Screening Commercial Dry Bean Cultivars and Experimental Breeding Lines for Performance in the Bighorn Basin under Deficit Irrigation

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Introduction:

Worldwide, having dry bean varieties that perform well under reduced rainfall or irrigation continues to be an important trait across many production environments. Water availability is often plentiful and cheap in Wyoming dry bean production and some would argue that Wyoming's dry bean cultivars do not need drought tolerance. However, there are some situations where producers might need or might want to provide limited water to their crops. These situations include a need to spray a field with a ground rig, a need to prioritize water for other fields, or temporary irrigation equipment failure. For these reasons, knowledge of how different cultivars as well as our experimental breeding lines perform under various watering regimes is going to be valuable. Testing lines under full-irrigation and deficit irrigation will also provide important data on yield stability of the lines. In 2024, we repeated a 2023 study with the same three early-maturing cultivars, the same three mid-maturity cultivars, and the same three late-maturing cultivars, and 14 of our advanced breeding lines to assess the entries for drought tolerance and in order to validate 2023 findings.

Methods:

In order to conduct this test, we planted 23 entries to repeat the 2023 trial. Entries included three early-maturing lines 88 days or less (Max, Othello, Poncho), three mid-maturity lines 89 to 92 days (Cowboy, Medicine Hat, SV6139GR), and three late-maturing lines 93 days or later (PT9-5-6, Monterrey, USDA-Rattler), and fourteen (14) of our experimental lines. Irrigation rates were 60% ET (ET, estimated evapotranspiration). For severe deficit irrigation, about 0.6 inches per week was applied; for 80% ET (moderate deficit irrigation), about 0.8 inches per week was applied, and for 100% ET (full-irrigation) about 1.0 inch per week was applied. Sprinkler irrigation was used and the differential rates were imposed beginning in July. Each entry was grown in nine plots, three plots each for each of the three irrigation rates and the experimental design was a split plot with irrigation as the main factor (three blocks) and entry as the subplot. Plots were three-rows wide, 15-feet long, row spacing was 22-inches, and seeding rate was 90,000 seeds/acre. The field received 0 units N, 50 units P, 40 units K, 3 units Zn, 3 units Mn, 50 units elemental S, and 50 units humic acid incorporated on 1 May. The field was pre-treated with Roundup (36 oz/acre), Kicker Plus (5 oz/gal), and Vincitro (0.9 oz/gal) on 17 May. The trial was planted on 4 June and the field was sprayed with Mustang Max (4 oz/acre) and Miravis Top (14 oz/acre) on 21 June, and with Outlook (16 oz/acre) and Orvale (16 oz/acre) on 3 July. Data collected were: canopy temperature (three times), flowering date, maturity date, upright stature, percentage of pods at maturity, residing above 4 inches, conventional yield (10-feet of center row), yield via direct harvest, and number of seed per pound. Conventional yield was collected by harvesting 10' of the center row and threshing in a Haldrup plot thresher and direct yield was collected with a Zurn research plot combine after the Haldrup harvest. Recovery was calculated by dividing direct yield by conventional yield.

Results and Discussion

Regarding canopy temperature, canopies from plots exposed to 60% and 80% irrigation were warmer than those exposed to full irrigation on all three sampling dates (Table 1 and Fig. 2). Yield was also increased with increasing irrigation (Fig. 1). These two sets of data confirmed that the water stress treatments were effective. Additionally, the yield increase from 60% irrigation to 100% irrigation was 72% (Table 2). The yield components that accounted for the yield increase were: 44% from increased pods per square foot, 15% from increased seed per pod, and 4% increase from weight per seed.

Based on the yield results, the 23 entries were either categorized as drought tolerant or drought susceptible (Tables 3 to 5). The yields under the three irrigation rates underwent calculations to determine ***Stability***, ***Geometric Mean***, and ***Drought Yield*** and those ranks were pooled to obtain an overall drought tolerance index. Stability compares the entry's performance under drought vs. full irrigation. The idea is that this trait would capture or elucidate genes preventing yield loss. Geometric Mean multiplies all values obtained regardless of stress level and taking the square root (if 2 treatments) or cube root (if 3 treatments). The idea for geometric mean is that an entry is not punished for performing well under full irrigation. Drought Yield takes only the performance of the entry under drought and ignores its performance under other environments. The idea for drought yield only is to remove bias from full

irrigation but not punishing a line that did well in full irrigation. Across the three maturity groups in 2024, we identified 6 commercial lines and 5 experimental lines. If the requirement for qualifying as drought tolerant was to be successful both years, only four commercial lines (Max, Poncho, PT9-5-6, and Rattler) and two experimental lines (G-3 and M-5) qualified as drought tolerant.

The number of seed per pound decreased as irrigation rate increased (Tabe 6). In general, canopy temperatures were negatively related to yield but the relationships were not particularly consistent (Figs. 3 to 11). As was observed in previous years, yield rank (1 being the highest yield and 23 being the lowest yield) was negatively correlated to the percentage of pods residing above four inches (Figs. 12 to 14) and negatively correlated to upright stature (Figs. 15 to 17).

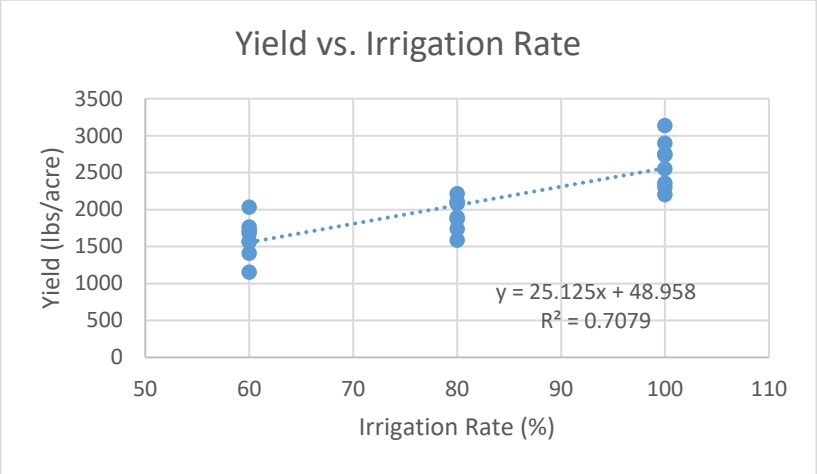

Figure 1. Yield vs. Irrigation Rate of late-maturing varieties. Each point represents three plots for each entry.

Table 1. Canopy temperatures as affected by irrigation at PREC in 2024. Values represent the mean of 90 plots. Values are averaged across entries.

Irrigation	22 July	1 August	12 August
Sixty	**32.9**	**28.2**	**30.9**
Eighty	**32.3**	**25.8**	**30.2**
Hundred	**31.5**	**24.4**	**28.8**

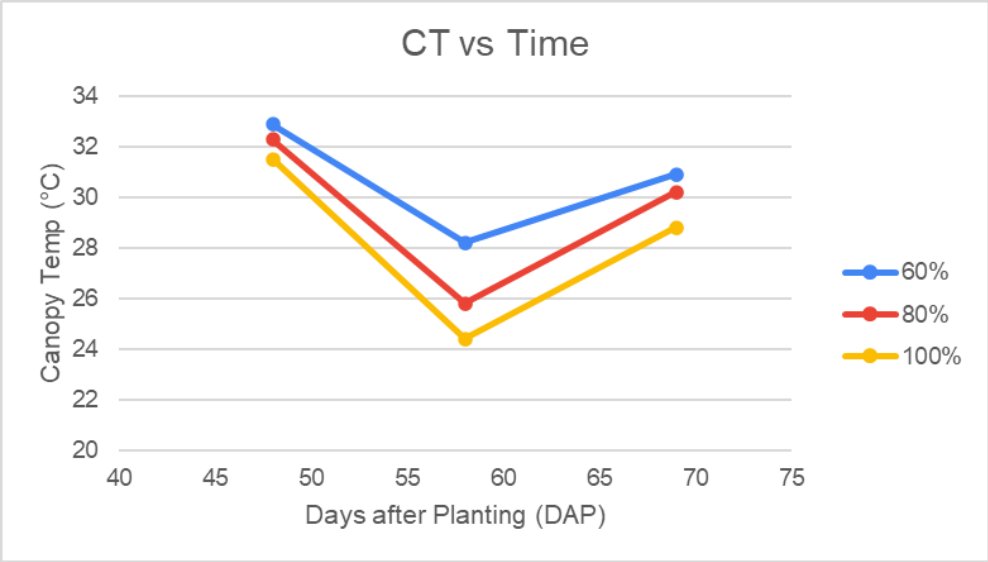

Figure 2: Canopy temperatures as affected by irrigation at PREC in 2024 across time. Values represent the mean of 90 plots. Values are averaged across entries.

Table 2: Yield and yield components (averaged across genotypes) of the 23 entries grown at Powell in 2024.

Trait	**60%**	**80%**	**100%**
Yield (lbs/a)	1450	1892	2492
Pods / ft^2	16.4	19.5	23.6
Seed per pod	2.90	3.15	3.34
Seed size (mg)	33.7	34.3	35.0

Table 3: Performance of early-maturing group (lbs/acre) and the respective drought tolerance rankings of dry bean entries grown at Powell in 2024.

Entry	Sixty	Eighty	Hundred	Stability	Geometric	Stress	Rank
C-9	2034	1892	2356	2.0	4	1	7.0
Max	1766	2102	2201	1.0	5	2	8.0
Poncho	1716	2080	2738	7.0	1	3	11.0
G-3	1567	2215	2750	3.5	2	6	11.5
MedHat	1680	1737	3135	7.0	3	4	14.0
OLV-3	1408	2102	2554	3.5	6	7	16.5
Othello	1570	1585	2900	7.0	7	5	19.0
E-3	1154	1872	2301	5.0	8	8	21.0

Table 4: Performance of mid-maturing group (lbs/acre) and the respective drought tolerance rankings of dry bean entries grown at Powell in 2024.

Entry	Sixty	Eighty	Hundred	Stability	Geometric	Stress	Rank
LPID-7	1992	1966	2908	4	1	1	6
Cowboy	1749	2024	2676	3	3	2	8
OSC-2	1726	1995	2486	1	4	3	8
H-3	1638	2368	2746	2	2	5	9
LPID-3	1706	1611	2620	5	6	4	15
SG6139GR	1560	1898	2854	6	5	6	17
C-6	1281	1678	2575	7	7	7	21

Table 5: Performance of late-maturing group (lbs/acre) and the respective drought tolerance rankings of dry bean entries grown at Powell in 2024.

Entry	Sixty	Eighty	Hundred	Stability	Geometric	Stress	Rank
PT9-5-6	1854	2144	2936	2.5	1	1	4.5
M-5	1540	2484	2935	2.5	2	3	7.5
Rattler	1721	1764	2387	1.0	5	2	8.0
B-3	1344	2213	2654	4.0	3	4	11.0
Z-1	1206	2250	2861	5.5	4	5	14.5
NTL-1	1110	1864	2983	8.0	6	6	20.0
Monterrey	969	1881	2673	7.0	7	7	21.0
LPID-9	903	1572	2628	5.5	8	8	21.5

Table 6. Effect of irrigation on seed per pound of the 23 lines used in the study at PREC 2024.

Entry	Sixty %	Eighty %	Hundred %	Average
B-3	1517	1517	1408	1481
C-9	1592	1437	1410	1480
C-6	1462	1494	1519	1492
Cowboy	1248	1223	1256	1243
E-3	1806	1901	1626	1778
G-3	1476	1422	1407	1435
H-3	1680	1545	1418	1548
LPID3	1163	1166	1121	1150
LPID7	1401	1426	1362	1396
LPID9	1242	1187	1204	1211
M-5	1132	1104	1043	1194
Max	1197	1100	1254	1330
MedHat	1434	1301	1219	1093
Monterrey	1127	1210	1182	1172
NTL-1	1161	1167	1199	1176
OLV-3	1789	1849	1667	1766
OSC-2	1783	1701	1717	1733
Othello	1298	1275	1241	1264
PT956	1417	1391	1236	1362
Poncho	1298	1251	1247	1265
Rattler	1226	1176	1200	1201
SV6139GR	1334	1348	1315	1332
Z-1	1237	1228	1148	1205
Average	**1412**	**1387**	**1359**	**1386**

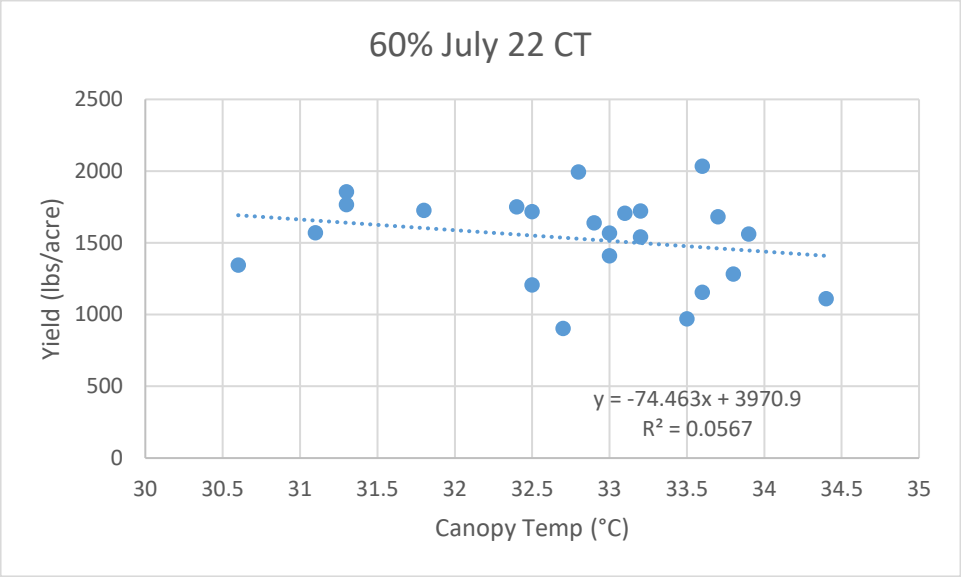

Figure 3: July 22 yield vs. canopy temp at 60% irrigation at PREC in 2024. Each value is the average of three plots for one entry.

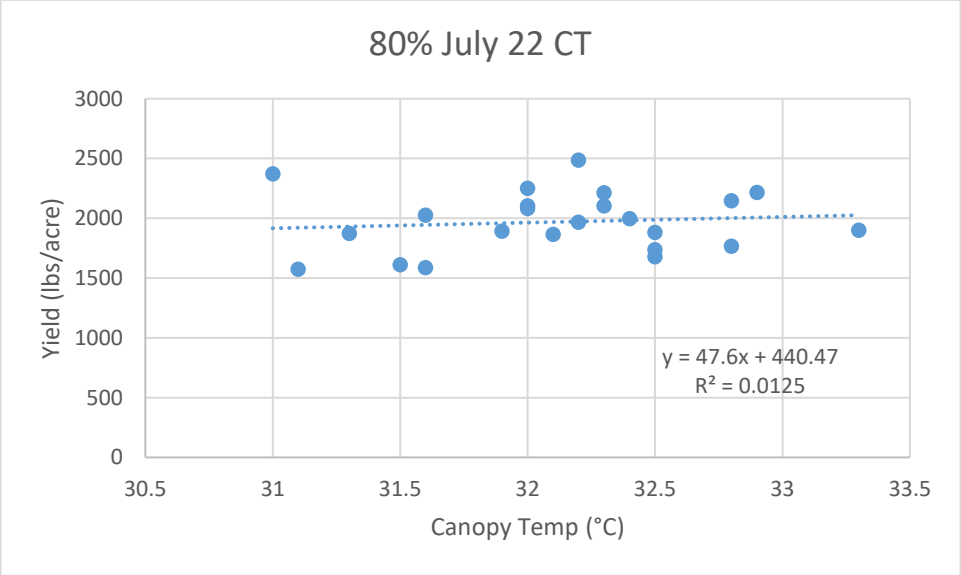

Figure 4: July 22 yield vs. canopy temperature at 80% Irrigation at PREC in 2024. Each value is the average of three plots for one entry.

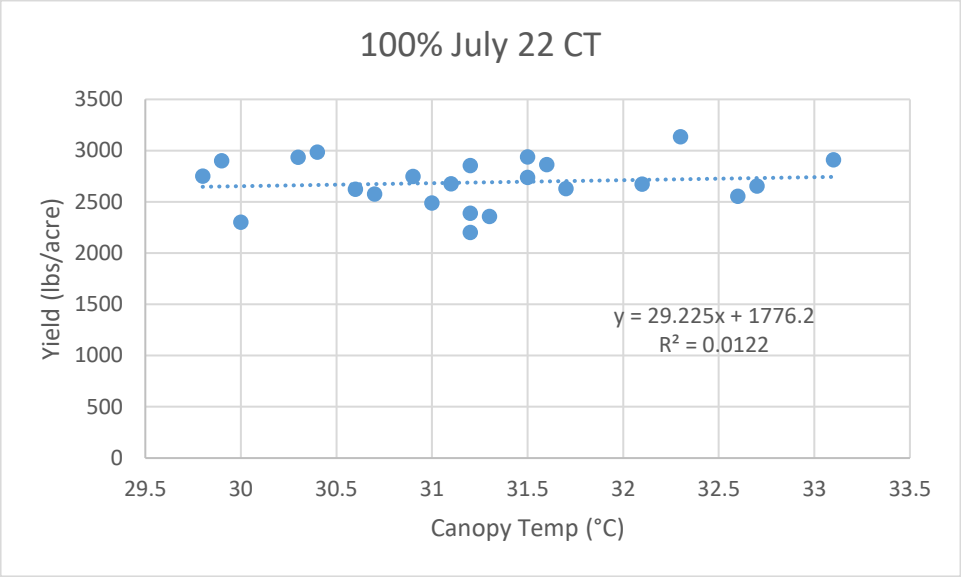

Figure 5: July 22 yield vs. canopy temperature at 100% Irrigation at PREC. Each value is the average of three plots for one entry.

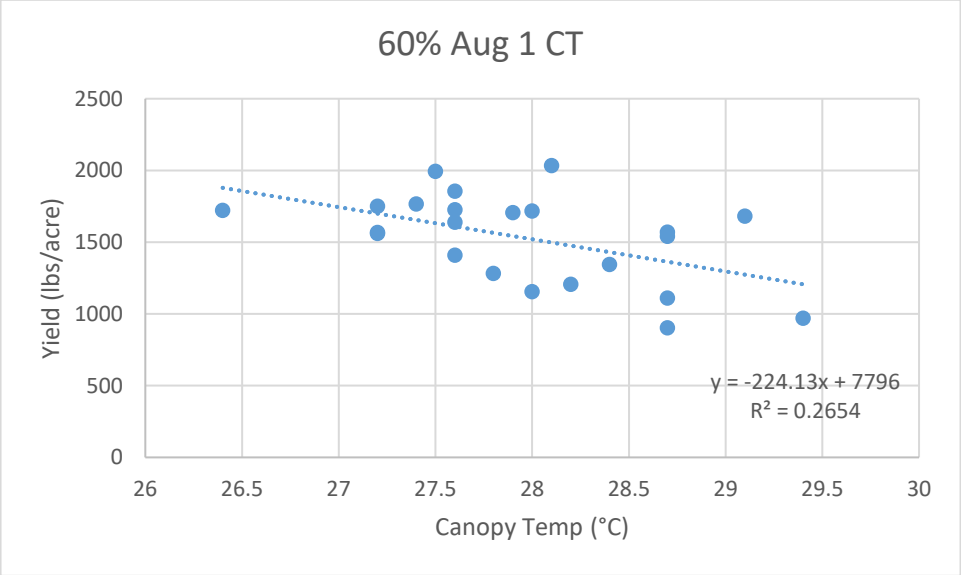

Figure 6: August 1 yield vs. canopy temperature at 60% Irrigation at PREC. Each value is the average of three plots for one entry.

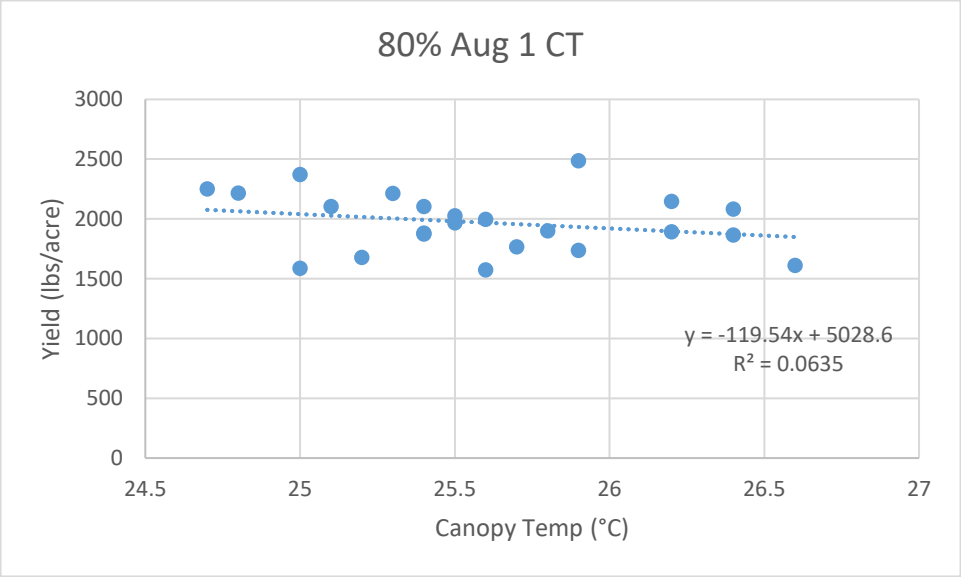

Figure 7: August 1 yield vs canopy temperature at 80% irrigation at PREC in 2024. Each value is the average of three plots for one entry.

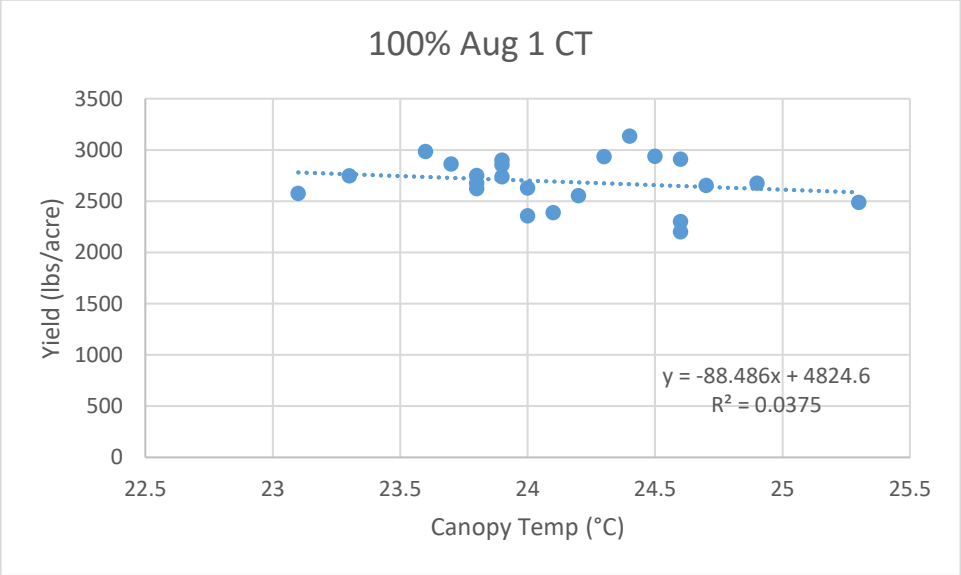

Figure 8: August 1 yield vs. canopy temperature at 100% Irrigation at PREC. Each value is the average of three plots for one entry.

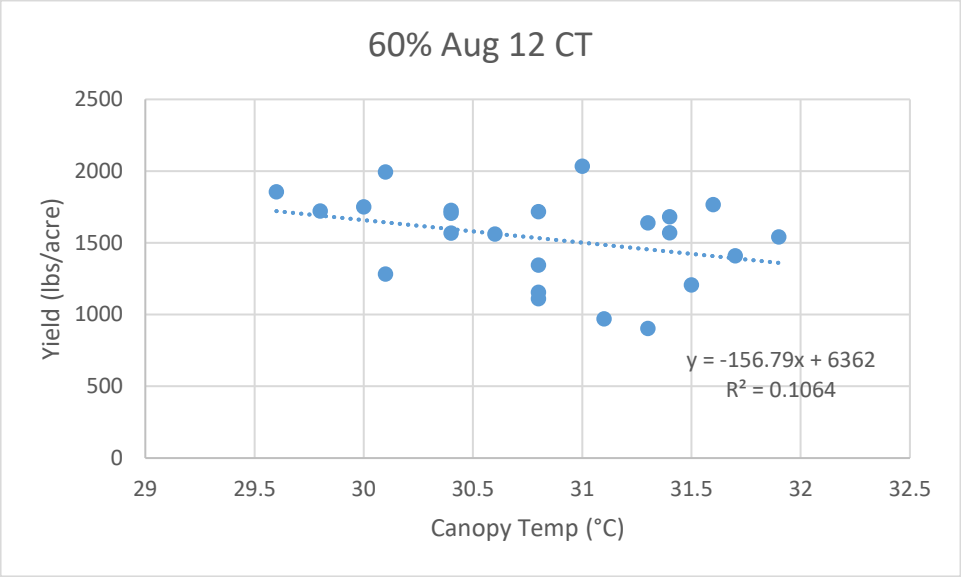

Figure 9: August 12 Canopy Temp vs. Yield at 60% Irrigation at PREC. Each value is the average of three plots for one entry.

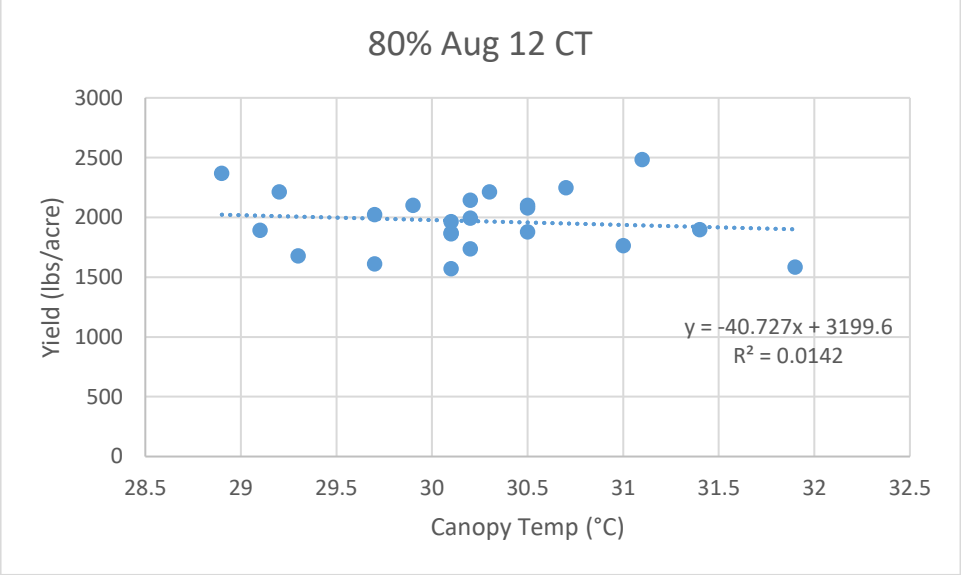

Figure 10: August 12 Canopy Temp vs. Yield at 80% Irrigation at PREC. Each value is the average of three plots for one entry.

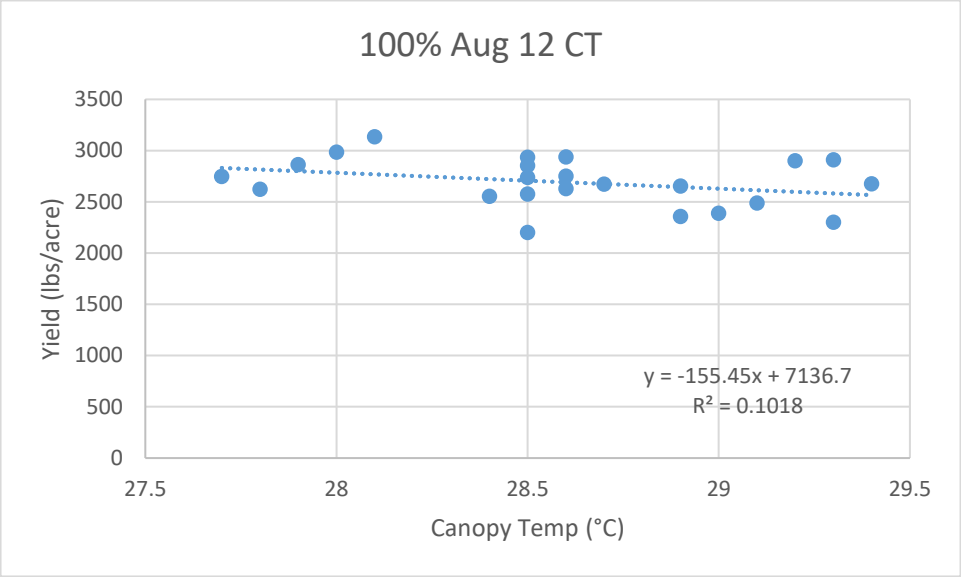

Figure 11: August 12 Canopy Temp vs. Yield at 100% Irrigation at PREC. Each value is the average of three plots for one entry.

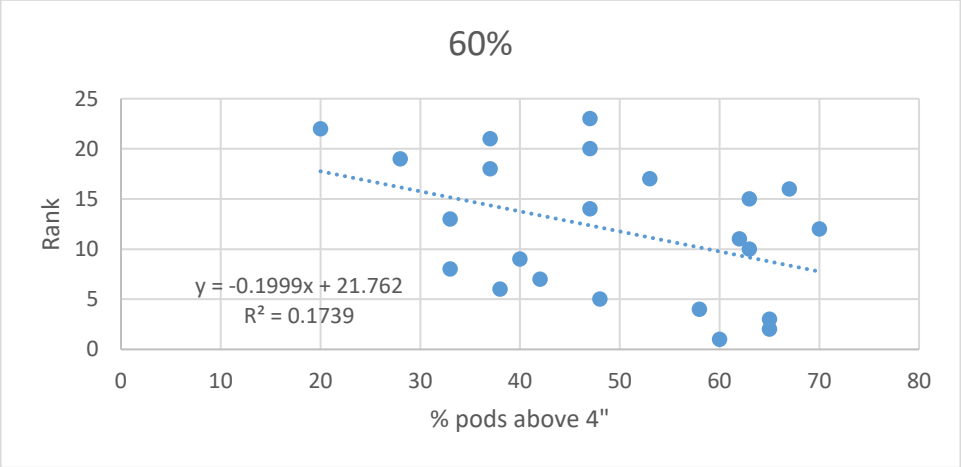

Figure 12: % of pods above 4 inches vs. Rank at 60% irrigation

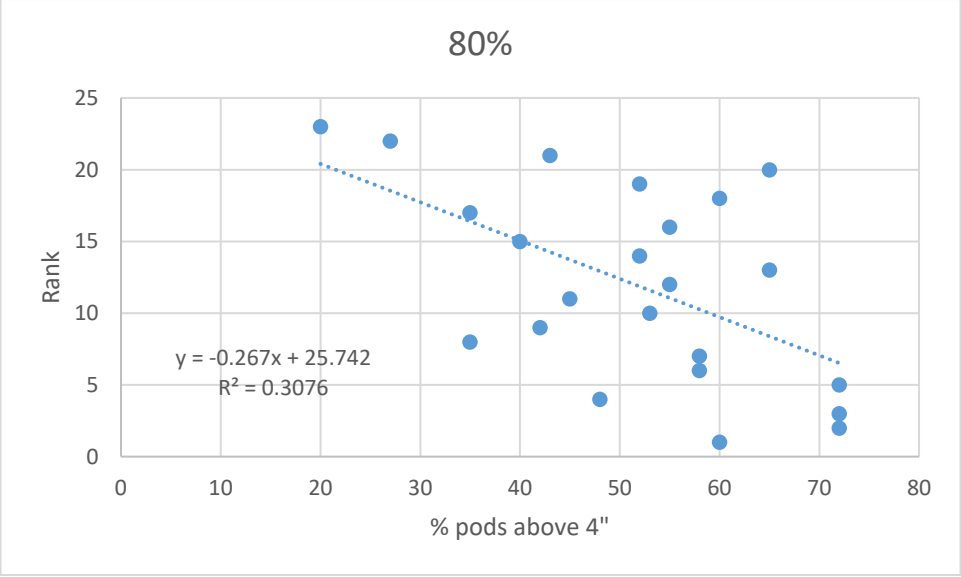

Figure 13: % of pods above 4 inches vs. Rank at 80% irrigation at PREC. Each value is the average of three plots for one entry.

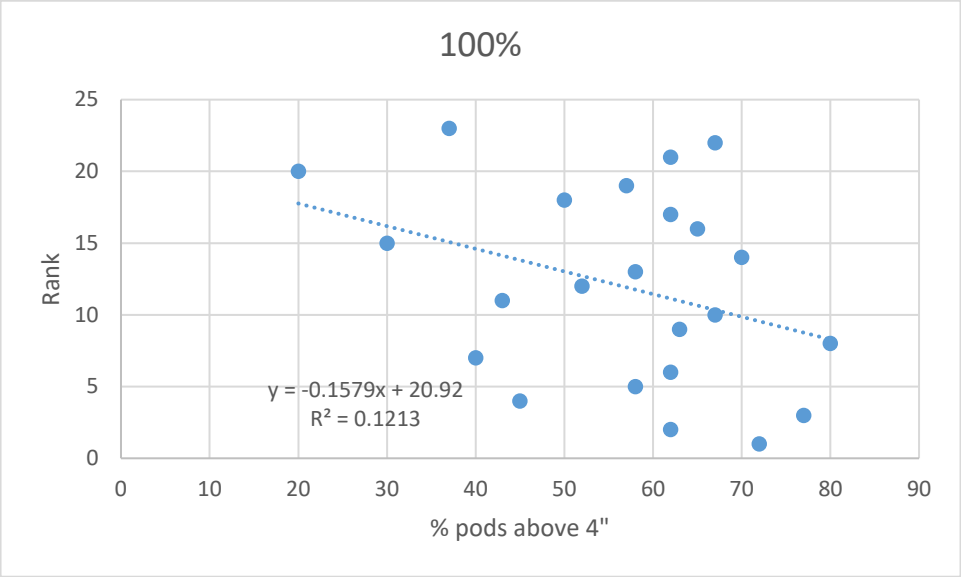

Figure 14: % of pods above 4 inches vs. Rank at 100% irrigation at PREC. Each value is the average of three plots for one entry.

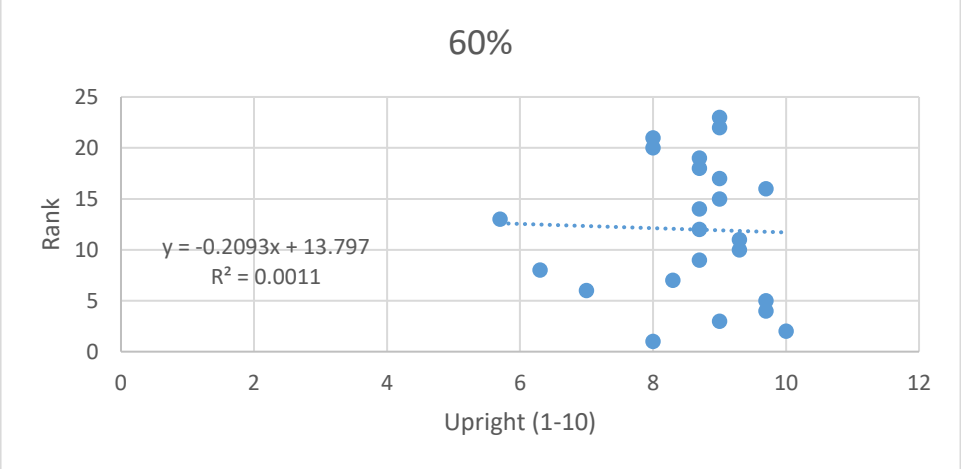

Figure 15: Upright Stature (1-10) vs. Rank at 60% irrigation at PREC. Each value is the average of three plots for one entry.

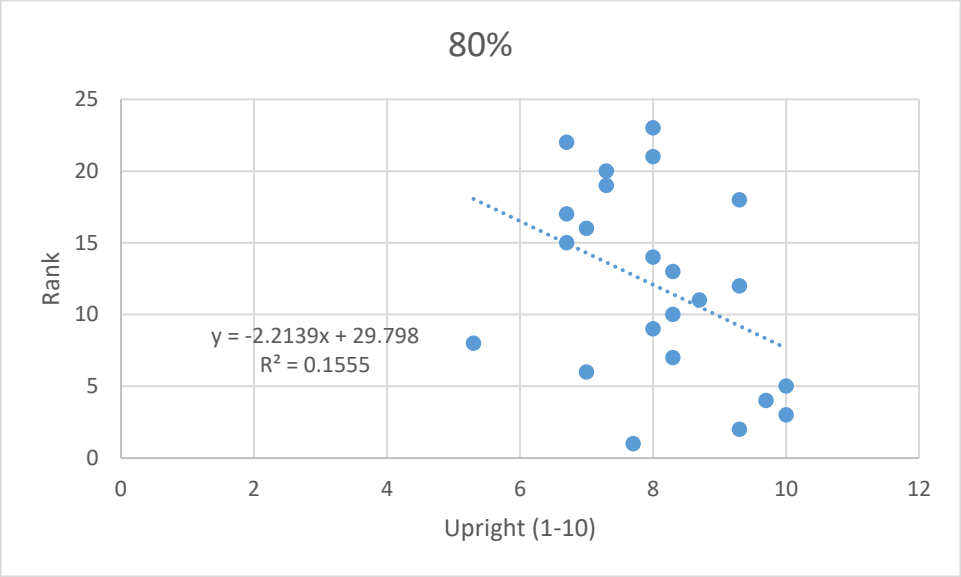

Figure 16: Upright Stature (1-10) vs. Rank at 80% irrigation at PREC. Each value is the average of three plots for one entry.

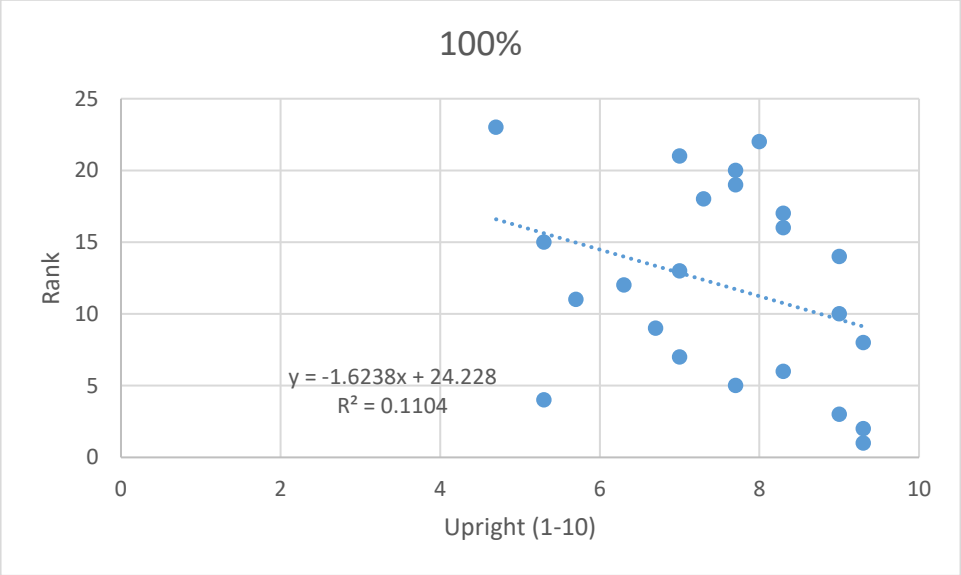

Figure 17: Upright Stature (1-10) vs. Rank at 100% irrigation at PREC. Each value is the average of three plots for one entry.

C: Summary:

Four cultivars (Max, Poncho, PT9-5-6, and Rattler) and two of our progeny lines (G-3 and M-5) were categorized as drought tolerance across 2023 and 2024. Canopy temperatures were only marginally useful in conferring drought tolerance. Entries that had upright stature and placed more pods above 4 inches had better direct harvest recovery.