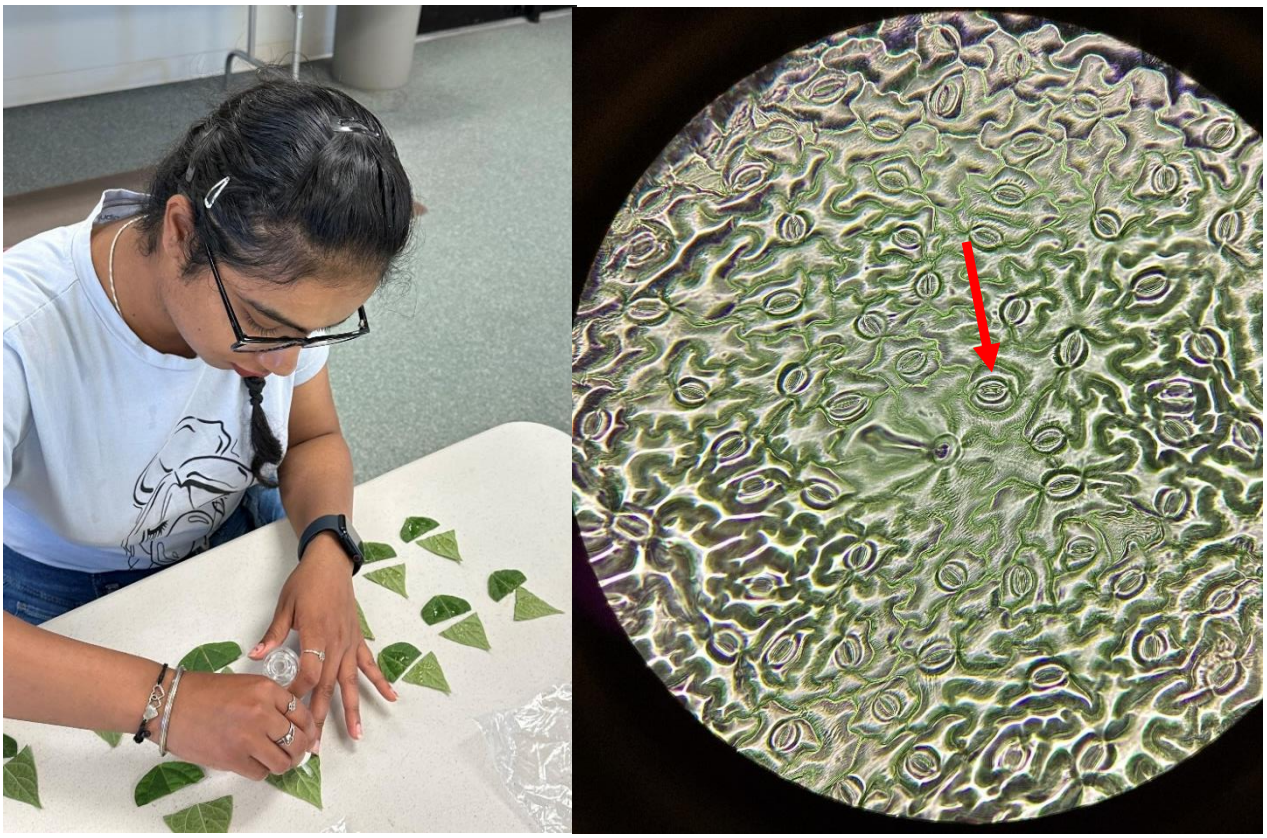

Figure 13. Preparation leaf epidermal segments (left photo) for placing on a slide and a microscopic image of the lower leaf surface (abaxial) of dry bean (right photo). Fingernail polish is brushed on the leaf surface, allowed to dry, and ultimately placed on a microscope slide for viewing. The red arrow indicates one stomata composed of two paired guard cells.

Results and Discussion – Durango Diversity Panel (DDP)

A list of the 169 DDP genotypes along with the respective market classes and 10 additional genotypes are provided in Table 13.

DDP Ecophysiology Measurements. On 27 July 2023, canopy temperatures paralleled the results of the SPDT trial with the 60% irrigation severe deficit plots averaging 27.7°C (81.9°F) which was warmer than the more fully irrigated plots (both at 26.4°C or 79.5°F). Regarding canopy health via NDVI, values on 23 July were similar across the three irrigation rates with an average of 0.54. However, differences among the 169 genotypes were observed (Table 14).

DDP Yield Related Observations. Grain yield of the 169 genotypes (averaged across three plots) ranged from 1189 to 2208 pounds per acre (Table 15). Maturity of the genotypes ranged from 74 dap to 91 dap (Table 16). Upright stature ranged from a prostrate 2.0 to a very upright 9.3 (Table 17). Direct harvest yields were low due to the same factors observed in the SPDT trial with a range from 368 to 1346 pounds per acre (Table 18).

Seed Quality. Across the three irrigation rates, seed protein concentration decreased as irrigation rate increased. Average across the 179 DDP genotypes, values were 18.1%, 17.0%, and 16.5%, for the severe deficit irrigation, the moderate deficit irrigation, and the full irrigation, respectively. Seed protein concentration for all 179 DDP genotypes are provided in Table 19.

Stomatal Density. We are still processing stomatal density values from the hundreds of microscopic slides from the DDP trial. However, there appears to be a trend for Great Northern types to have a greater adaxial (upper surface) stomatal density than small red types and our goal is to confirm or negate that with our 2024 trial (Table 20).

DDP Summary – This was the first year of our screening of the DDP lines for various anatomical, ecophysiological, and agronomic traits. We will repeat this DDP screening in 2024 with nine plots for each genotype (3 plots in each irrigation) and we expect to identify specific genes that govern the expression of these traits.

Acknowledgments

Thanks to the seed companies, Kelley Bean and Treasure Valley Seed, for donating the commercial check varieties. We also thank WBC for funding the trial, and USDA-NIFA for equipment and financial support. Also, our research team of Sidney Althoff, Morgan Chenoweth, Samual George, Kik Hayano, Cody Hurford, Heidi Pick, and Chloe Winkler played instrumental roles in helping the study come to fruition.

Table 13. Market class for the 169 Durango Diversity Panel (DDP) genotypes plus 10 ad-hoc entries (mostly from our breeding program). * Designates an ad-hoc entry.

Genotype	Market Class	Genotype	Market Class	Genotype	Market Class	Genotype	Market Class
3138	Great Northern	Croissant	pinto	Max	pinto	Santa Fe	pinto
6R-42	pink	Desert Rose	Flor de Mayo	Medicine Hat	Pinto	Sapphire	Great Northern
92US-1006	pinto	Durango	pinto	Merlot	small red	Sawtooth	Great Northern
ABC-Weihing	Great Northern	Ember	small red	Monterrey	pinto	Sedona	pink
ABCP-8	pinto	Fargo	pinto	Montrose	pinto	Sequoia	pinto
AC-Island	pinto	Fiesta	pinto	ND-307	pinto	Shoshone	pinto
AC-Polaris	Great Northern	Fisher	pinto	ND041062-1	pinto	Sierra	pinto
AC-RedBond	small red	Flint	pinto	ND060197	pinto	Sinaloa	pinto
AC-Earlired	small red	Focus	pinto	NE1-09-19	Great Northern	Sonora	pinto
AC-EarlyRose	pink	Frontier	pinto	NE1-09-22	Great Northern	Stampede	pinto
AC-Resolute	Great Northern	GN-Harris	Great Northern	NE2-09-10	pinto	Starlight	Great Northern
AC-Scarlet	small red	GN-Star	Great Northern	NE2-09-3	pinto	TARS-VCI-4B	pinto
Agassiz	pinto	GN9-1	Great Northern	NE2-09-4	pinto	TARS09-RR023	pinto
ALX-7*	Great Northern	GN9-4	Great Northern	NW-410	pinto	Topaz	pinto
Apache	pinto	Gala	pinto	NW-590	pinto	UI-123	Great Northern
Arapaho	pinto	Galeena	pinto	NW-63	small red	UI-126	pinto
Aries	Great Northern	Garnet	small red	Nodak	pinto	UI-196	pinto
Baja	pinto	Gemini	Great Northern	ORCA	black&white	UI-228	small red
BelDakMi-RR-5	pinto	Gloria	pink	OLV-3*	-	UI-239	small red
BelMiNeb-1	Great Northern	Grand Mesa	pinto	Orion	Great Northern	UI-3	small red
BelMiNeb-RMR-4	Great Northern	G-3*	Great Northern	Othello	pinto	UI-37	small red
BelMiNeb-RMR-7	Great Northern	Gypsy Rose †	Flor de Mayo	Ouray	pinto	UI-425	Great Northern
BelMiNeb-RR-2	Great Northern	H-3*	Great Northern	P12-606	pinto	UI-537	pink
BelMiNebRr-2	-	Harold	pink	PK9-1	pink	UCD-9623	Flor de Mayo
BelNeb-RR-1	Great Northern	Hatton	pinto	PK9-7	pink	UCD-9634	pink
Beryl	Great Northern	Holberg	pinto	PK915	pink	UI-111	pinto
Beryl-R	Great Northern	Hungerford	Great Northern	PT11-13	pinto	UI-114	pinto
Big Bend	small red	I06-2575-17	pinto	PT7-2	pinto	UI-59	Great Northern
BillZ	pinto	ICB-12	pinto	PT9-17	pinto	URS-117	pink
B-3*	Great Northern	Ivory	Great Northern	PT9-22	pinto	US-1140	Great Northern
Buckskin	pinto	JM-126	pinto	PT9-5-6	pinto	USPT-ANT-1	pinto
Burke	pinto	Jackpot	pinto	Pindak	pinto	USPT-CBB-1	pinto
Buster	pinto	Kimberly	pinto	Pink Floyd	pink	USPT-CBB-3	pinto
CDC-Camino	pinto	Kodiak	pinto	Poncho	pinto	USPT-CBB-5	pinto
CDC-Crocus	Great Northern	LaPaz	pinto	Powderhorn	Great Northern	USPT-WM-1	pinto
CDC-Pinnacle	pinto	L-3*	yellow	Quincy	pinto	USRM-20	small red
CDC-Pintium	pinto	Lariat	pinto	R-1*	Great Northern	USWA-12	Great Northern
CDC-Rosalee	pink	LeBaron	small red	Red Ryder	small red	USWA-13	Great Northern
CDCWM-2	pinto	Longs Peak	pinto	Rosa	pink	Victor	pink
C-9*	light brown	Mariah	pinto	Rosetta	pink	Vision	pinto
Chase	pinto	M-5*	dark brown	SDIP-1	pinto	Viva	pink
ComRedMx	small red	Marquis	Great Northern	SR7-3	small red	Weihing	Great Northern
Common Pinto	pinto	Matterhorn	Great Northern	SR9-4	small red	WinMor	pinto
Coulee	small red	Maverick	pinto	SWGold*	gold & white	Windbreaker	pinto
Coyne	Great Northern			Santa Cruz	pinto	Yolano	pink

† Gypsy Rose is also found elsewhere as R11806

Table 14. NDVI on 23 July 2023 at Powell of 169 Durango Diversity Panel (DDP) genotypes plus 10 ad-hoc entries (most from our breeding program) averaged across three irrigation rates. Each genotype was grown in only three plots (once for each irrigation rate). Due to a growth problem that showed up incrementally in this field, only the average values are presented. NDVI values were adjusted using field coordinates as a covariate.

Genotype	NDVI	Genotype	NDVI	Genotype	NDVI	Genotype	NDVI
3138	0.63	Croissant	0.61	Max	0.50	SantaFe	0.35
6R-42	0.59	DesertRose	0.44	MedicineHat	0.57	Sapphire	0.55
92US-1006	0.42	Durango	0.57	Merlot	0.45	Sawtooth	0.50
ABC-Weihing	0.51	Ember	0.55	Monterrey	0.53	Sedona	0.55
ABCP-8	0.54	Fargo	0.49	Montrose	0.64	Sequoia	0.58
AC-Island	0.45	Fiesta	0.61	ND-307	0.48	Shoshone	0.47
AC-Polaris	0.58	Fisher	0.59	ND041062-1	0.46	Sierra	0.59
AC-RedBond	0.67	Flint	0.50	ND060197	0.52	Sinaloa	0.53
AC-Earlired	0.57	Focus	0.64	NE1-09-19	0.46	Sonora	0.52
AC-EarlyRose	0.64	Frontier	0.61	NE1-09-22	0.56	Stampede	0.52
AC-Resolute	0.52	GN-Harris	0.64	NE2-09-10	0.52	Starlight	0.46
AC-Scarlet	0.60	GN-Star	0.53	NE2-09-3	0.53	TARS-VCI-4B	0.56
Agassiz	0.59	GN9-1	0.49	NE2-09-4	0.56	TARS09-RR023	0.52
ALX-7*	0.59	GN9-4	0.51	NW-410	0.65	Topaz	0.58
Apache	0.55	Gala	0.55	NW-590	0.48	UI-123	0.56
Arapaho	0.51	Galeena	0.49	NW-63	0.60	UI-126	0.63
Aries	0.53	Garnet	0.54	Nodak	0.58	UI-196	0.58
Baja	0.52	Gemini	0.53	ORCA	0.42	UI-228	0.64
BelDakMi-RR-5	0.55	Gloria	0.57	OLV-3*	0.46	UI-239	0.70
BelMiNeb-1	0.60	GrandMesa	0.52	Orion	0.47	UI-3	0.55
BelMiNeb-RMR-4	0.52	G-3*	0.55	Othello	0.54	UI-37	0.57
BelMiNeb-RMR-7	0.51	GypsyRose	0.61	Ouray	0.54	UI-425	0.49
BelMiNeb-RR-2	0.46	H-3*	0.55	P12-606	0.50	UI-537	0.60
BelMiNebRr-2	0.55	Harold	0.56	PK9-1	0.63	UCD-9623	0.44
BelNeb-RR-1	0.57	Hatton	0.48	PK9-7	0.58	UCD-9634	0.48
Beryl	0.54	Holberg	0.64	PK915	0.52	UI-111	0.56
Beryl-R	0.52	Hungerford	0.52	PT11-13	0.46	UI-114	0.53
BigBend	0.59	I06-2575-17	0.53	PT7-2	0.46	UI-59	0.59
BillZ	0.51	ICB-12	0.57	PT9-17	0.46	URS-117	0.62
B-3*	0.52	Ivory	0.63	PT9-22	0.51	US-1140	0.48
Buckskin	0.55	JM-126	0.52	PT9-5-6	0.58	USPT-ANT-1	0.54
Burke	0.56	Jackpot	0.63	Pindak	0.59	USPT-CBB-1	0.45
Buster	0.44	Kimberly	0.49	PinkFloyd	0.52	USPT-CBB-3	0.50
CDC-Camino	0.57	Kodiak	0.52	Poncho	0.50	USPT-CBB-5	0.62
CDC-Crocus	0.56	LaPaz	0.57	Powderhorn	0.45	USPT-WM-1	0.40
CDC-Pinnacle	0.53	L-3*	0.58	Quincy	0.51	USRM-20	0.50
CDC-Pintium	0.47	Lariat	0.60	R-1*	0.57	USWA-12	0.50
CDC-Rosalee	0.70	LeBaron	0.59	RedRyder	0.57	USWA-13	0.47
CDCWM-2	0.47	LongsPeak	0.47	Rosa	0.57	Victor	0.59
C-9*	0.63	Mariah	0.51	Rosetta	0.45	Vision	0.47
Chase	0.53	M-5*	0.67	SDIP-1	0.60	Viva	0.59
ComRedMx	0.56	Marquis	0.49	SR7-3	0.62	Weihing	0.64
CommPinto	0.56	Matterhorn	0.47	SR9-4	0.51	WinMor	0.60
Coulee	0.64	Maverick	0.54	SWGold*	0.56	Windbreaker	0.57
Coyne	0.59	**LSD (0.05)**	**0.06**	SantaCruz	0.51	Yolano	0.49

Table 15. Yields of 169 Durango Diversity Panel (DDP) genotypes plus 10 ad-hoc entries averaged across three irrigation rates in Powell 2023. Each genotype was grown in only three plots (once for each irrigation rate). Due to a growth problem that showed up incrementally in this field, only the average values are presented. Yield values were adjusted using field coordinates as a covariate. * Designates an ad-hoc entry.

Genotype	Yield	Genotype	Yield	Genotype	Yield	Genotype	Yield
	lbs/a		lbs/a		lbs/a		lbs/a
3138	1921	Croissant	1959	Max	1903	SantaFe	1769
6R-42	1947	DesertRose	1189	MedicineHat	1692	Sapphire	1429
92US-1006	1621	Durango	1860	Merlot	1423	Sawtooth	1869
ABC-Weihing	1678	Ember	1942	Monterrey	1952	Sedona	1930
ABCP-8	1779	Fargo	1850	Montrose	1964	Sequoia	1315
AC-Island	1759	Fiesta	2008	ND-307	1540	Shoshone	1677
AC-Polaris	1888	Fisher	1760	ND041062-1	1527	Sierra	1571
AC-RedBond	1714	Flint	1884	ND060197	1833	Sinaloa	1463
AC-Earlired	1937	Focus	2029	NE1-09-19	1749	Sonora	1789
AC-EarlyRose	2156	Frontier	1822	NE1-09-22	1682	Stampede	1515
AC-Resolute	1678	GN-Harris	1674	NE2-09-10	1353	Starlight	1482
AC-Scarlet	1696	GN-Star	1196	NE2-09-3	1656	TARS-VCI-4B	1706
Agassiz	1883	GN9-1	1741	NE2-09-4	1785	TAS09-RR023	1690
ALX-7*	1915	GN9-4	1512	NW-410	1944	Topaz	1974
Apache	1886	Gala	1797	NW-590	1756	UI-123	1662
Arapaho	1476	Galeena	1549	NW-63	1990	UI-126	1873
Aries	1698	Garnet	1714	Nodak	1636	UI-196	2047
Baja	1679	Gemini	1835	ORCA	1705	UI-228	2192
BelDakMi-RR-5	1732	Gloria	2067	OLV-3*	1655	UI-239	1748
BelMiNeb-1	1556	GrandMesa	1854	Orion	1690	UI-3	2052
BelMiNeb-RMR-4	1246	Greta G-3*	1935	Othello	2208	UI-37	1813
BelMiNeb-RMR-7	1664	GypsyRose	1719	Ouray	1599	UI-425	1565
BelMiNeb-RR-2	1578	H-3*	2013	P12-606	1702	UI-537	1893
BelMiNebRr-2	1495	Harold	2003	PK9-1	2089	UCD-9623	1697
BelNeb-RR-1	1824	Hatton	1795	PK9-7	2166	UCD-9634	1823
Beryl	2039	Holberg	2086	PK915	1746	UI-111	1492
Beryl-R	2040	Hungerford	1833	PT11-13	2039	UI-114	1850
BigBend	1710	I06-2575-17	1483	PT7-2	2210	UI-59	1737
BillZ	1715	ICB-12	1631	PT9-17	2084	URS-117	1975
B-3	1703	Ivory	2127	PT9-22	1758	US-1140	2089
Buckskin	1456	JM-126	1807	PT9-5-6	1686	USPT-ANT-1	1625
Burke	1929	Jackpot	1820	Pindak	1802	USPT-CBB-1	1584
Buster	1878	Kimberly	1601	PinkFloyd	1571	USPT-CBB-3	1327
CDC-Camino	2194	Kodiak	1809	Poncho	1850	USPT-CBB-5	2121
CDC-Crocus	1824	LaPaz	1867	Powderhorn	1839	USPT-WM-1	1579
CDC-Pinnacle	2025	L-3*	1354	Quincy	2136	USRM-20	1738
CDC-Pintium	1818	Lariat	1898	R-1*	1914	USWA-12	1715
CDC-Rosalee	2026	LeBaron	1929	RedRyder	1703	USWA-13	1617
CDCWM-2	1563	LongsPeak	1746	Rosa	1871	Victor	1971
C-9*	2190	Mariah	1569	Rosetta	1486	Vision	1926
Chase	1895	M-5*	2001	SDIP-1	1707	Viva	2036
ComRedMx	1581	Marquis	1938	SR7-3	1749	Weihing	1698
CommPinto	1836	Matterhorn	1385	SR9-4	1745	WinMor	1643
Coulee	1925	Maverick	1706	SWGold	1817	Windbreaker	1710
Coyne	1918	**LSD (0.05)**	**493**	SantaCruz	1815	Yolano	1948

Table 16. Maturity (days after planting, dap) of the DDP genotypes averaged across all three irrigation rates in Powell, 2023. * Designates an ad-hoc entry.

Genotype	Maturity	Genotype	Maturity	Genotype	Maturity	Genotype	Maturity
	dap		dap		dap		dap
3138	87	Croissant	80	Max	77	SantaFe	91
6R-42	83	DesertRose	81	MedicineHat	81	Sapphire	91
92US-1006	79	Durango	83	Merlot	85	Sawtooth	83
ABC-Weihing	89	Ember	78	Monterrey	89	Sedona	78
ABCP-8	81	Fargo	78	Montrose	78	Sequoia	83
AC-Island	74	Fiesta	79	ND-307	87	Shoshone	76
AC-Polaris	78	Fisher	91	ND041062-1	91	Sierra	91
AC-RedBond	80	Flint	76	ND060197	81	Sinaloa	87
AC-Earlried	77	Focus	79	NE1-09-19	88	Sonora	87
AC-EarlyRose	79	Frontier	91	NE1-09-22	85	Stampede	89
AC-Resolute	78	GN-Harris	85	NE2-09-10	87	Starlight	85
AC-Scarlet	81	GN-Star	87	NE2-09-3	83	TARS-VCI-4B	91
Agassiz	77	GN9-1	83	NE2-09-4	83	TAS09-RR023	81
ALX-7*	87	GN9-4	85	NW-410	76	Topaz	78
Apache	78	Gala	75	NW-590	78	UI-123	85
Arapaho	91	Galeena	89	NW-63	78	UI-126	78
Aries	89	Garnet	80	Nodak	75	UI-196	83
Baja	75	Gemini	76	ORCA	91	UI-228	78
BelDakMi-RR-5	83	Gloria	85	OLV-3*	79	UI-239	78
BelMiNeb-1	82	GrandMesa	83	Orion	89	UI-3	89
BelMiNeb-RMR-4	89	G-3*	85	Othello	79	UI-37	81
BelMiNeb-RMR-7	87	GypsyRose	91	Ouray	83	UI-425	83
BelMiNeb-RR-2	91	H-3*	85	P12-606	91	UI-537	80
BelMiNebRr-2	87	Harold	79	PK9-1	79	UCD-9623	76
BelNeb-RR-1	89	Hatton	78	PK9-7	87	UCD-9634	78
Beryl	78	Holberg	80	PK915	87	UI-111	75
Beryl-R	83	Hungerford	87	PT11-13	85	UI-114	81
BigBend	87	I06-2575-17	83	PT7-2	81	UI-59	82
BillZ	79	ICB-12	87	PT9-17	79	URS-117	78
B-3*	91	Ivory	80	PT9-22	85	US-1140	83
Buckskin	78	JM-126	83	PT9-5-6	91	USPT-ANT-1	91
Burke	77	Jackpot	80	Pindak	77	USPT-CBB-1	80
Buster	89	Kimberly	83	PinkFloyd	79	USPT-CBB-3	86
CDC-Camino	79	Kodiak	89	Poncho	80	USPT-CBB-5	74
CDC-Crocus	76	LaPaz	91	Powderhorn	89	USPT-WM-1	87
CDC-Pinnacle	74	L-3*	78	Quincy	77	USRM-20	85
CDC-Pintium	77	Lariat	89	R-1*	91	USWA-12	83
CDC-Rosalee	78	LeBaron	76	RedRyder	79	USWA-13	87
CDCWM-2	78	LongsPeak	85	Rosa	89	Victor	75
C-9*	80	Mariah	87	Rosetta	81	Vision	80
Chase	81	M-5*	87	SDIP-1	85	Viva	78
ComRedMx	80	Marquis	81	SR7-3	79	Weihing	83
CommPinto	79	Matterhorn	89	SR9-4	83	WinMor	85
Coulee	81	Maverick	85	SWGold	81	Windbreaker	80
Coyne	83	**LSD (0.05)**	**6**	SantaCruz	89	Yolano	76

Table 17. Upright stature of the 169 DDP genotypes in 2023 averaged across three irrigation rates. Each value is the average across three plots (once in each irrigation rate). * Designates an ad-hoc entry.

Genotype	Upright Stature	Genotype	Upright Stature	Genotype	Upright Stature	Genotype	Upright Stature
3138	6.3	Croissant	7.7	Max	6.3	SantaFe	5.3
6R-42	5.0	DesertRose	7.3	MedicineHat	7.7	Sapphire	4.3
92US-1006	7.3	Durango	8.0	Merlot	8.3	Sawtooth	7.7
ABC-Weihing	8.0	Ember	7.0	Monterrey	8.3	Sedona	6.3
ABCP-8	6.0	Fargo	7.0	Montrose	6.3	Sequoia	8.7
AC-Island	8.0	Fiesta	8.3	ND-307	8.3	Shoshone	8.7
AC-Polaris	4.3	Fisher	4.7	ND041062-1	9.0	Sierra	7.0
AC-RedBond	7.3	Flint	7.7	ND060197	8.0	Sinaloa	9.3
AC-Earlired	6.7	Focus	7.0	NE1-09-19	7.7	Sonora	6.7
AC-EarlyRose	2.7	Frontier	7.6	NE1-09-22	8.0	Stampede	8.7
AC-Resolute	8.0	GN-Harris	4.0	NE2-09-10	9.0	Starlight	8.7
AC-Scarlet	6.3	GN-Star	4.3	NE2-09-3	9.0	TARS-VCI-4B	5.3
Agassiz	8.3	GN9-1	6.7	NE2-09-4	6.7	TARS09-RR023	7.3
ALX-7*	6.3	GN9-4	7.3	NW-410	6.7	Topaz	6.7
Apache	7.3	Gala	5.7	NW-590	6.3	UI-123	5.7
Arapaho	4.3	Galeena	8.0	NW-63	6.3	UI-126	5.3
Aries	7.7	Garnet	6.0	Nodak	6.0	UI-196	3.7
Baja	7.7	Gemini	6.3	ORCA	6.3	UI-228	7.0
BelDakMi-RR-5	8.7	Gloria	4.0	OLV-3*	6.7	UI-239	5.3
BelMiNeb-1	7.7	GrandMesa	6.0	Orion	6.3	UI-3	6.0
BelMiNeb-RMR-4	8.7	G-3*	7.3	Othello	6.7	UI-37	6.0
BelMiNeb-RMR-7	7.0	GypsyRose	8.0	Ouray	8.3	UI-425	6.3
BelMiNeb-RR-2	8.0	H-3*	6.0	P12-606	8.0	UI-537	4.3
BelMiNebRr-2	7.7	Harold	6.0	PK9-1	6.3	UCD-9623	8.7
BelNeb-RR-1	4.7	Hatton	9.0	PK9-7	8.0	UCD-9634	9.0
Beryl	5.7	Holberg	3.3	PK915	8.7	UI-111	7.0
Beryl-R	5.0	Hungerford	8.0	PT11-13	9.0	UI-114	5.3
BigBend	2.0	I06-2575-17	7.7	PT7-2	9.0	UI-59	7.0
BillZ	7.7	ICB-12	5.0	PT9-17	8.0	URS-117	6.7
B-3*	7.3	Ivory	4.3	PT9-22	6.0	US-1140	3.3
Buckskin	6.0	JM-126	5.7	PT9-5-6	8.0	USPT-ANT-1	5.3
Burke	7.3	Jackpot	4.7	Pindak	4.3	USPT-CBB-1	6.7
Buster	7.7	Kimberly	6.3	PinkFloyd	5.0	USPT-CBB-3	7.7
CDC-Camino	4.3	Kodiak	6.0	Poncho	6.3	USPT-CBB-5	9.3
CDC-Crocus	6.0	LaPaz	7.0	Powderhorn	8.3	USPT-WM-1	5.7
CDC-Pinnacle	6.7	L-3*	8.7	Quincy	6.3	USRM-20	7.3
CDC-Pintium	7.7	Lariat	6.7	R-1*	4.3	USWA-12	6.7
CDC-Rosalee	7.7	LeBaron	4.3	RedRyder	6.0	USWA-13	8.7
CDCWM-2	9.3	LongsPeak	8.7	Rosa	4.3	Victor	6.7
C-9*	4.7	Mariah	8.0	Rosetta	9.7	Vision	8.0
Chase	5.0	M-5*	6.0	SDIP-1	4.0	Viva	6.0
ComRedMx	6.0	Marquis	6.7	SR7-3	7.0	Weihing	7.3
CommPinto	6.0	Matterhorn	7.0	SR9-4	9.3	WinMor	6.3
Coulee	6.3	Maverick	6.0	SWGold	8.7	Windbreaker	7.3
Coyne	8.3	**LSD (0.05)**	**3.0**	SantaCruz	7.7	Yolano	8.0

Table 18. **Direct** harvest yields of 169 Durango Diversity Panel (DDP) genotypes plus 10 ad-hoc entries averaged across three irrigation rates. Each genotype was grown in only three plots (once for each irrigation rate). Due to a growth problem that showed up incrementally in this field, only the average values are presented. Yield values were adjusted using field coordinates as a covariate.
* Designates an ad-hoc entry.

Genotype	Yield	Genotype	Yield	Genotype	Yield	Genotype	Yield
	lbs/a		lbs/a		lbs/a		lbs/a
3138	1043	Croissant	864	Max	912	SantaFe	423
6R-42	866	DesertRose	485	MedicineHat	857	Sapphire	730
92US-1006	981	Durango	691	Merlot	1091	Sawtooth	954
ABC-Weihing	1080	Ember	437	Monterrey	1173	Sedona	637
ABCP-8	819	Fargo	728	Montrose	725	Sequoia	932
AC-Island	698	Fiesta	808	ND-307	773	Shoshone	539
AC-Polaris	991	Fisher	867	ND041062-1	777	Sierra	1064
AC-RedBond	898	Flint	776	ND060197	744	Sinaloa	1011
AC-Earlired	407	Focus	1346	NE1-09-19	1001	Sonora	877
AC-EarlyRose	845	Frontier	1106	NE1-09-22	727	Stampede	687
AC-Resolute	965	GN-Harris	631	NE2-09-10	1027	Starlight	644
AC-Scarlet	691	GN-Star	493	NE2-09-3	874	TARS-VCI-4B	698
Agassiz	770	GN9-1	1010	NE2-09-4	870	TARS09-RR023	810
ALX-7*	794	GN9-4	754	NW-410	723	Topaz	776
Apache	910	Gala	674	NW-590	600	UI-123	651
Arapaho	1107	Galeena	1068	NW-63	868	UI-126	775
Aries	873	Garnet	511	Nodak	862	UI-196	713
Baja	953	Gemini	700	ORCA	892	UI-228	618
BelDakMi-RR-5	932	Gloria	785	OLV-3*	915	UI-239	1108
BelMiNeb-1	720	GrandMesa	992	Orion	944	UI-3	880
BelMiNeb-RMR-4	682	G-3*	1164	Othello	708	UI-37	574
BelMiNeb-RMR-7	783	GypsyRose	753	Ouray	974	UI-425	792
BelMiNeb-RR-2	628	H-3*	1087	P12-606	1263	UI-537	692
BelMiNebRr-2	730	Harold	572	PK9-1	1108	UCD-9623	625
BelNeb-RR-1	688	Hatton	681	PK9-7	1470	UCD-9634	676
Beryl	945	Holberg	775	PK915	1177	UI-111	557
Beryl-R	1051	Hungerford	778	PT11-13	689	UI-114	778
BigBend	590	I06-2575-17	687	PT7-2	1109	UI-59	700
BillZ	567	ICB-12	792	PT9-17	967	URS-117	1010
B-3*	1005	Ivory	634	PT9-22	867	US-1140	549
Buckskin	661	JM-126	574	PT9-5-6	1361	USPT-ANT-1	1133
Burke	1102	Jackpot	917	Pindak	854	USPT-CBB-1	776
Buster	570	Kimberly	757	PinkFloyd	671	USPT-CBB-3	814
CDC-Camino	742	Kodiak	958	Poncho	731	USPT-CBB-5	565
CDC-Crocus	690	LaPaz	1235	Powderhorn	1239	USPT-WM-1	593
CDC-Pinnacle	951	L-3*	621	Quincy	948	USRM-20	801
CDC-Pintium	1105	Lariat	1129	R-1*	759	USWA-12	801
CDC-Rosalee	1017	LeBaron	807	RedRyder	773	USWA-13	671
CDCWM-2	368	LongsPeak	991	Rosa	1020	Victor	1104
C-9*	1000	Mariah	742	Rosetta	683	Vision	889
Chase	765	M-5*	1106	SDIP-1	961	Viva	582
ComRedMx	684	Marquis	930	SR7-3	819	Weihing	1005
CommPinto	665	Matterhorn	914	SR9-4	906	WinMor	760
Coulee	768	Maverick	1173	SWGold	577	Windbreaker	861
Coyne	797	**LSD (0.05)**	**473**	SantaCruz	1376	Yolano	923

Table 19. **Seed protein concentration** of 169 Durango Diversity Panel (DDP) genotypes plus 10 ad-hoc entries averaged across three irrigation rates. Each genotype was grown in only three plots (once for each irrigation rate) and the values presented are the raw average across those three plots. A Perten DA7250 infrared analyzer was used to estimate protein. * Designates an ad-hoc entry.

Genotype	Protein	Genotype	Protein	Genotype	Protein	Genotype	Protein
	%		%		%		%
3138	19.1	Croissant	18.3	Max	15.5	SantaFe	18.8
6R-42	17.0	DesertRose	14.1	MedicineHat	17.8	Sapphire	19.7
92US-1006	17.0	Durango	15.9	Merlot	16.4	Sawtooth	16.5
ABC-Weihing	17.9	Ember	17.1	Monterrey	16.6	Sedona	16.1
ABCP-8	17.0	Fargo	15.6	Montrose	16.1	Sequoia	17.6
AC-Island	15.2	Fiesta	16.2	ND-307	18.7	Shoshone	16.6
AC-Polaris	18.0	Fisher	19.8	ND041062-1	17.8	Sierra	20.2
AC-RedBond	17.7	Flint	16.2	ND060197	16.7	Sinaloa	17.2
AC-Earlired	17.0	Focus	17.2	NE1-09-19	17.8	Sonora	15.8
AC-EarlyRose	18.2	Frontier	18.2	NE1-09-22	17.8	Stampede	17.2
AC-Resolute	18.9	GN-Harris	18.7	NE2-09-10	18.3	Starlight	16.2
AC-Scarlet	17.4	GN-Star	18.9	NE2-09-3	17.7	TARS-VCI-4B	18.2
Agassiz	16.0	GN9-1	17.5	NE2-09-4	17.0	TARS09-RR023	16.4
ALX-7*	18.7	GN9-4	19.4	NW-410	16.4	Topaz	16.9
Apache	15.5	Gala	16.7	NW-590	16.1	UI-123	18.1
Arapaho	19.5	Galeena	17.5	NW-63	18.2	UI-126	16.8
Aries	18.6	Garnet	17.5	Nodak	15.3	UI-196	16.9
Baja	14.9	Gemini	17.8	ORCA	18.0	UI-228	16.4
BelDakMi-RR-5	17.6	Gloria	17.3	OLV-3*	18.7	UI-239	19.0
BelMiNeb-1	18.8	GrandMesa	17.3	Orion	20.0	UI-3	16.7
BelMiNeb-RMR-4	19.4	G-3*	16.1	Othello	15.0	UI-37	18.1
BelMiNeb-RMR-7	21.1	GypsyRose	15.7	Ouray	16.3	UI-425	16.8
BelMiNeb-RR-2	20.3	H-3*	17.2	P12-606	18.1	UI-537	17.7
BelMiNebRr-2	19.1	Harold	16.1	PK9-1	16.8	UCD-9623	13.8
BelNeb-RR-1	18.9	Hatton	15.7	PK9-7	16.2	UCD-9634	15.9
Beryl	18.2	Holberg	17.1	PK915	16.6	UI-111	15.7
Beryl-R	18.9	Hungerford	16.6	PT11-13	16.7	UI-114	18.4
BigBend	20.3	I06-2575-17	17.5	PT7-2	15.5	UI-59	18.6
BillZ	14.9	ICB-12	19.8	PT9-17	16.7	URS-117	16.7
B-3*	18.3	Ivory	18.6	PT9-22	18.1	US-1140	17.4
Buckskin	15.8	JM-126	17.9	PT9-5-6	15.6	USPT-ANT-1	16.7
Burke	18.6	Jackpot	17.0	Pindak	16.2	USPT-CBB-1	17.4
Buster	16.4	Kimberly	16.6	PinkFloyd	16.4	USPT-CBB-3	17.0
CDC-Camino	16.6	Kodiak	17.5	Poncho	16.1	USPT-CBB-5	14.2
CDC-Crocus	17.6	LaPaz	17.7	Powderhorn	19.6	USPT-WM-1	16.1
CDC-Pinnacle	15.7	L-3*	16.3	Quincy	15.7	USRM-20	17.0
CDC-Pintium	15.3	Lariat	16.8	R-1*	18.3	USWA-12	17.8
CDC-Rosalee	16.6	LeBaron	16.7	RedRyder	18.3	USWA-13	18.0
CDCWM-2	15.0	LongsPeak	19.8	Rosa	16.3	Victor	16.6
C-9*	15.9	Mariah	16.4	Rosetta	17.5	Vision	15.4
Chase	17.0	M-5*	14.8	SDIP-1	16.3	Viva	17.3
ComRedMx	17.3	Marquis	17.9	SR7-3	16.3	Weihing	17.8
CommPinto	16.8	Matterhorn	19.5	SR9-4	15.7	WinMor	17.2
Coulee	16.8	Maverick	18.9	SWGold *	17.3	Windbreaker	17.2
Coyne	16.9	**LSD (0.05)**	**0.4**	SantaCruz	17.9	Yolano	17.3

Table 20. Stomatal densities (upper side, adaxial only) of leaves from the different market classes represented in the DDP from Powell 2023. Values are the average of 3 plots per genotype.

Market Class	Adaxial Stomatal Density	Number of Genotypes
	number per square millimeter	
Black & White	93	1
Flor de Mayo	74	3
Great Northern	96	39
Pink	79	18
Pinto	99	90
Small Red	83	18
LSD (0.05)	23	Total =169

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