

# **Effect of Dry Bean Planting Configuration and Deficit Irrigation on Direct Harvest Efficiency – PREC 2022**

## **Report for Wyoming Bean Commission; Funded at \$10,000 for the 2022 season**

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*Note: Because this has been an ongoing project for several years, this report will include findings from 2020, 2021, and 2022.*

### **Abstract**

Standard planting configuration for dry bean in the Bighorn Basin of Wyoming is 22-inch rows and a planting rate of 100K seed per acre. Although this management practice has proven quite efficient to the region, other configurations may provide greater yield potential. This planting configuration (i.e., row spacing-by-seeding rate) study was performed with cultivars varying in maturity and canopy architecture across three growing seasons, 2020 to 2022, at Powell (WY) under a sprinkler-irrigation system where full- and two deficit-irrigation treatments were imposed. Two harvest methods were compared to quantify yield, conventional vs. direct. Effects of seeding rate (40K to 80K per acre) were inconsistent. Final plant stands of less than 40K per acre tended to reduce grain yield, especially for tall, late-maturing cultivars under full irrigation, but there were many instances where yield was unaffected by low densities. Under severe deficit irrigation (60% ET), when the 7-inch row spacing was compared to the standard 22-inch spacing, the 7-inch row spacing outyielded the standard by 59%. Under 80% ET irrigation, there was only a 14% yield advantage for 7-inch rows. There was no 7-inch row advantage under full irrigation (100% ET). Similarly, when 15-inch rows were compared to the standard 22-inch rows, there was a 34% yield advantage under 60% ET irrigation. At 80% ET and 100% ET, the 15-inch yield advantage dropped to 18% and 12%, respectively. Deficit irrigation had the expected effect of reducing yield but there was no consistent trend as far as irrigation interacting with cultivar. Yield loss upon direct harvest was substantial (roughly 25% to 31% across years, irrigations, row spacings, and seeding rates). This harvest efficiency finding indicates that modifications to harvest equipment would be needed if direct harvest practice were to be employed by producers. However, direct harvest yield and percent recovery of the two upright, late-maturing cultivars were consistently greater than the prostrate cultivars. Overall, this project quantified expected performance of multiple irrigation-by-planting configuration-by-cultivar combinations and clearly documented in what plant configuration and harvest management situations tall-upright cultivars would be preferred.

### **Methods**

The test was conducted across 2020 to 2022 on a Garland clay loam near Powell WY. Each of the three irrigation treatments were considered separate experiments because we allocated only one-0.25 acre piece of land to each irrigation section each year. The three irrigation regimes consisted of weekly waterings ranging from 60% of evapotranspiration (ET), 80% ET, and full irrigation (100% ET) and sprinkler irrigation was used. Irrigation amounts were roughly 0.6-inch, 0.8-inch, and 1.0-inch per week, respectively. Each of the three irrigation sections included three matching factors: row spacings, cultivars, and two seeding rates (typically a low, 40K per acre and a high, 80K per acre) for each cultivar. Three replicates were planted in 2020 (29 May) and 2021 (4 and 5 June) and two replicates were sown in 2022 (8 and 9 June). Each of the year's three irrigation studies consisted of 60, 72, and 32 plots in 2020, 2021, and 2022, respectively. Plots were 11-feet wide by 25-feet long. The experimental design was a split-plot with row spacing the main plot and cultivar-seeding rate combinations as the subplots. Row spacings were 7-inch,

15-inch, and 22-inch in 2020 and 2021 but only 15-inch and 22-inch row spacings were used in 2022. Despite the targeted seeding rates of 40K and 80K per acre, final plant densities varied greatly and were recorded at harvest. Cultivars were Poncho (early prostrate, 2021/2022), Blackfoot (early upright, 2020/2021), Windbreaker (mid-maturity, mid-upright stature, 2020/2021), Max (early, prostrate, 2022 only), PT9-5-6 (late, upright, 2022 only) and Monterrey (late-maturing upright, 2021/2022).

Data collected during mid-season included canopy temperature, light interception, and leaf area index. Leaf area index and light interception was recorded on seven dates in 2020, one date in 2021 (actually 6, 7, and 8 August 2021 but only one replicate per day), and on one date in 2022 (actually 8 and 9 August, but only one replicate per day). Light interception was recorded only during sunny days and during midday hours for each plot with an Accupar LP-80 canopy analyzer. During those same days but during the late afternoon, LAI was recorded with a LAI2200C plant canopy analyzer (Licor, Inc., Lincoln, NE) for each plot. The Accupar LP-80 unit also records LAI but the LAI2200C unit is designed specifically and only for LAI so the LAI values from the Accupar LP-80 are not included in this report. Incidentally, the LAI values between the two units were rather similar between the two devices.

Plots were walked weekly to monitor flowering and maturity dates. At maturity, plant height and upright stature were recorded. In 2021 and 2022, the percentage of pods above 4-inches above the soil surface was recorded for each plot. Just before harvest, each plot was subdivided into two Sections (A&B) at harvest time. Plots were end-trimmed on all four sides and the remaining dimensions and plant counts (to determine plant density) of Section A and Section B of every plot were then recorded. Later that morning, mature plants from Section A were hand-pulled and allowed to sit on the ground for several hours. On those same afternoons, the bundle of pulled plants were fed into a research plot combine. For Part B, intact plants were direct harvested immediately after each Part A bundle was threshed. Seed was collected from all A and B Sections and grain yield [conventional (A) vs. direct (B)] and seed size (number of seed per pound) were recorded. The final seed size value for each plot was calculated from the averaged across the two harvest methods.

### ***Results – Yield as Affected by Row Spacing and Loss Due to Direct Harvest***

Under 60% ET deficit irrigation in 2020, the conventionally-harvested yields of Blackfoot and Windbreaker were slightly greater under 7-inch rows than wider row spacings but the difference was not statistically significant (Table 1). A similar trend was observed for direct-harvested yield. Under 80% ET deficit irrigation and the 100% ET irrigation, conventionally-harvested yields were greater than the 60% ET irrigation yields (Tables 2 and 3 compared to Table 1). As was the case for row spacing effects with the 60% ET irrigation, conventionally-harvested yields of the 7-inch rows under 80% ET and 100% ET irrigations tended to be greater than for wider rows but the differences were not significant. Across the three irrigations, the percent loss of grain yield due to direct harvest was variable across the different row spacing-cultivar combinations but when averaged across row spacings, the loss percentage value had a tight range (22-31%; Tables 1, 2, 3).

Under 60% ET deficit irrigation in 2021, the conventionally-harvested yields of all four cultivars tended to have greater yield under 7-inch and 15-inch row spacing than under 22-inch row spacing (Table 4). The narrow-row advantage was less apparent for direct-harvested yield. Poncho was the highest yielding cultivar for the conventionally-harvested system but under direct harvest, cultivars had similar yield. For the 80% ET irrigation in 2021, there was a significant row spacing effect (for both harvest methods) that appeared to be attributed to higher yield in the 15-inch row spacing compared to the other two row spacings (Table 5). Cultivars had similar yield when harvested conventionally (except for Blackfoot lagging behind the other three) but Monterrey had the highest yield under direct harvest. Under full irrigation (100% ET), there was no row

spacing effect but Poncho and Windbreaker out-yielded Monterrey and Blackfoot when conventionally-harvested (Table 6). However, under direct harvest, Monterrey out-yielded the other three cultivars. Under 60% ET irrigation, percent loss of grain yield due to direct harvest was similar across cultivars (ranged from 32-41%) but under 80% ET and 100% ET irrigation, Monterrey lost only 4 to 17% of its grain due to direct harvest compared 32% to 37% loss for the other three cultivars.

Under 60% ET deficit irrigation in 2022, the conventionally-harvested yields of Max, Monterrey, and Poncho tended to have greater yield under 15-inch row spacing than under 22-inch row spacing but differences were significant only for Max and Monterrey (Table 7). As was found in 2021, there was no narrow-row yield advantage when direct-harvested yield was analyzed. For the 80% ET irrigation, a similar situation was observed with conventionally-harvested yields of Max, Monterrey, and Poncho showing a slight advantage for narrow rows but this effect was not observed for direct-harvested yield (Table 8). For the 100% ET irrigation, there was a narrow-row yield advantage for all four cultivars when conventionally-harvested but more mixed results for the direct harvested yield (Table 9). Across all three irrigation regimes in 2022 (and using the averages across row spacings), the percent loss of grain yield due to direct harvest was greater for the two early-maturing prostrate cultivars Max and Poncho (range from 41% to 54%) whereas Monterrey and PT9-5-6 lost less (range from 7% to 22%).

Across the three years, the effects of narrow rows (7-inch vs. 22-inch and 15-inch vs. 22-inch) on conventionally-harvested yield were consistent with strong trends and high percentage yield increases under more severe deficit irrigation but diminished effects under full irrigation (Tables 10 and 11). Yield of certain cultivars seemed to respond more favorably to narrow rows than other cultivars but this did not appear to be associated with the cultivar's growth habit or maturity. The mid-maturity and mid-upright cultivar Windbreaker responded the most favorably to 7-inch and 15-inch rows. The early-maturity prostrate Max responded next most favorably, followed by Monterrey (upright and late-maturity). In contrast, yields of Blackfoot (early-maturity, upright) and Poncho (early-maturing and prostrate) showed only modest or neutral response to 7-inch and 15-inch rows vs. 22-inch rows. Yield of PT9-5-6 (late-maturity and upright) was relatively unresponsive to narrow rows.

Across years, the effect of irrigation on the percent loss due to direct harvest appeared to be unaffected by irrigation but there were clear differences across cultivars (Table 12). Monterrey and PT-9-5-6 lost less grain to direct harvest whereas Blackfoot, Poncho, Max, and Windbreaker lost substantial grain due to direct harvest.

**Table 1.** Yield of two dry bean cultivars as affected by row spacing under 60% ET irrigation in 2020. Values are averaged across seeding rates.

<b>60% ET</b>		Grain Yield		
Cultivar	Row Spacing	Conventional	Direct	Percent Loss
		----- lbs per acre -----		%
Blackfoot	7	1482	1213	18
	15	1008	723	28
	22	1201	871	28
Average		1203	936	25
Windbreaker	7	1408	860	39
	15	985	750	24
	22	729	703	4
Average		1041	771	22
LSD (0.05)		298	217	

**Table 2.** Yield of two dry bean cultivars as affected by row spacing under 80% ET irrigation in 2020. Values are averaged across seeding rates.

<b>80% ET</b>		Grain Yield		
Cultivar	Row Spacing	Conventional	Direct	Percent Loss
		----- lbs per acre -----		%
Blackfoot	7	1921	1509	21
	15	1501	1199	20
	22	1765	1296	27
Average		1729	1335	23
Windbreaker	7	2024	1454	28
	15	1674	1173	30
	22	1463	1253	14
Average		1720	1293	24
LSD (0.05)		379	266	

**Table 3.** Yield of two dry bean cultivars as affected by row spacing under 100% ET irrigation in 2020. Values are averaged across seeding rates.

<b>100% ET</b>	Cultivar	Row Spacing	Grain Yield		Percent Loss
			Conventional	Direct	
			----- lbs per acre -----		%
	Blackfoot	7	2691	2044	24
		15	2147	1523	29
		22	2454	1483	40
	Average		2431	1683	31
	Windbreaker	7	2768	1931	30
		15	2105	1446	31
		22	2443	1867	24
	Average		2439	1748	28
	LSD (0.05)		338	287	

**Table 4.** Yield of two dry bean cultivars as affected by row spacing under 60% ET irrigation in 2021. Values are averaged across seeding rates.

<b>60% ET</b>	Cultivar	Row Spacing	Grain Yield		Percent Loss
			Conventional	Direct	
			----- lbs per acre -----		%
	Blackfoot	7	1854	888	52
		15	1656	1103	33
		22	1229	747	39
	Average		1580	913	41
	Monterrey	7	1656	1323	20
		15	1590	1069	33
		22	1075	627	42
	Average		1440	1006	32
	Poncho	7	1914	1123	41
		15	1927	1230	36
		22	1563	1143	27
	Average		1801	1165	35
	Windbreaker	7	1690	934	45
		15	1770	1032	42
		22	808	611	24
	Average		1423	859	37
	LSD (0.05)		562	339	

**Table 5.** Yield of two dry bean cultivars as affected by row spacing under 80% ET irrigation in 2021. Values are averaged across seeding rates.

<i>80% ET</i> Cultivar	Row Spacing	Grain Yield		Percent Loss %
		Conventional ----- lbs per acre -----	Direct	
Blackfoot	7	2250	1149	49
	15	2152	1426	34
	22	2018	1472	27
Average		2140	1349	37
Monterrey	7	2478	1982	20
	15	2942	2518	14
	22	1938	1613	17
Average		2453	2038	17
Poncho	7	2302	1921	16
	15	2828	1681	41
	22	2463	1470	40
Average		2531	1691	32
Windbreaker	7	2240	1444	35
	15	3378	2293	32
	22	2122	1425	33
Average		2580	1721	33
LSD (0.05)		658	589	

**Table 6.** Yield of two dry bean cultivars as affected by row spacing under 100% ET irrigation in 2021. Values are averaged across seeding rates.

<b>100% ET</b>		Grain Yield		
Cultivar	Row Spacing	Conventional	Direct	Percent Loss
		----- lbs per acre -----		%
Blackfoot	7	2370	1319	44
	15	2457	1878	24
	22	2437	1665	32
Average		2421	1621	
Monterrey	7	2067	2176	- 5
	15	2770	2901	- 5
	22	2533	2004	21
Average		2457	2360	4
Poncho	7	2558	1757	31
	15	3033	2022	33
	22	2694	1570	42
Average		2762	1783	35
Windbreaker	7	3238	1404	57
	15	3089	2370	23
	22	2513	1867	26
Average		2947	1880	35
LSD (0.05)		536	495	

**Table 7.** Yield of two dry bean cultivars as affected by row spacing under 60% ET irrigation in 2022. Values are averaged across seeding rates.

<b>60% ET</b> Cultivar	Row Spacing	Grain Yield		Percent Loss
		Conventional ----- lbs per acre -----	Direct	
Max	15	1728	572	67
	22	1211	782	35
Average		1469	677	51
Monterrey	15	1633	1314	19
	22	1116	1035	7
Average		1374	1174	14
Poncho	15	1607	733	54
	22	1437	816	43
Average		1522	774	49
PT9-5-6	15	1231	950	23
	22	1270	1045	18
Average		1250	997	20
LSD (0.05)		351	330	

**Table 8.** Yield of two dry bean cultivars as affected by row spacing under 80% ET irrigation in 2022. Values are averaged across seeding rates.

<b>80% ET</b>		Grain Yield		
Cultivar	Row Spacing	Conventional	Direct	Percent Loss
		----- lbs per acre -----		%
Max	15	2384	1337	44
	22	1925	1118	42
Average		2154	1227	43
Monterrey	15	2387	2042	14
	22	2177	2171	0
Average		2282	2106	7
Poncho	15	2472	1413	43
	22	2111	1285	39
Average		2291	1349	41
PT9-5-6	15	2021	1662	18
	22	2075	1670	19
Average		2048	1666	19
LSD (0.05)		573	436	

**Table 9.** Yield of two dry bean cultivars as affected by row spacing under 100% ET irrigation in 2022. Values are averaged across seeding rates.

<b>100% ET</b> Cultivar	Row Spacing	Grain Yield		Percent Loss %
		Conventional ----- lbs per acre -----	Direct	
Max	15	2313	1017	56
	22	1683	809	52
Average		1998	913	54
Monterrey	15	2328	1733	26
	22	1935	1717	11
Average		2131	1725	19
Poncho	15	2415	1230	49
	22	1959	1162	41
Average		2187	1196	45
PT9-5-6	15	2118	1350	36
	22	1823	1696	7
Average		1970	1523	22
LSD (0.05)		526	308	

**Table 10.** Percent yield increase of 7-inch row spacing vs. 22-inch rows across years (2020 and 2021) and irrigation rates. Only conventionally-harvested yield values were considered.

Year	Cultivar	Irrigation Rate		
		60% ET	80% ET	100% ET
2020	Blackfoot	23	9	10
	Windbreaker	93	38	13
2021	Blackfoot	51	11	- 3
	Monterrey	54	28	- 18
	Poncho	22	- 7	- 5
	Windbreaker	109	5	29
Average		59	14	4

**Table 11.** Percent yield increase of 15-inch row spacing vs. 22-inch rows across years (2020, 2021, and 2022) and irrigation rates.

Year	Cultivar	Irrigation Rate		
		60% ET	80% ET	100% ET
2020	Blackfoot	- 16	- 15	- 12
	Windbreaker	35	14	- 14
2021	Blackfoot	35	7	1
	Monterrey	48	52	9
	Poncho	23	15	13
	Windbreaker	119	59	23
2022	Max	43	24	37
	Monterrey	46	10	20
	Poncho	12	17	23
	PT9-5-6	- 3	- 3	16
Average		34	18	12

**Table 12.** Effect of irrigation rate and cultivar on the percentage grain yield loss due to direct harvest. Values were obtained from Tables 1 to 9.

Year	Cultivar	Irrigation Rate		
		60% ET	80% ET	100% ET
2020	Blackfoot	25	23	31
	Windbreaker	22	24	28
2021	Blackfoot	41	37	32
	Monterrey	32	17	4
	Poncho	35	32	35
	Windbreaker	37	33	35
2022	Max	51	43	54
	Monterrey	14	7	19
	Poncho	49	41	45
	PT9-5-6	20	19	22
Average		33	28	30

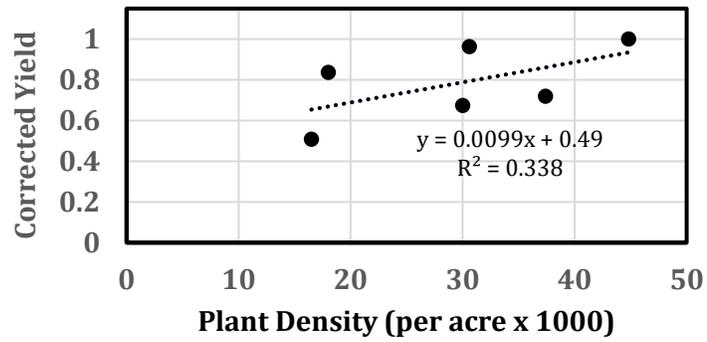
### Results – How Yield Responded to Plant Density

For this report, I am only going to present an abbreviated set of results as to how the crop responded to plant density. Although plant density was originally one of the two primary foci for this project, it turns out that yield response to plant density was often absent across many of the year-irrigation rate-row spacing-cultivar combinations. Across the three years, final plant densities ranged from around 20K plants per acre to around 80K plants per acre and yet yield was relatively stable across those densities. Exceptions are discussed later.

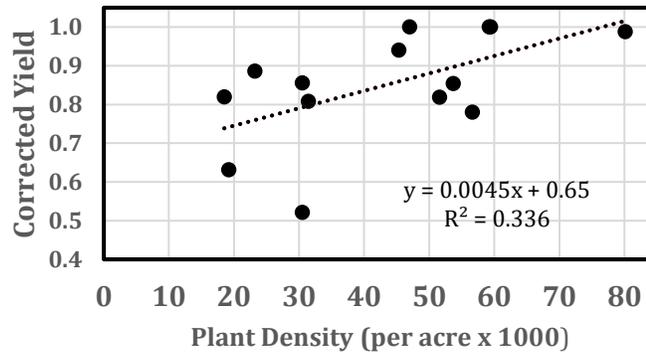
As far as a crop physiological response to plant density, this lack of response is not too surprising. Crops such as dry bean have some capacity to compensate by producing more seed per plant when plant density is low. But the observation that plant densities well below 40K per acre (i.e., 20K to 30K) were able to sustain grain yields comparable to plant densities of 80K per acre, does raise a question as to the efficacy/validity of current dry bean seeding rate recommendations. Although there were some exceptions where low plant density led to low yield (the expected result), this compensatory response where low plant densities yielded relatively well was observed

across years, irrigation rates, row spacing, and cultivars. The overall data set as it relates to plant density is very extensive (albeit quite variable) and going forward, I intend to further analyze the data and learn more about how the five experimental factors (years, irrigation, row spacing, seeding rate, and cultivar) interacted and whether or not there are any solid take-home lessons that producers can use.

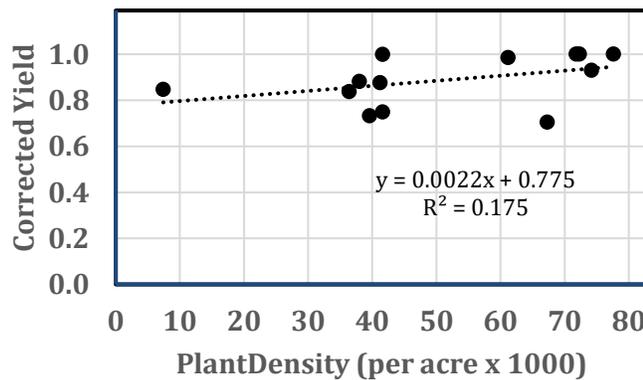
One pattern that I have observed was associated with the two late-maturing upright cultivars (Monterrey and PT9-5-6) and their response to plant density under full irrigation (100% ET). Using the  $x$ -coefficient (0.0099) reported in Figure 1, the result suggests that under full-irrigation and 7-inch rows, yield of an upright late-maturing cultivar would increase by 1.0% for each 1K plant per acre increase from a plant density of 20K to 50K plants per acre. Likewise from Figure 2 (with an  $x$ -coefficient of 0.0045), for full-irrigation and 15-inch rows, yield of an upright late-maturing cultivar would increase by 0.45% for each 1K plant per acre increase from a plant density of 20K to 80K plants per acre. Finally, from Figure 3 (with an  $x$ -coefficient of 0.0022), under full-irrigation and 22-inch rows, yield of an upright late-maturing cultivar would increase by 0.22% for each 1K plant per acre increase from a plant density of 20K to 80K plants per acre. The decreasing steepness of three slopes (1.0%, 0.45%, and 0.22%) as row spacing increased, all fit well with historic crop physiology and canopy architecture findings that have indicated that the optimal plant density for narrow-row management is higher than optimal plant density for wide-row management.



**Figure 1.** Corrected yield as affected by final plant density of Monterrey in 7-inch rows in 2021 under full irrigation (100% ET). Corrected yield was calculated by dividing the actual yield by the highest yield among the year-irrigation-row space-cultivar combination.



**Figure 2.** Corrected yield as affected by final plant density of Monterrey and PT9-5-6 in 15-inch rows in 2021 and 2022 under full irrigation (100% ET). Corrected yield was calculated by dividing the actual yield by the highest yield among the year-irrigation-row space-cultivar combination.

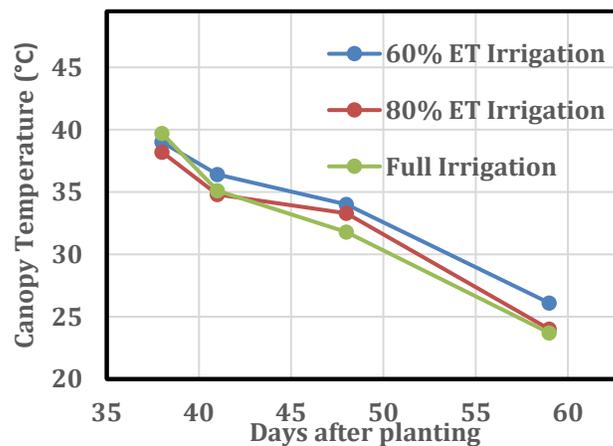


**Figure 3.** Corrected yield as affected by final plant density of Monterrey and PT9-5-6 in 22-inch rows in 2021 and 2022 under full irrigation (100% ET). Corrected yield was calculated by dividing the actual yield by the highest yield among the year-irrigation-row space-cultivar combination.

### Results – Canopy Temperature

In general, I collected canopy temperature on selected clear days during the middle of the growing season to document the effectiveness (or lack thereof) of the deficit irrigation across the three irrigation experiments. Additionally, I documented the extent to which the different row spacings and/or cultivars responded within the same irrigation treatment. As for how canopy temperature was affected by plant density, that relationship turned out to be complicated and I am delaying my discussion of canopy temperature vs. plant density for a later time (and not in this report).

In 2020, there were no differences in canopy temperature among treatments on the first sampling date (Fig. 4 and Tables 13 and 14, °C and °F). However, on the second sampling date (9 July) the 60% ET plots were slightly warmer than the two treatments receiving more irrigation. Canopy temperature of Blackfoot was cooler than for Windbreaker across row spacings and the poor stand density associated with Windbreaker could be involved in the difference. In mid-July (16 July), there was the expected trend for the 60% ET irrigation to have warmer canopies than plots receiving greater irrigation amounts. Also on that date, canopy temperature of Blackfoot was consistently cooler than Windbreaker across the three irrigation rates, again, possibly due to Windbreaker's weaker stand. By late July (27 July), the canopy temperature situation remained the same, with the 60% ET irrigation treatment showing warmer temperatures than the two more fully-watered treatments. Also, canopy temperature of Blackfoot remained cooler than Windbreaker. By 4 August, the only conspicuous effect was with irrigation; the 60% ET irrigation had warmer temperatures than the 100% ET irrigation. Row spacing and cultivar did not affect canopy temperature on the 4 August date. By 16 August, Blackfoot had matured and data was only collected on Windbreaker. For the 60% ET irrigation, the 22-inch spacing had cooler canopy temperature than the two narrower row spacings. This difference is possibly explained by the narrower rows exhausting the available soil water earlier in the season as compared to the soil below the 22-inch.



**Figure 4.** Graphical representation of canopy temperatures in 2020. Data are averaged across row spacings, cultivars, and seeding rates. Each data point represents 60 plots.

**Table 13.** Effect of row spacing and cultivar on canopy temperature (°C) during 2020. Each data point is an average across several plots with varying plant densities as described in the narrative.

Date - 2020	Row Space	Cultivar	Irrigation			Average
			60% ET	80% ET	100% ET	
6 July	all	both	39.0	38.2	39.7	39.0
9 July	7-inch	Blackfoot	34.8	33.3	33.9	34.0
		Windbreaker	37.2	35.9	36.2	36.4
	15-inch	Blackfoot	34.7	32.8	32.0	33.2
		Windbreaker	37.5	36.8	36.2	36.8
	22-inch	Blackfoot	35.2	33.2	35.0	34.5
		Windbreaker	37.1	35.1	35.7	36.0
LSD(0.05)			1.5	1.7	2.0	na
Average			36.4	34.8	35.1	35.4
16 July	all	Blackfoot	33.2	32.7	30.7	32.2
		Windbreaker	34.5	33.7	32.5	33.6
LSD (0.05)			1.1	1.4	1.3	na
		Average	34.0	33.3	31.8	33.0
27 July	all	Blackfoot	26.4	24.4	23.7	24.8
		Windbreaker	27.4	25.3	24.4	25.7
LSD (0.05)			0.8	0.9	0.7	na
		Average	26.9	24.9	24.2	25.3
4 Aug	all	all	31.5	-	27.7	29.4
16 Aug	7-inch	Windbreaker	36.1	33.6	31.7	33.8
	15-inch	Windbreaker	35.7	33.1	31.3	33.4
	22-inch	Windbreaker	34.7	34.1	32.1	33.6
LSD (0.05)			1.0	ns	ns	na
		Average	35.5	33.6	31.7	33.6

**Table 14.** Effect of row spacing and cultivar on canopy temperature (°F) during 2020. Each data point is an average across several plots with varying plant densities as described in the narrative.

Date - 2020	Row Space	Cultivar	Irrigation			Average
			60% ET	80% ET	100% ET	
6 July	all	both	102	101	103	102
9 July	7-inch	Blackfoot	95	92	93	93
		Windbreaker	99	97	97	97
	15-inch	Blackfoot	94	91	90	92
		Windbreaker	99	98	97	98
	22-inch	Blackfoot	95	92	95	94
		Windbreaker	99	95	96	97
LSD(0.05)			3	3	4	
Average			97	95	95	96
16 July	all	Blackfoot	92	91	87	90
		Windbreaker	94	93	90	92
LSD (0.05)			2	3	2	
		Average	93	92	89	91
27 July	all	Blackfoot	79	76	75	77
		Windbreaker	81	77	76	78
LSD (0.05)			2	2	2	
		Average	80	77	76	77
4 Aug	all	all	89		82	85
16 Aug	7-inch	Windbreaker	97	92	89	93
	15-inch	Windbreaker	96	92	88	92
	22-inch	Windbreaker	94	93	90	92
LSD (0.05)						
		Average	96	92	89	92

In 2021, canopy temperature was collected on 11 and 12 August prior to a scheduled irrigation. Two replicates were measured on the 11<sup>th</sup> and the final replicate was measured on the 12<sup>th</sup> (Tables 15 and 16). Averaged across all 72 plots in the 60% irrigation field showed a high canopy temperature of 30.1°C but the average for the 80% ET and the 100% ET treatments were similar (26.9°C and 26.2°C, respectively). As far as row spacing, there was a trend for canopies from the 7-inch rows to be warmer than the wider row spacing and this was consistent across the 80% ET and 100% ET irrigation regimes. Monterrey had the coolest canopy temperatures across the three irrigation regimes and canopies from Windbreaker ranked second for lowest canopy temperature. It is possible that the early maturity of Blackfoot and Poncho and possible onset of senescence at that time, may have contributed to the Blackfoot/Poncho canopies being warmer during this mid-August sampling.

**Table 15.** Effect of row spacing and cultivar on canopy temperature (°C) during mid-August 2021 under three irrigation regimes.

Date - 2021	Row Space	Cultivar	Irrigation			Average
			60% ET	80% ET	100% ET	
11-12 July	7-inch	Blackfoot	32.5	28.9	29.2	30.2
		Monterrey	30.2	27.3	26.6	28.0
		Poncho	30.0	27.7	26.2	28.0
		Windbreaker	30.0	28.0	27.7	28.6
Average			30.6	27.4	27.4	28.4
	15-inch	Blackfoot	29.8	26.1	25.9	27.3
		Monterrey	28.7	25.3	25.1	26.4
		Poncho	28.8	26.1	25.5	26.8
		Windbreaker	29.1	25.6	25.1	26.6
Average			29.1	25.4	25.4	26.6
	22-inch	Blackfoot	31.4	26.9	26.2	28.2
		Monterrey	29.7	26.7	25.6	27.3
		Poncho	31.3	27.0	26.0	28.1
		Windbreaker	30.3	26.6	25.5	27.5
Average			30.7	25.8	25.8	27.4
LSD (0.05)			1.4	1.1	1.4	na
Average	all	all	30.1	26.9	26.2	na

**Table 16.** Effect of row spacing and cultivar on canopy temperature (°F) during mid-August 2021 under three irrigation regimes.

Date - 2021	Row Space	Cultivar	Irrigation			Average
			60% ET	80% ET	100% ET	
11-12 July	7-inch	Blackfoot	90	84	85	86
		Monterrey				
		Poncho	86	82	79	82
		Windbreaker	86	82	82	83
Average			87	81	81	83
	15-inch	Blackfoot	86	79	79	81
		Monterrey	84	77	77	79
		Poncho				
		Windbreaker	84	78	77	80
Average						
	22-inch	Blackfoot	88	80	79	83
		Monterrey				
		Poncho	88	81	79	83
		Windbreaker				
Average			87	78	78	81
LSD (0.05)			3	2	3	na
Average	all	all	86	80	79	na

In 2022, on 19 July, canopy temperature was affected by row spacing and cultivar (Tables 17 and 18). In general, canopies with the 22-inch rows were cooler than those from 15-inch rows. Also, the cultivar Max had the coolest canopy temperatures on this date. As expected, canopies of the 60% ET irrigation plots were warmer than those from the other two irrigation regimes. On 10 August 2022, canopy temperatures were unaffected by any of the row spacing and cultivar treatments but again, as expected, the canopies of the 60% ET irrigation plots were warmer than the other two irrigation rates. On the final sampling date (18 Aug 2022), canopy temperature of Monterrey was the coolest and this was likely associated with its later maturing as compared to the early-maturing Max and Poncho. The 60% ET irrigation showed to have the warmest temperatures on 18 Aug 2022 as compared to the 80% ET and 100% ET irrigation rates.

**Table 17.** Effect of row spacing and cultivar on canopy temperature (°C) on three sampling dates during 2022 under three irrigation regimes.

Date 2022	Row Space	Cultivar	Irrigation		
			60% ET	80% ET	100% ET
19 July	15-inch	Max	37.4	35.7	37.5
		Monterrey	37.8	37.2	38.3
		Poncho	37.9	37.4	39.1
		PT9-5-6	38.2	38.0	38.8
Average			37.8	37.1	38.4
	22-inch	Max	34.2	34.2	34.6
		Monterrey	35.3	35.0	35.0
		Poncho	35.8	34.2	36.2
		PT9-5-6	35.2	34.6	35.1
LSD (0.05)			0.8	0.9	1.0
Average			35.1	34.5	35.2
10 Aug	all	all	32.3	29.5	30.0
18 Aug	all	Max	27.4	25.4	25.9
		Monterrey	25.7	24.5	24.4
		Poncho	27.0	24.8	25.4
		PT9-5-6	26.4	25.3	24.9
LSD (0.05)			0.6	0.4	0.4
Average			26.6	25.0	25.2

**Table 18.** Effect of row spacing and cultivar on canopy temperature (°F) on three sampling dates during 2022 under three irrigation regimes.

Date 2022	Row Space	Cultivar	Irrigation		
			60% ET	80% ET	100% ET
19 July	15-inch	Max	99	96	99
		Monterrey	100	99	102
		Poncho	101	100	102
		PT9-5-6	101	99	101
Average			100	99	101
	22-inch	Max	94	94	94
		Monterrey	95	95	95
		Poncho	95	94	95
		PT9-5-6	95	94	95
Average			95	94	95
LSD (0.05)			2	3	3
10 Aug	all	all	90	85	95
18 Aug	all	Max	81	78	79
		Monterrey	78	76	76
		Poncho	81	77	78
		PT9-5-6	79	77	77
LSD (0.05)			1	1	1
Average			80	77	77

### Results – Leaf Area Index (LAI)

Canopy development, as quantified by LAI, was relatively unaffected by row spacing and cultivar during the first sampling in 2020 which occurred on 18/19 July (Table 19). By 26 July, however, LAI had increased and was slightly greater in the 80% ET and 100% ET irrigation rates than the 60% ET rate. Also, LAI appeared to be affected by a row spacing-by-cultivar interaction within the three irrigation rates. Blackfoot had a larger LAI within the two narrow-row systems whereas Windbreaker had the larger LAI within the 22-inch system. By 1 August, Blackfoot tended to have greater LAI than Windbreaker across the three irrigation regimes but row spacing effects were not observed. On 7 August, no effects of row spacing or cultivar were observed although the expected trends across irrigation rates were observed (greater LAI with more water). By 15 August, Blackfoot has started to senesce and consequently, the later-maturing Windbreaker expressed greater LAI than Blackfoot. On the final sampling date, (22 Aug), only Windbreaker was measured and no row spacing effects were found except for the 60% ET irrigation where the wider rows retained greater LAI.

**Table 19.** Effect of row spacing and cultivar on leaf area index (LAI) under three irrigation regimes during the 2020 growing season.

Date	Row Space	Cultivar	60%	80%	100%	Average
18/19 July	all	all	0.90	1.14	1.17	1.07
26 July	7-inch	Blackfoot	2.84	3.01	3.59	3.15
		Windbreaker	1.92	2.42	2.53	2.29
	15-inch	Blackfoot	2.64	2.91	3.36	2.97
		Windbreaker	2.26	2.63	2.91	2.60
	22-inch	Blackfoot	2.00	3.28	2.45	2.58
		Windbreaker	2.51	2.96	2.83	2.78
LSD (0.05)			0.46	0.54	0.60	
1 August	all	Blackfoot	3.14	3.81	4.54	3.83
		Windbreaker	2.70	3.41	3.92	3.34
LSD (0.05)			0.31	0.43	0.37	
7 August	all	all	3.11	3.64	4.26	3.67
15 August	all	Blackfoot	1.99	2.32	2.80	2.37
		Windbreaker	2.71	3.26	3.91	3.29
LSD (0.05)			0.23	0.34	0.41	
22 August	7-inch	Windbreaker	2.67	3.24	3.91	3.27
	15-inch	Windbreaker	2.27	3.04	3.78	3.03
	22-inch	Windbreaker	3.29	3.73	4.06	3.69
LSD (0.05)			0.44	ns	ns	

In 2021, LAI was only collected once (7, 8, and 9 August, one replicate per day) and row spacing and cultivar effects were significant across all three irrigation rates (Table 20). Regarding row spacing, 15-inch rows had higher LAI than 7-inch and 22-inch rows under the two deficit irrigation rates. Under 100% ET, however, LAI for both 15-inch and 22-inch rows had greater LAI than 7-inch rows. The aforementioned effects of row spacing are thought to be associated with poorer emergence and subsequent lower plant density in the 7-inch rows than the wider row spacings. Regarding cultivars, Monterrey and Poncho expressed greater LAI than Blackfoot across the three irrigation rates and the three row spacings. In general, Windbreaker had a lower LAI than Monterrey and Poncho under the two narrow spacings but its LAI was similar under 22-inch rows.

**Table 20.** Effect of row spacing and cultivar on LAI on 8 Aug 2021 under three irrigation regimes.

Row Spacing	Cultivar	Irrigation			Average
		60%	80%	100%	
7-inch	Blackfoot	1.95	1.89	2.24	2.02
	Monterrey	2.66	3.81	3.78	3.42
	Poncho	2.78	4.37	4.49	3.88
	Windbreaker	1.83	3.03	2.04	2.30
Average		2.30	3.28	3.14	2.91
15-inch	Blackfoot	2.97	4.15	3.11	3.41
	Monterrey	4.25	5.66	5.93	5.28
	Poncho	3.84	5.37	5.49	4.90
	Windbreaker	3.20	5.52	4.79	4.50
Average		3.57	5.17	4.83	4.52
22-inch	Blackfoot	1.97	4.15	3.77	3.30
	Monterrey	3.43	5.08	5.60	4.70
	Poncho	2.84	4.54	5.58	4.32
	Windbreaker	2.79	3.91	5.63	4.11
Average		2.76	4.42	5.14	4.11
LSD (0.05)		1.04	1.49	1.09	

In 2022, LAI was only collected once (5 and 7 August, one replicate per day). The 60% ET irrigation had the lowest LAI across both row spacings (Table 21). Within the three irrigation rates, there was a significant row spacing-by-cultivar interaction. Under 60% ET and 80% ET, Monterrey had a low LAI within 15-inch rows but the highest LAI within 22-inch rows. Under 100% ET, Poncho had the lowest LAI with 15-inch rows had an LAI nearly as high as Monterrey within 22-inch rows.

**Table 21.** Effect of row spacing and cultivar on LAI on 6 Aug 2022 (average of the two sampling dates, 5/7 Aug) under three irrigation regimes.

Row Spacing	Cultivar	Irrigation			Average
		60%	80%	100%	
15-inch	Max	1.34	2.37	1.92	1.88
	Monterrey	1.74	2.12	2.41	2.09
	Poncho	1.27	2.43	1.73	1.81
	PT9-5-6	1.42	2.05	1.96	1.81
Average		1.44	2.24	2.00	1.89
22-inch	Max	1.08	1.96	1.66	1.57
	Monterrey	1.41	3.23	2.74	2.46
	Poncho	1.96	1.89	2.67	2.17
	PT9-5-6	1.85	2.40	1.50	1.92
Average		1.57	2.37	2.14	2.03
LSD (0.05)		0.49	1.07	0.66	

## Results – Canopy Light Interception

For 2020, light interception for all dates is provided in Tables 22 and 23.

**Table 22.** Light interception across all of the treatments for the first four samplings in 2020.

Date	Row Space	Cultivar	Light Interception (%)		
			60% ET	80% ET	100% ET
5 July	7-inch	Blackfoot	25	26	23
		Windbreaker	17	18	15
	15-inch	Blackfoot	27	40	29
		Windbreaker	15	33	18
	22-inch	Blackfoot	22	37	18
		Windbreaker	20	34	20
11 July	7-inch	Blackfoot	36	36	40
		Windbreaker	29	26	27
	15-inch	Blackfoot	40	40	40
		Windbreaker	57	33	28
	22-inch	Blackfoot	33	37	33
		Windbreaker	34	34	33
18 July	7-inch	Blackfoot	43	42	52
		Windbreaker	34	32	38
	15-inch	Blackfoot	38	40	45
		Windbreaker	33	36	37
	22-inch	Blackfoot	36	33	41
		Windbreaker	34	36	35
25 July	7-inch	Blackfoot	64	71	78
		Windbreaker	56	63	70
	15-inch	Blackfoot	62	64	77
		Windbreaker	62	66	71
	22-inch	Blackfoot	50	62	63
		Windbreaker	53	64	67

**Table 23.** Light interception across all of the treatments for the final three samplings in 2020.

Date	Row Space	Cultivar	Light Interception (%)		
			60% ET	80% ET	100% ET
31 July	7-inch	Blackfoot	60	73	80
		Windbreaker	54	59	71
	15-inch	Blackfoot	61	66	80
		Windbreaker	52	63	77
	22-inch	Blackfoot	52	63	73
		Windbreaker	55	63	72
7 Aug	7-inch	Blackfoot	63	69	76
		Windbreaker	65	66	77
	15-inch	Blackfoot	54	65	76
		Windbreaker	57	66	82
	22-inch	Blackfoot	51	53	67
		Windbreaker	61	66	76
18 Aug	7-inch	Blackfoot	56	63	70
		Windbreaker	63	69	77
	15-inch	Blackfoot	57	64	71
		Windbreaker	65	68	77
	22-inch	Blackfoot	35	60	60
		Windbreaker	57	68	71

In 2021, for mid-season light interception within the 60% ET irrigation, the only consistent effect was that of cultivar (Tables 24, 25, and 26). Additionally, there were no interactions; thus, only the main effects are shown. For the 80% ET irrigation, the higher seeding rate had increased light interception and this was observed across all three row spacings (Table 27). Poncho and Monterrey tended to have higher light interception than the other two cultivars (Table 28). For mid-season (early August) within the 100% ET irrigation, we found that the increased seeding rate increased light interception (Table 29). As for row spacing and cultivar effects on light interception, there was a significant row spacing-by-cultivar interaction (Table 30). The row spacing-by-cultivar interaction for light interception was partly due to low values for Windbreaker in the 7-inch spacing whereas Windbreaker had values similar light interception values to Monterrey and Poncho at 15-inch and 22-inch. The full 2021 data set for light interception is provided in Table 31. For convenience to the reader, I have also provided a table for light interception for each irrigation rate in 2021 when averaged across all plots within a given irrigation (Table 32). And finally, light interception for 2022 for all row spacing-by-cultivar combinations across all irrigations are provided in Table 33.

**Table 24.** Effect of seeding rate on leaf area index and light interception of dry bean grown at Powell on 7 Aug 2021 (actually averaged across 6, 7, 8 Aug) under 60% ET irrigation. Data value are average across cultivars and row spacings; thus each data value represents 36 plots.

Seeding Rate (per	Light Interception (%)
40K	62
80K	66
P-value	0.0850

**Table 25.** Effect of row spacing on leaf area index and light interception of dry bean grown at Powell on 7 Aug (actually 6, 7, 8 Aug) 2021 under 60% ET irrigation. Data value are average across cultivars and seeding rate; thus each data value represents 24 plots.

Seeding Rate (per	Light Interception (%)
7-inch	58
15-inch	71
22-inch	63
P-value	0.0648

**Table 26.** Effect of cultivar on leaf area index and light interception of dry bean grown at Powell on 7 Aug (actually 6, 7, 8 Aug) 2021 under 60% ET irrigation. Data value are average across row spacings and seeding rates; thus each data value represents 18 plots.

Cultivar	Light Interception (%)
Blackfoot	58
Monterrey	72
Poncho	65
Windbreaker	62
LSD (0.05)	6
P-value	0.0003

**Table 27.** Effect of row spacing and seeding rate on light interception under 80% ET irrigation in 2021.

Row Spacing	Seeding Rate (per acre)	Light Interception (%)
7-inch	40K	59
	80K	79
15-inch	40K	82
	80K	90
22-inch	40K	82
	80K	85
P-value		0.0034

**Table 28.** Effect of row spacing and cultivar on light interception on 7 Aug 2021 at Powell under 80% ET irrigation.

Row Spacing	Cultivar	Light Interception (%)
7-inch	Blackfoot	58
	Monterrey	75
	Poncho	77
	Windbreaker	66
15-inch	Blackfoot	81
	Monterrey	90
	Poncho	88
	Windbreaker	87
22-inch	Blackfoot	76
	Monterrey	89
	Poncho	80
	Windbreaker	79
LSD (0.05)		9
P-value (RS-by-Cult)		0.2346

**Table 29.** Effect of seeding rate on leaf area index and light interception of dry bean grown at Powell on 7 Aug (actually 6, 7, 8 Aug) 2021 under 100% ET irrigation. Data values are average across cultivars and row spacings; thus each data value represents 36 plots.

Seeding Rate (per acre)	Light Interception (%)
40K	77
80K	84
P-value	0.003

**Table 30.** Effect of row spacing and cultivar on light interception on 7 Aug 2021 at Powell under 100% ET irrigation. Data are averaged across seeding rates. Each data point represents six plots.

Row Spacing	Cultivar	Light Interception (%)
7-inch	Blackfoot	52
	Monterrey	75
	Poncho	83
	Windbreaker	57
15-inch	Blackfoot	76
	Monterrey	92
	Poncho	90
	Windbreaker	87
22-inch	Blackfoot	79
	Monterrey	93
	Poncho	91
	Windbreaker	88
P-value (RS-by-Cult)		0.0093

**Table 31.** Light interception values for the 2021 study under full irrigation. Data were recorded on 6, 7, and 8 August 2021 at Powell with the Accupar LP-80 unit. Each value is 1.0 minus the quotient of light recorded by the sensor below the canopy divided by the light intensity recorded above the canopy. Values are the average of three plots with at least three below-canopy readings taken per plot. Seeding rates are per acre.

Row Space	Cultivar	Seeding Rate		Average
		40 K	80 K	
7-inch	Blackfoot	0.45	0.59	0.52
	Monterrey	0.67	0.83	0.75
	Poncho	0.79	0.87	0.83
	Windbreaker	0.58	0.57	0.57
	Average	0.62	0.72	0.67
15-inch	Blackfoot	0.70	0.83	0.76
	Monterrey	0.91	0.93	0.92
	Poncho	0.90	0.91	0.90
	Windbreaker	0.80	0.94	0.87
	Average	0.83	0.90	0.86
22-inch	Blackfoot	0.72	0.87	0.79
	Monterrey	0.92	0.93	0.93
	Poncho	0.92	0.90	0.91
	Windbreaker	0.90	0.87	0.88
	Average	0.86	0.89	0.88
LSD (0.05)†				
<b>P-values</b>				
RS Effect		0.004		
Cultivar		0.001		
Seeding Rate		0.001		
RS-by-Cult		0.009		
RS-by-SeedRate		0.336		
Cult-by-SeedRate		0.125		
RS-by-Cult-by-SR		0.333		

**Table 32.** Effect of irrigation rate on light interception in 2021. Values are averaged across all factors, row spacing, seeding rate, and cultivar (72 plots for each value).

Irrigation Rate	Light Interception (%)
60% ET	64
80% ET	79
100% ET	80

**Table 33.** Light interception on 8/9 August 2022 across all treatments. Values are averaged across seeding rates.

Row Space	Cultivar	Light Interception (%)		
		60% ET	80% ET	100% ET
15-inch	Max	58	66	61
	Monterrey	62	76	75
	Poncho	63	67	73
	PT9-5-6	64	73	73
22-inch	Max	48	57	53
	Monterrey	55	73	70
	Poncho	52	70	65
	PT9-5-6	66	74	73

***Flowering Date, Maturity Date, Seed Size, and Upright Stature***

In 2020, row spacing did not affect flowering date or maturity but Windbreaker matured substantially later than Blackfoot (Table 34). Likewise, neither seed size nor the number of seed per pound was affected by row spacing although Windbreaker had larger seeds than Blackfoot as expected. Deficit irrigation resulted in smaller seed across cultivars. Blackfoot was shorter but tended to have better upright stature than Windbreaker (Table 35). Deficit irrigation reduced plant height but improved upright stature.

In 2021, there was a pattern that was consistent across the three irrigation regimes in that Monterrey located the highest percentage of pods above 4-inches (Table 36). Poncho located most of its pods below the 4-inch mark. As for maturity under the 60% irrigation in 2021, the only conspicuous effects were associated with cultivar. As expected, Blackfoot and Poncho matured earlier than Monterrey and Windbreaker (Table 37). As for maturity under 80% ET, there was a row spacing-by-cultivar interaction and a seeding rate effect. The row spacing-by-cultivar interaction was caused by Windbreaker maturing earlier than expected in the 15-inch spacing (Table 38). The higher seeding rate hastened maturity by two days (Table 39).

**Table 34.** Flowering and maturity dates for the different treatments in two dry bean cultivars grown at Powell in 2020.

Water	Cultivar	Row Space	Flower	Maturity	Seed Size	Seeds per pound
			dap	dap	mg	
60%	Blackfoot	7	50	81	284	1604
		15	50	81	287	1583
		22	50	80	284	1599
60%	Windbreaker	7	52	99	382	1189
		15	53	96	362	1255
		22	52	100	396	1146
LSD (0.05)			1	3	19	45
80%	Blackfoot	7	50	83	307	1479
		15	50	84	311	1458
		22	50	81	301	1508
80%	Windbreaker	7	51	101	415	1093
		15	52	100	407	1116
		22	51	100	427	1062
LSD (0.05)			2	3	4	31
100%	Blackfoot	7	50	89	319	1423
		15	50	92	328	1386
		22	51	87	312	1454
100%	Windbreaker	7	52	103	420	1081
		15	53	102	411	1104
		22	52	101	422	1077
LSD (0.05)			2	6	15	29
Irrigation Avg. †						
100%			51	97	379	1197
80%			51	93	367	1236
60%			51	91	334	1358

† Irrigation rates were separate fields; thus, no statistical analysis was performed to test the significance of irrigation.

**Table 35.** Upright stature and plant height for the different treatments in two dry bean cultivars grown at Powell in 2020.

Water	Cultivar	Row Space	Upright †	Height ‡
				cm
60%	Blackfoot	7	8.9	49
		15	9.1	45
		22	7.9	42
60%	Windbreaker	7	7.8	66
		15	8.7	61
		22	7.3	62
LSD (0.05)			1.3	15
80%	Blackfoot	7	7.0	47
		15	7.9	53
		22	4.9	53
80%	Windbreaker	7	6.3	84
		15	6.5	84
		22	5.7	81
LSD (0.05)			1.9	18
100%	Blackfoot	7	6.9	62
		15	5.6	59
		22	4.6	59
100%	Windbreaker	7	5.3	86
		15	6.2	91
		22	6.5	75
LSD (0.05)			1.5	17
Irrigation Avg. ‡				
60%			8.2	56
80%			6.3	70
100%			5.9	74

† Statistically-significant row spacing-by-cultivar interactions were found for each of the three irrigation levels. Thus, the LSD value can be used to compare any of the six values within an irrigation.

‡ Irrigation rates were separate fields; thus, no statistical analysis was performed to test irrigation significance.

**Table 36.** Percent of pods above 4-inch for the four cultivars and three irrigation rates in 2021. Data are averaged across row spacings and seeding rates. Each data point represents 18 plots.

<b>Cultivar</b>	<b>60% ET</b>	<b>80% ET</b>	<b>100% ET</b>	<b>Average</b>
Blackfoot	67	65	62	65
Monterrey	89	87	84	87
Poncho	50	44	45	46
Windbreaker	67	66	61	65
LSD (0.05)	5	6	5	na
P-value	0.0001	0.0001	0.0001	na

**Table 37.** Effect of cultivar on maturity of the four cultivars grown under 60% ET at Powell in 2021. Values represent the means across 18 plots.

<b>Cultivar</b>	<b>Maturity</b>
	days after planting
Blackfoot	81
Monterrey	97
Poncho	82
Windbreaker	94
LSD (0.05)	2
P-value	0.0001

**Table 38.** Effect of row spacing and cultivar on maturity at 80% ET irrigation. Values are the mean of six plots.

Row Spacing	Cultivar	Maturity
		dap
7-inch	Blackfoot	82
	Monterrey	94
	Poncho	82
	Windbreaker	92
15-inch	Blackfoot	76
	Monterrey	95
	Poncho	80
	Windbreaker	85
22-inch	Blackfoot	82
	Monterrey	98
	Poncho	82
	Windbreaker	97
LSD (0.05)		4
P-value (RS-by-Cult)		0.006

**Table 39.** Effect of seeding rate on maturity at 80% ET. The values are the average of 36 plots.

Seeding Rate	Maturity
	days after planting
40K	88
80K	86
LSD (0.05)	1.5
P-value	0.006

**Table 40.** Effect of row spacing and cultivar on maturity at 100% ET in 2021. The values are the mean of 6 plots.

Row Spacing	Cultivar	Maturity
		dap
7-inch	Blackfoot	83
	Monterrey	98
	Poncho	86
	Windbreaker	98
15-inch	Blackfoot	82
	Monterrey	97
	Poncho	83
	Windbreaker	97
22-inch	Blackfoot	78
	Monterrey	95
	Poncho	79
	Windbreaker	87
LSD (0.05)		4
P-value (RS-by-Cult)		0.027

As for maturity dates in 2021 as affected by the treatments at 100% ET, the patterns were mostly as expected but there was a row spacing-by-cultivar interaction with Windbreaker having delayed maturity under the two narrow row spacings (Table 41). As expected, Blackfoot and Poncho matured earlier than Monterrey and Windbreaker although there was also a cultivar-by-seeding rate interaction with Poncho at the low seeding rate having delayed maturity. Averaged across the 72 plots per irrigation treatment (and including all three irrigation regimes in one table), the 60% ET matured earlier (84 dap) than the 80% ET (87 dap) and the 100% ET (89 dap) as expected (Table 42).

As for upright stature under 60% ET, the only effects observed were the expected differences with Monterrey being the most upright and Poncho being prostrated (Table 43). Under the 80% irrigation regime there was a cultivar-by-seeding rate interaction for upright stature with Monterrey improving its upright stature under the higher seeding rate (Table 44). For the 100% ET, a significant row space-by-cultivar interaction and a significant cultivar-by-seeding rate interaction was observed on upright stature. The row spacing-by-cultivar interaction was attributed to Poncho

having a more severe and very prostrate architecture under 22-inch rows (Table 45). The cultivar-by-seeding rate interaction was caused by the tall/late-maturing cultivars improving their upright stature at the high seeding rates whereas the short/early-maturing cultivar Poncho became more prostrate at the higher seeding rates (Table 46). The more prostrate growth for the heavier irrigations are expected because the fully irrigated plots yield more and thus, pods weigh down the plants and the canopy.

In 2022, at 60% ET irrigation, maturity, upright stature, and percentage of pods above 4-inches were only affected by cultivar and seeding rate (Tables 47 and 48). As expected Monterrey and PT9-5-6 matured later, were more upright, and had a greater percentage of pods above 4-inches. For the 80% irrigation, as for the 60% irrigation, cultivars and seeding rates differed with the Monterrey maturing later and being more upright than Poncho and Max (Tables 49) and with the higher seeding rate resulting in earlier maturity and more upright plants (Table 50). For 100% ET, the cultivars again differed with Monterrey and PT9-5-6 showing the later maturity, more upright posture, and a greater percentage of pods above 4-inches (Table 51). In addition to cultivar effects at 100% ET, there was a significant row spacing-by-seeding rate interaction. This was caused by the 15-inch rows combined with a reduced seeding rate to have more prostrate growth and a fewer percentage of pods above 4-inch than the other three row space-by-seeding rate combinations (Table 52). Irrigation regimes did not appear to differentially affect flowering, maturity, upright stature, and percentage of pods above 4-inches (Table 53).

**Table 41.** The effect of cultivar and seeding rate on maturity of dry bean grown at 100% ET in 2021. The values are the means of 9 plots.

Cultivar	Seeding Rate	Maturity
		days after planting
Blackfoot	40K	81
	80K	80
Monterrey	40K	98
	80K	95
Poncho	40K	87
	80K	78
Windbreaker	40K	94
	80K	94
LSD (0.05)		3
P-value (Cult-by-SR)		0.0001

**Table 42.** Effect of irrigation on maturity (dap) in 2021.

	Irrigation		
	60% ET	80% ET	100% ET
Maturity	84	87	88

**Table 43.** Effect of cultivar on upright stature under 60% ET in 2021 at Powell.

Cultivar	Upright Stature
Blackfoot	8.3
Monterrey	9.3
Poncho	5.2
Windbreaker	8.7
LSD (0.05)	0.5
P-value	0.0001

**Table 44.** Effect of cultivar and seeding rate on upright stature under 80% ET in 2021 at Powell. Values represent the mean of six plots.

Cultivar	Seeding Rate	Upright Stature
Blackfoot	40K	7.4
	80K	7.4
Monterrey	40K	7.8
	80K	8.8
Poncho	40K	5.2
	80K	4.7
Windbreaker	40K	7.7
	80K	8.0
LSD (0.05)		0.8
P-value (Cult-by-SR)		0.0314

**Table 45.** Effect of row spacing and cultivar on upright stature under 100% ET in 2021 at Powell.

<b>Row Spacing</b>	<b>Cultivar</b>	<b>Upright Stature</b>
7-inch	Blackfoot	7.8
	Monterrey	8.3
	Poncho	5.2
	Windbreaker	7.5
15-inch	Blackfoot	7.3
	Monterrey	7.3
	Poncho	5.0
	Windbreaker	7.3
22-inch	Blackfoot	6.5
	Monterrey	8.8
	Poncho	3.7
	Windbreaker	7.7
LSD (0.05)		1.2
P-value (RS-by-Cult)		0.0204

**Table 46.** Effect of cultivar and seeding rate on upright stature under 100% ET in 2021 at Powell. Values represent the mean of six plots.

Cultivar	Seeding Rate	Upright Stature
Blackfoot	40K	7.7
	80K	6.8
Monterrey	40K	7.9
	80K	8.4
Poncho	40K	4.8
	80K	4.4
Windbreaker	40K	7.1
	80K	7.9
LSD (0.05)		1.0
P-value (Cult-by-SR)		0.054

**Table 47.** Effect of cultivar on flowering date, maturity, upright stature, and percentage of pod above 4-inches under 60% ET irrigation in 2022 at Powell. Each value is averaged across row spacings and seeding rates and represents 8 plots. The P-values were <0.001 for all four traits.

Cultivar	Flowering	Maturity	Upright	Pods Above 4-inch
	dap	dap		%
Max	42	74	8.5	31
Monterrey	54	88	9.5	83
Poncho	45	79	7.5	34
PT9-5-6	50	88	9.5	61
LSD (0.05)	2	3	0.6	18

**Table 48.** Effect of seeding rate on flowering date, maturity, upright stature, and percentage of pod above 4-inches under 60% ET irrigation in 2022 at Powell. Each value is averaged across row spacings and cultivars and represents 16 plots. The P-values for maturity and upright were 0.017 and 0.013, respectively.

Seeding Rate	Flowering	Maturity	Upright	Pods Above 4-inch
	dap	dap		%
40 K	49	83	8.4	51
80 K	48	81	9.0	54
LSD (0.05)	ns	2	0.4	ns

**Table 49.** Effect of cultivar on flowering date, maturity, upright stature, and percentage of pod above 4-inches under 80% ET irrigation in 2022 at Powell. Each value is averaged across row spacings and seeding rates and represents 8 plots. The P-values were <0.001 for all four traits.

Cultivar	Flowering	Maturity	Upright	Pods Above 4-inch
	dap	dap		%
Max	43	76	8.2	38
Monterrey	56	94	9.0	84
Poncho	45	84	6.7	37
PT9-5-6	51	92	9.0	70
LSD (0.05)	3	3	0.6	9

**Table 50.** Effect of seeding rate on flowering date, maturity, upright stature, and percentage of pod above 4-inches under 80% ET irrigation in 2022 at Powell. Each value is averaged across row spacings and cultivars and represents 16 plots. The P-values for maturity and upright were 0.002 and 0.013, respectively.

Seeding Rate	Flowering	Maturity	Upright	Pods Above 4-inch
	dap	dap		%
40 K	49	88	8.1	56
80 K	48	85	8.4	59
LSD (0.05)	ns	2	ns	ns

**Table 51.** Effect of cultivar on flowering date, maturity, upright stature, and percentage of pod above 4-inches under 100% ET irrigation in 2022. Each value is averaged across row spacings and seeding rates and represents 8 plots. The P-values were <0.001 for all four traits.

Cultivar	Flowering	Maturity	Upright	Pods Above 4-inch
	dap	dap		%
Max	42	78	8.7	34
Monterrey	54	91	8.9	81
Poncho	46	84	6.7	39
PT9-5-6	51	91	8.9	66
LSD (0.05)	2	2	0.6	8

**Table 52.** Effect of row spacing and seeding rate on flowering date, maturity, upright stature, and percentage of pod above 4-inches under 100% ET irrigation in 2022. The P-values for the row space-by-seeding rate interaction for upright stature and percentage of pods above 4-inch were 0.039 and 0.014.

Row Space	Seeding Rate	Flower	Maturity	Upright	Pods Above 4-inch
		dap	dap		%
15-inch	40 K	49	89	7.2	46
	80 K	49	87	8.4	59
22-inch	40 K	47	84	8.7	59
	80 K	49	82	8.9	56
LSD (0.05)		ns	ns	0.6	6

**Table 53.** Summary of irrigation rates for flowering, maturity, upright stature, and pods above 4-inch.

Trait	Irrigation (% ET)		
	60%	80%	100%
Flowering (dap)	48	49	48
Maturity (dap)	82	87	86
Upright	8.7	8.2	8.3
Pods above 4-inch	52	57	55

## **Discussion and Summary**

This study incorporated four factors across three years and for the most part the treatment effects were distinct. Thus, we have chosen to summarize each factor separately.

*Irrigation* – For irrigation, we did not compare the three irrigations statistically because they were separate experiments. Nevertheless, full 100% ET irrigation increased yield as expected.

*Row Spacing* – Narrow rows increased yield although these effects were lessened under 80% ET and 100% ET irrigation.

*Seeding Rate* – The effects of seeding rate and concomitantly plant density were extremely complicated. Low plant density did not reduce yield as much as expected although trends with upright cultivars did show a rather positive relationship (the greater plant density the greater the yield). The lack of effect of plant density on the prostrate cultivars may be due to their ability to capture more light due to their posture.

*Cultivar* – In this research, six cultivars varying in maturity and stature were tested across the three years. In general, the response of these cultivar was not as consistent as we expected. From a visual standpoint, the upright cultivars appeared more adapted to the different row spacings and seeding rates due to their architecture but this was not necessarily borne out by the yield data. The upright cultivars definitely showed greater potential for direct harvest.

*Overall* – The results suggest that narrow row spacing may have yield advantages under deficit irrigation. However, for current growers in the Bighorn Basin where water is plentiful, the hassle associated with weed control in narrow rows may not be worth it. Narrow rows definitely improved light interception and conceptually, this extra interception of radiant was expected to increase yield. Unfortunately, other unknown factors are preventing that captured light energy from being translated into yield.

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