Summary of Dry Bean Seeding Rate Study at Powell – 2018 to 2020

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Jim Heitholt, Eric Oleson, Vivek Sharma
University of Wyoming, PREC

Introduction

Much of the dry bean production in the Bighorn Basin uses 22-inch rows, a seeding rate of around 100,000 seed per acre, and full irrigation. Obviously, this planting configuration and irrigation strategy has proven successful but questions remain as to whether alternative management practices might prove more successful. Only during the past few years have research data become available for other planting configurations and irrigation practices in the Bighorn Basin. Some of the findings suggest that narrower row spacings and reduced seeding rates might be more profitable. Planting configuration studies with cultivars varying in plant architecture are also needed. Challenges and risks accompany these alterative configurations such as susceptibility to reduced stand from disease. Harvest options for narrow rows appear to be less efficient than the standard windrowing and threshing. Nevertheless, we propose that producers will benefit from having data on side-by-side comparisons of these alternative configurations as compared to the standard 22-inch rows.

Methods

In 2018 and 2019, three cultivars (Poncho, Sundance, La Paz) were grown in all combinations of the following configurations and irrigation levels (% ET = EvapoTranspiration with amount applied):

Seeding Rates	Row Spacings	Irrigation	2018 applied	2019 applied
50 K	7-inch	60% ET	10.0 inches	10.0 inches
75 K	22-inch	80% ET	10.8 inches	10.8 inches
90 K		100% ET	11.6 inches	11.6 inches
105 K			13 events	14 events
120 K				

There were 270 plots each year (2018 and 2019). Sowing dates were 3 June 2018 and 5 June 2019. Rainfall was 3.0 inches in 2018 and 3.5 inches in 2019. Soil type was a Garland loam and sprinkler irrigation was used.

Variables collected included: seed yield, yield components, leaf area index (LAI), normalized difference vegetative index (NDVI), soil moisture, light interception, and mid-season biomass. Irrigation was applied via a lateral irrigation system. LAI and light interception were measured with a ceptometer. Pod harvest index was calculated as the ratio of seed weight/intact pod weight.

In 2020, the study was conducted differently with two cultivars (Blackfoot and Windbreaker), three row spacings (7-inch, 15-inch, 22-inch). Planting occurred on 29 May 2020. There were three different studies involved. One at 60% ET, one at 80% ET, and a third at 100% ET, all applied with sprinkler. The statistical analysis for the three irrigations tests were conducted separately because those areas were not replicated.

Full irrigation was applied to all three 2020 tests during the first two weeks of June to ensure good stand establishment. In late June, the three tests received their assigned deficit irrigations rates for the duration of the season. Once the canopies began to establish, readings of canopy temperature, light interception, and LAI were recorded periodically. The goal was to record these variables weekly and for the most part that was achieved. The LAI data for 2020 are not provided in this report.

For 2020, we intended to vary seeding rate at exact intervals (50K, 70K, 90K, and 110K) but there were emergence problems. So instead, the final (and "natural") plant density was determined and all graphs of yield and other variables were plotted against the final plant densities which varied in the ranges we had hoped. Overall, final plant densities ranged from 27K to 84K.

Throughout the 2020 mid-season, flowering and maturity dates were recorded twice weekly. As each plot reached harvest maturity, all edge plants from each plot were removed by hand and discarded to eliminate edge effects. Next, to assess yield, the plot was divided into two components of similar size (designated A and B). For Component A, the exact area was measured and the number of plants were counted. Then, all plants from Component A were pulled from the ground, allowed to sit for four hours, and were then tossed into a research plot combine for threshing and grain collection. For Component B, the exact area was also measured, the number of plants counted, and the plot was direct harvested with the same research plot combine used for threshing component A. Thus, for each of the 180 plots, two yield values were obtained, one using conventional methodology that is common in the Bighorn Basin (A) and the alternative methodology common in North Dakota and Michigan which is called direct harvest and is a one-step process (B). Average seed size was determined by weighing 100 seed from all plots. A hard freeze occurred on 8 Sept 2020 which compromised the seed development of the late harvesting cultivar Windbreaker.

Results and Discussion

For the 2018-2019 studies (which were identical studies), much of the data presented below were averaged across years. Yield was 4220 pounds per acre for the 100% ET irrigation, 3810 pounds per acre for the 80% irrigation, and 3550 pounds per acre for the 60% irrigation. This indicated that the deficit irrigation had its intended effect. Averaged across cultivars and irrigations, and seeding rates, the 7-inch rows outyielded 22-inch rows by 3990 to 3600 pounds per acre. The narrow-row yield increase was consistent across cultivars but only for the two deficit irrigation regimes. For the 100% ET irrigation, yields of Poncho and La Paz were unaffected by row spacing. For Sundance, narrow rows increased yield by 13% (2018) and 8% (2019) under 100% ET irrigation. Averaged across all treatments, Poncho (4060 pounds per acre) outyielded Sundance (3700 pounds per acre) and La Paz (3630 pounds per acre). Yield was unaffected by seeding rate and this is an observation that we have noticed for several growing seasons now.

Seed size was larger for Poncho (420 mg) vs. Sundance (350 mg) and La Paz (340 mg). Irrigation, seeding rate, and row spacing had no effect on seed size. Seed per pods was greater in Poncho (4.60) than Sundance (3.8) and La Paz (3.8). The seeding rate, row spacing, and irrigation treatments did not affect the number of seed per pod. Pod harvest index was greatest in Poncho compared to La Paz and Sundance but irrigation, seeding rate, and row spacing had little effect with values averaging 0.785.

Light interception was consistently greater for 7-inch rows as compared to 22-inch rows (Table 1). The photo at the end of this report shows that more light energy strikes the soil surface and not plant leaves during the early part of the growing season in 22-inch rows as compared to narrower rows (Fig. 4). The middle seeding rates (75K, 90K, and 105K) for Poncho in 2018 tended to have greater light interception than the thinnest and thickest seeding rates. Light interception for Sundance across the five seeding rates in 2019 trended more as expected with higher seeding rates increasing light interception. The relationship between grain yield and light interception was not conspicuous in 2018 but our preliminary analysis for the 2019 data with Sundance suggests that increase light interception likely played a role in the narrow row yield increase observed in that cultivar.

Although LAI values were recorded throughout the season, only the maximum values for selected treatments are reported here. The maximum LAI values for each treatment ranged from 3.3 to 7.5 (Table 2). Maximum LAI was greater for some of the lightest seeding rates in 7-inch rows which does not seem logical but could be related to physics of how the ceptometer device detects and calculates LAI. Leaves in high seeding rates tend to overlap each other and may not be detected as easily as in a canopy with slightly less plants per unit area. However, LAI was proportional to seeding rate in the 22-inch rows which is what we expected. NDVI was greater in the 100% ET irrigation than either of the two deficit irrigation treatments. NDVI was also higher for 7-inch rows vs. 22-inch rows.

For 2020, plant densities within the ranges we tested (27K to 84K plants per acre) had minimal effect on yield under most of the irrigation and planting configurations we tested (Table 3). Note that seeding rate (used for 2018-2019) and plant densities (used for 2020) are similar but different variables. Obviously, not all seed planted produce viable plants. In Table 3, a positive slope indicates that there was an increase in yield as function of plant density and a negative slope indicates that increased plant density reduced yield. In theory, we expect that this slope would trend positive at lower plant densities and trend negative at higher plant densities. But because almost all of the slopes were not significantly different from zero, the take-home lesson is that plant density was pretty neutral within the ranges we had. Our 2020 findings suggest that under severe deficit irrigation (60% ET), a plant density of 50K plants per acre might be better than a plant density above 70K per acre (Figs. 1&2). However, we want to observe additional environments before making definitive conclusions about this.

In the 2020 study, the narrowest row spacing (7-inch) appeared to have greater yield potential than 22-inch rows (Table 5). In all six side-by-side comparisons, the 7-inch row yield was greater than its 22-inch counterpart. The narrow-row yield advantage ranged from 5% to 64% and was greater under deficit irrigation. This 2020 narrow-row deficit-irrigation yield observation and this was consistent with what we observed in 2018 and 2019. Deficit irrigation reduced yield and seed size in 2020 as expected and is provided here to document that irrigation targets were indeed achieved (but not for statistically comparing between them). It is unclear why the yields of the 15-rows did not consistently fall in-between the two extreme row spacings (7-inch and 22-inch). From a visual standpoint, the 15-inch plots appeared the healthiest and most uniform of all three row spacings which reminds us that appearance does not always equate to end-of-season success.

The percent yield loss due to direct harvest averaged about 24% across all plots and there was little difference between the two cultivars and among row spacings (Table 6). However, Windbreaker appeared to suffer a lower percentage loss due to direct harvest in 22-inch rows for all three irrigation rates than Blackfoot. We are going to continue this study in future years and document the percent yield loss due to direct harvest trait. We are not ready to make any sweeping conclusions about which varieties will be more successful in narrow rows.

Canopy temperatures for four dates during the year (2020) are presented in Figure 3. At 48 and 59 days after planting, the 60% ET treatment had a warmer canopy temperature than the 80% and 100% ET field. These canopy temperatures further document that we did indeed achieve water stress in the 60% ET and 80% ET plots (as mentioned earlier, irrigations were not compared statistically to each other in 2020). Flowering and maturity data are present in Table 7. Blackfoot matured earlier than Windbreaker but the planting configuration treatments did not have much effect on flowering and maturity dates. As expected, the fully-irrigated plots matured later than the deficit-irrigated plots but as stated earlier, this was not compared statistically.

Upright stature and height data are provided in Table 8. Theoretically, a more upright stature would lend itself to a more efficient direct harvest but we are still trying to document whether or not data support that contention. For the 100% irrigation, upright stature from Blackfoot declined as row spacing increased but upright stature increased for Windbreaker. For the 80% and 60% ET irrigations, Blackfoot's upright stature also declined as row spacing widened to 22-inch but Windbreaker's stature was relatively unchanged. For plant height, the main differences observed were between cultivars with Windbreaker taller than Blackfoot. At 60% ET, plant height tended to be lower as row spacing went from 7-inch to 22-inch in both cultivars. A photo of the study is provided in Figure 4.

Summary

There are few take-home lessons from the results to date. The most important observation is that seeding rates and/or plant densities in the range of 50K per acre appear to be adequate to optimize yield. However, there does not appear to be any penalty for using higher seeding rates up to 100K when full irrigation is employed. Seeding rates of 100K may also provide "insurance" for growers if and when early-season stands are compromised by disease, frost, or hail.

Regarding row spacing, there appears to be a yield advantage for narrow rows (7-inch) as compared to 22-inch rows but this difference was only consistent under deficit irrigation. Under full irrigation (100% ET), yield of La Paz and Poncho did not appear to increase with narrow rows but yield of Sundance and Blackfoot did appear to increase with 7-inch rows. Obviously, we need to see if cultivars respond consistently to narrow rows before making any definitive conclusions.

With regard to direct harvest yield losses, our results showed that around 23% of seed is lost when direct harvesting as compared to conventional harvest. Cultivar, row spacing, seeding rate, and irrigation did not conspicuously affect the direct harvest loss.

Ecophysiological factors that we collected such as light interception and LAI followed the expected trends for the most part. Increased seeding rate and reduced row width increased light interception as expected although there were some exceptions at the higher densities. For LAI, narrow rows as well as increased seeding rate tended to increase LAI but again there were exceptions for some of the high seeding rates.

Finally, a more thorough analysis of the data collected in these three years as well as our planned 2021 and 2022 studies will help explain what grower-controllable factors are involved in planting configuration yield increases.

Table 1. Seasonal (cumulative) solar radiation energy interception by canopies of Poncho in the 100% irrigation treatment during 2018 and Sundance in 2019. Values were obtained by (1) measuring light interception (a light bar sensor remained in the field all season) and (2) values from a pyranometer placed above the canopy. The percent intercepted was then multiplied by the cumulative pyranometer values.

2018-Poncho	Seeding Rate (1000s per acre)				
	50	75	90	105	120
Row Space	----------------------------- Seasonal MJ/m^2 ------------------------------				
7-inch	714	710	792	894	823
22-inch	505	539	615	974	704
% increase	41	32	29	33	16
2019-Sundance					
Row Space					
7-inch	624	718	776	821	821
22-inch	530	644	654	731	741
% increase	17	11	8	25	10

Table 2. Maximum leaf area index (LAI) for the three cultivars in two row spacings and five seeding rates in 2018 and 2019. LAI was collected on six dates from 41 dap to 71 dap in 2018 and on ten dates from 45 dap to 103 dap in 2019. The value below was the maximum for its respective treatment and usually occurred around 67 dap in 2018 and 75 dap in 2019.

Cultivar	Row Space	Seeding Rate (1000s per acre)				
2018		50	75	90	105	120
La Paz	7	7.0	7.3	6.5	6.0	7.3
	22	3.3	4.2	5.9	3.5	3.5
Poncho	7	7.0	6.8	6.5	7.0	5.5
	22	4.8	5.5	5.5	6.5	6.0
Sundance	7	7.2	6.8	6.4	6.0	7.5
	22	5.0	5.8	4.8	6.2	6.2
2019						
La Paz	7	7.2	7.0	6.8	6.5	7.5
	22	7.0	7.3	7.3	7.2	6.8
Poncho	7	5.2	7.5	7.4	5.2	7.2
	22	6.4	6.5	5.8	6.0	7.2
Sundance	7	7.0	5.5	6.2	5.8	6.3
	22	6.2	6.7	7.2	7.0	6.3

Table 3. Effect of water regime (i.e., irrigation rate), cultivar, and row spacing on the relationship between grain yield and stand density of dry bean studies grown at Powell, WY in 2020. Linear regression was performed on the 18 different combinations.

Water	Cultivar	Row Space	Slope †	P > F ‡	Significance
100%	Blackfoot	7	-2.65	0.729	no
		15	3.28	0.854	no
		22	-0.34	0.972	no
	Windbreaker	7	7.06	0.437	no
		15	5.75	0.565	no
		22	6.78	0.409	no
80%	Blackfoot	7	8.23	0.578	no
		15	1.49	0.846	no
		22	3.42	0.543	no
	Windbreaker	7	4.00	0.625	no
		15	5.63	0.559	no
		22	-6.04	0.456	no
60%	Blackfoot	7	6.66	0.702	no
		15	-1.50	0.533	no
		22	-3.31	0.494	no
	Windbreaker	7	-32.4	0.005	yes
		15	-26.3	0.010	yes
		22	-3.32	0.494	no

† The slope (m) is the PROC REG (SAS, Inc) estimate for the equation.
Yield (pounds per acre) = *m* × (plant density in thousands of plants per acre) + intercept. In 16 of the tests, the slope was not significantly different from zero as indicated by the "Significance" column.
‡The statistical test (i.e., P>F) represents the level of significance associated with the slope value.

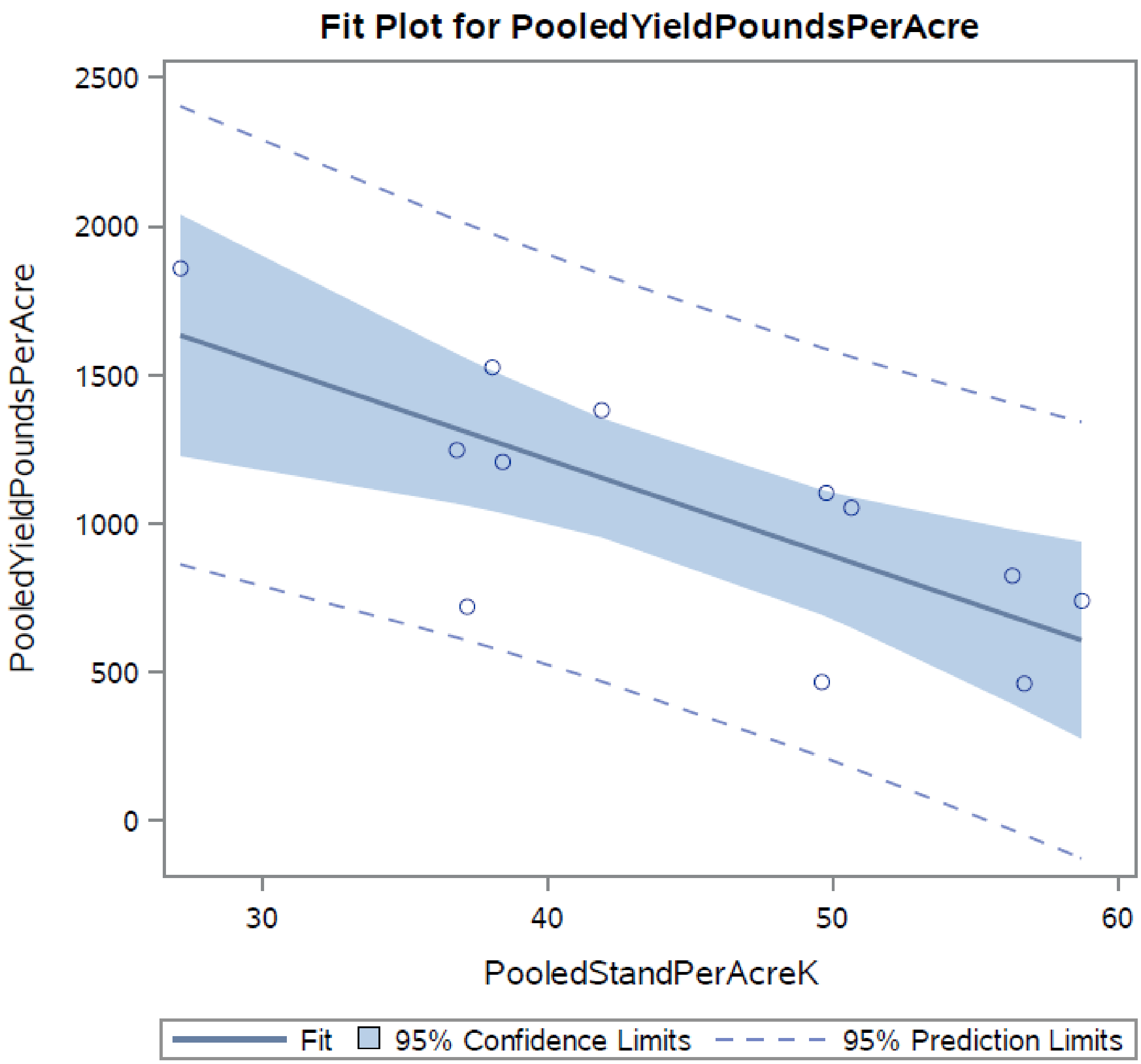

Figure 1. Effect of plant density on yield of Windbreaker dry bean in 7-inch rows under severe deficit irrigation. Note that densities of 50K plants per acre or greater appear to be associated with lower yield.

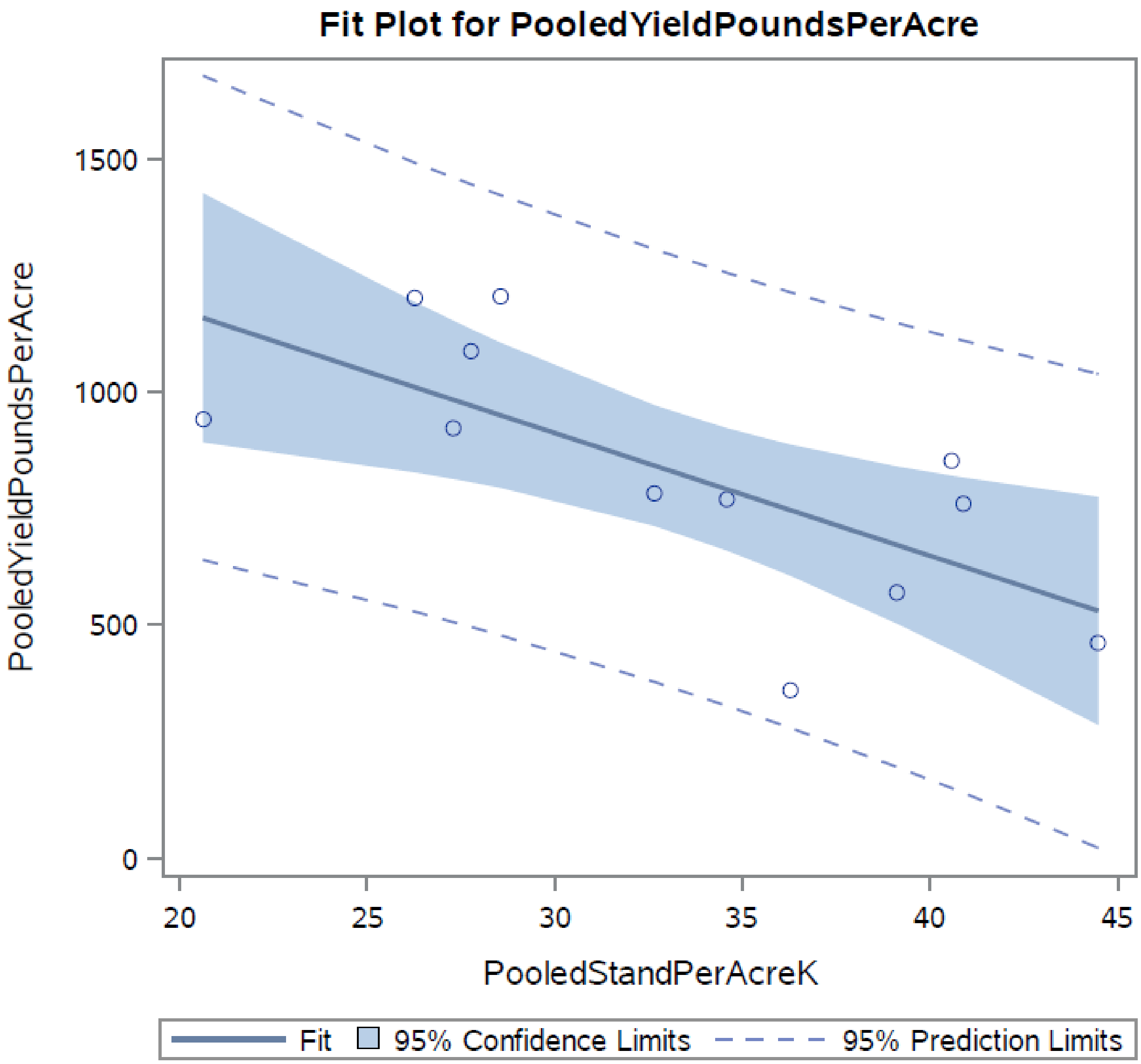

Figure 2. Effect of plant density on yield of Windbreaker dry bean in 15-inch rows under severe deficit irrigation. Note that densities of 35K plants per acre or greater appear to be associated with lower yield.

Table 4. Effect of water regime (i.e., irrigation rate), cultivar, and row spacing on the relationship between grain yield and stand density of dry bean studies grown at Powell, WY in 2020. Linear regression was performed on the 18 different combinations.

Water	Cultivar	Row Space	Slope †	P > F ‡	Significance
100%	Blackfoot	7	-2.65	0.729	no
		15	3.28	0.854	no
		22	-0.34	0.972	no
	Windbreaker	7	7.06	0.437	no
		15	5.75	0.565	no
		22	6.78	0.409	no
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		15	1.49	0.846	no
		22	3.42	0.543	no
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		15	5.63	0.559	no
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60%	Blackfoot	7	6.66	0.702	no
		15	-1.50	0.533	no
		22	-3.31	0.494	no
	Windbreaker	7	-32.4	0.005	yes
		15	-26.3	0.010	yes
		22	-3.32	0.494	no

† The slope (m) is the PROC REG (SAS, Inc.) estimate for the equation
Yield (pounds per acre) = m × (plant density in thousands of plants per acre) + intercept.
‡ In 16 of the tests, the slope was not significantly different from zero (which translates into no effect for plant density) and as indicated by the "P > F" column having a P-value greater than 0.05 and/or the "Significance" column with "no".

Table 5. Yield and average seed size of all 18 combinations of irrigation, cultivar, and row spacing of the dry bean study grown at Powell. Means are averaged across 8 plots where plant density varied from 20K to 80K plants per acre and also averaged across the conventional and direct harvested components of each plot. Each irrigation rate was analyzed separately.

Water	Cultivar	Row Space	Yield	Seed Size
			lbs/acre	mg
100%	Blackfoot	7	2274	319
		15	1724	328
		22	1859	312
100%	Windbreaker	7	2215	420
		15	1672	411
		22	2115	422
LSD (0.05)			427	15
80%	Blackfoot	7	1651	307
		15	1307	311
		22	1462	301
80%	Windbreaker	7	1650	415
		15	1360	407
		22	1328	427
LSD (0.05)			260	4
60%	Blackfoot	7	1307	284
		15	822	287
		22	988	284
60%	Windbreaker	7	1050	382
		15	826	362
		22	638	396
LSD (0.05)			181	19
Irrigation Avg. †				
100%			1981	379
80%			1466	367
60%			961	334

Table 6. Percent loss of grain due to direct harvest. Yield per acre values from Component (A) and Component (B) were obtained from all 180 plots and the percent loss was calculated by the equation, PercentLoss = [(YieldA - YieldB) / YieldA] × 100.

Water	Cultivar	Row Space	Percent Yield Loss Due to Direct Harvest
			%
100%	Blackfoot	7	24
		15	29
		22	39
100%	Windbreaker	7	27
		15	31
		22	12
LSD (0.05)			14
80%	Blackfoot	7	21
		15	19
		22	25
80%	Windbreaker	7	27
		15	29
		22	13
LSD (0.05)			13
60%	Blackfoot	7	19
		15	26
		22	28
60%	Windbreaker	7	30
		15	26
		22	7
LSD (0.05)			8
Averages			
Row Space		7	25
		15	27
		22	21
Cultivar		Blackfoot	25
		Windbreaker	22

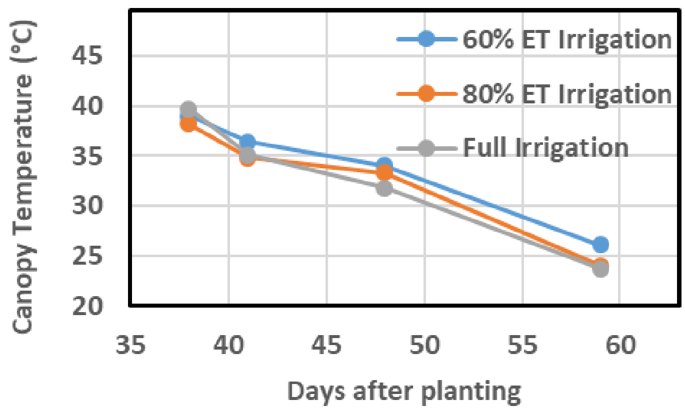

Figure 3. Canopy temperature of the three different field areas during the 2020 season.

Table 7. Flowering and maturity dates for the different treatments in two dry bean cultivars grown at Powell in 2020.

Water	Cultivar	Row Space	Flower	Maturity
			dap	dap
100%	Blackfoot	7	50	89
		15	50	92
		22	51	87
100%	Windbreaker	7	52	103
		15	53	102
		22	52	101
LSD (0.05)			2	6
80%	Blackfoot	7	50	83
		15	50	84
		22	50	81
80%	Windbreaker	7	51	101
		15	52	100
		22	51	100
LSD (0.05)			2	3
60%	Blackfoot	7	50	81
		15	50	81
		22	50	80
60%	Windbreaker	7	52	99
		15	53	96
		22	52	100
LSD (0.05)			1	3
Irrigation Avg. †				
100%			51	97
80%			51	93
60%			51	91

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

Table 8. 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
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
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
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
Irrigation Avg. ‡				
100%			5.9	74
80%			6.3	70
60%			8.2	56

† 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.

Figure 4. Photo of the seeding rate and row spacing study in 2020. The foreground area is a buffer strip separating the different irrigation areas. The middle is the 60% ET irrigation area. Behind that is another buffer strip and behind that is the 80% ET irrigation area. The picture was taken while standing in the 100% ET section.