

The Effect of Plant Spacing on New Round-up Ready Sugar Beet Varieties in the Imperial Valley

Final Report

2015 – 2016, 2016 – 2017, and 2017 - 2018 Growing Seasons

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Justification: Agricultural response to increased plant population, and thus seeding rate, is well documented. The generalized response is simple; increasing population increases competition for resources which decreases individual plant production. However, increasing population increases production per unit area (acres, hectares, etc.) until a population maximum is attained then production per unit area decreases. One of the facts seen in modern agriculture is the increase in recommended plant population over time. As agricultural production is a response to environmental management and genomics, it is thought variety competitiveness allows for a larger plant population.

Sugar beets are planted in rows. Increasing plant population occurs by either decreasing row spacing (distance between rows) or increasing the number of plants per linear foot of row (decreasing distance between plants). Changing row spacing affects most, if not all, mechanical manipulation of the crop as well as modifying all the equipment used to manage and harvest the crop. Altering the plant in-row spacing is much simpler as the planter is adjusted to modify spacing.

Currently, in southern California, the recommended plant spacing on 30 inch rows is between 3.0" – 5.5" (Kaffka and Hills, 1999), or plant populations of 36,000 – 70,000 seed/acre with a number of the Imperial Valley growers using 2 ³/₈" - 3 ¹/₂" (Santiago, I., Personal communication, 2014) or plant spacings of 60,000 – 88,000 plants/acre. With the introduction of Round-Up Ready technology, producers are curious if an increased plant spacing will result in a change for either sugar beet yield and/or sugar concentration. The newer varieties may be even more responsive to decreased plant spacing. Thus as new technology (varieties) becomes made available to growers, the question of proper plant spacing needs to be addressed.

Objective: Determine the yield and quality response of five (3 new and 2 currently used) Round Up Ready varieties to varying plant spacing at early, mid or late planting/harvest dates.

Methods and Materials:

2015-2016: Treatments for each of the planting/harvest dates are listed in Table 1. The study was conducted with split plot randomized complete block experimental design for each planting/harvest date. The main plot were plant spacings of 2, 3.5, and 5 inches between plants (spacings of 105, 60 or 42 thousand plants per acre) in 30 inch row width. The split plot was the variety. In this study the following varieties were used: Beta 52RR45, Beta 5499, SES 2013, SES 2014, and SES 2016. The planting dates were September 18, 2015 for Trial 1, October 2, 2015 for Trial 2, and October 14, 2015 for Trial 3. The harvest dates were May 2, 2016 for Trial 1, June 1, 2016 for Trial 2 and July 5, 2016 for Trial 3. There were 6 replications in each trial. The study was located at the Imperial Valley Research Center near Brawley, California. The fertilizer applied for Trial 1 was 200 pounds 11-52-0 per acre and 20 gallons of 32-0-0 per acre at pre-plant. For Trial 2, 200 pounds of 11-52-0 per acre and 20 gallons of 32-0-0 per acre at were applied at pre-plant and 22 gallons of 32-0-0 per acre at layby. Finally for Trial 3, 200 pounds 11-52-0 per acre and 20 gallons 32-0-0 per acre were applied at preplant while 44 gallon of 32-0-0 was applied at layby. Root yield, sucrose, extractable sucrose percent, extractable sucrose per ton, extractable sucrose per acre, purity, sugar beet nitrate-N, and number of bolters were measured. The plots were machine harvested and the quality information was determined in the Spreckels Tare Laboratory.

Table 1. Treatments for Trials 1, 2, and 3 for the 2015-2016 growing season in the Imperial Valley.

Treatment number	Plant spacing (inches)	Variety
1	2	Beta 52RR45
2	3.5	Beta 52RR45
3	5	Beta 52RR45
4	2	Beta 5499
5	3.5	Beta 5499
6	5	Beta 5499
7	2	SES 2013
8	3.5	SES 2013
9	5	SES 2013
10	2	SES 2014
11	3.5	SES 2014
12	5	SES 2014
13	2	SES 2016
14	3.5	SES 2016
15	5	SES 2016

2016-2017: Because of changed experimental design the treatments are listed in Table 2. The study was conducted at two locations. The experimental design was a completely randomized experimental design. There were two factors in this study, plant spacing (2, 3.5, and 5 inches between plants which is 105,000, 60,000, or 42,000 plants per acre in 30 inch row width) and variety (Beta 52RR45, Beta 5499, SES 2013, SES 2014, and SES 604). At the trial 1 site, the planting date was October 5, 2016 and harvest date was June 16, 2017. The other site, at Trial 2, the planting data was October 12, 2016 and harvest was on June 28, 2017. There were four replications in each trial. Root yield, sucrose, extractable sucrose percent, extractable sucrose per ton, extractable sucrose per acre, purity, sugar beet nitrate-N, and number of bolters were measured. Mildew occurrence was also rated at Trial 2 location. The plots were machine harvested and the quality information was determined in the Spreckels Tare Laboratory.

Table 2. Treatments for the 2016-2017 growing season in the Imperial Valley.

Treatment number	Plant spacing (inches)	Variety
1	2	Beta 52RR45
2	3.5	Beta 52RR45
3	5	Beta 52RR45
4	2	Beta 5499
5	3.5	Beta 5499
6	5	Beta 5499
7	2	SES 2013
8	3.5	SES 2013
9	5	SES 2013
10	2	SES 2014
11	3.5	SES 2014
12	5	SES 2014
13	2	SES 604
14	3.5	SES 604
15	5	SES 604

2017-2018: In the third year of this study the number of varieties was reduced because of poor stands of SV 2013. The experimental design was a randomized complete block with four replications. The treatments are listed in Table 3. The study was conducted at two locations. There were two factors in this study, Plant spacing (2, 3.5, and 5 inches between plants which is 105,000, 60,000, or 42,000 plants per acre in 30 inch row width) and variety (Beta 52RR45, Beta 5499, SES 2014, and SES 604). At the Trial 1 site, the planting date was September 21, 2017 and harvest date was April 18, 2018. The other site, Trial 2, the planting date was October 18, 2017 and harvest on June 13, 2018. Root yield, sucrose, extractable sucrose percent, extractable sucrose per ton, extractable sucrose per acre,

purity, and sugar beet nitrate-N were measured. The plots were machine harvested and the quality information was determined in the Spreckels Tare Laboratory.

Table 3. Treatments for the 2017-2018 growing season in the Imperial Valley.

Treatment number	Plant spacing (inches)	Variety
1	2	Beta 52RR45
2	3.5	Beta 52RR45
3	5	Beta 52RR45
4	2	Beta 5499
5	3.5	Beta 5499
6	5	Beta 5499
7	2	SES 2014
8	3.5	SES 2014
9	5	SES 2014
10	2	SES 604
11	3.5	SES 604
12	5	SES 604

Results and Discussion:

2015-2016 Trial 1

Trial 1 as the earliest planted and harvested study of the three. The statistical analysis for root yield, sucrose concentration, extractable sucrose in %, lb/ton, and lb/acre, purity, and beet nitrate-N concentration are presented in Table 4. The only factor that significantly affected all of these parameters was variety. There was no effect from plant spacing or interaction of plant spacing and variety. The means for root yield, sucrose concentration, extractable sucrose, purity, and beet nitrate-N concentration as affected by variety are reported in Table 5. Beta 5499 had the greatest root yield while SES 2014 was the least. The difference between the greatest root yield and least root yield was 4.3 tons per acre. The variety with the greatest concentration of sucrose and extractable sucrose per ton was SES 2013 while the varieties with the least sucrose concentration and extractable sucrose per ton were Beta 52RR45 and SES 2016. The variety with the greatest extractable sucrose per acre and purity was SES 2013 while SES 2014 had the least extractable sucrose per acre and purity. The beet nitrate-N concentrations were elevated compared to what the goal of high quality sugar beet production. All the treatment means for root yield, sucrose concentration, extractable sucrose, purity, and beet nitrate-N are listed for the readers information in Table 6.

Table 4. Statistical analysis for root yield, sucrose, extractable sucrose, purity, and beet nitrate-N for Trial 1 2015-2016.

Source of Variation	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N
	ton/A	%	%	lb/ton	lb/A	%	ppm
Plant spacing	0.82	0.93	0.97	0.97	0.94	0.95	0.84
Variety	0.0002	0.0001	0.0001	0.0001	0.0002	0.0004	0.0002
Plant spacing X variety	0.94	0.98	0.97	0.97	0.90	0.83	0.65
C.V. (%)	6.0	2.6	3.8	3.8	7.0	1.1	37.3
Grand mean	45.4	16.3	13.1	261	11871	87.4	118

Table 5. The effect of variety on root yield, sucrose, extractable sucrose, purity, and beet nitrate-N for Trial 1 2015-2016.

Variety	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N
	ton/A	%	%	lb/ton	lb/A	%	ppm
Beta 52RR45	46.2	16.0	12.7	254	11744	86.9	159
Beta 5499	47.0	16.2	13.1	262	12338	87.7	99
SES 2013	45.5	16.8	13.6	272	12360	88.0	127
SES 2014	42.7	16.4	13.1	261	11172	86.8	94
SES 2016	45.6	16.0	12.9	257	11743	87.6	110

Table 6. The means for root yield, sucrose, extractable sucrose, purity, and beet nitrate-N for all treatments in Trial 1 2015-2016.

Plant spacing Inch	Variety	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N
		ton/A	%	%	lb/ton	lb/A	%	ppm
2	Beta 52RR45	46.7	16.1	12.9	258	12068	87.8	139
2	Beta 5499	47.4	16.2	13.0	261	12383	87.6	99
2	SES 2013	45.7	16.8	13.6	272	12473	88.1	126
2	SES 2014	42.2	16.3	13.0	259	10945	86.9	96
2	SES 2016	46.3	16.0	12.9	257	11930	87.5	100
3.5	Beta 52RR45	46.5	15.9	12.6	251	11682	86.4	180
3.5	Beta 5499	47.3	16.3	13.1	262	12444	87.6	111
3.5	SES 2013	45.1	16.7	13.6	271	12217	88.0	151
3.5	SES 2014	43.3	16.4	13.0	160	11280	86.7	81
3.5	SES 2016	46.3	15.9	12.8	257	11919	87.8	132
5	Beta 52RR45	45.4	16.0	12.7	253	11481	86.7	158
5	Beta 5499	46.4	16.3	13.2	263	12186	87.9	86
5	SES 2013	45.7	16.8	13.6	272	12391	87.8	103
5	SES 2014	42.7	16.6	13.2	264	11290	86.8	104
5	SES 2016	44.1	16.0	12.9	258	11381	87.6	98

Also measured as part of trial 1 was the rating for curly top and occurrence of bolters. The means and statistical analysis are reported in Table 7. Curly top and bolter occurrence was affected by variety and plant spacing. At the 2 inch plant spacing, SES 2016 and Beta 52RR45 had the greatest number of plants affected by curly top. At the 3.5 inch plant spacing, SES 2016 had the most occurrence of curly top, while SES 2014 and Beta 52RR45 were in the middle and Beta 5499 and SES 2013 had the least curly top. At the 5 inch plant spacing, SES 2016 had a large amount of curly top, while the rest were much less.

The number of bolters was interesting. Beta 5499 consistently had a significantly greater numbers of bolters. Only Beta 52RR45 grown in a 3.5 inch plant spacing had bolters besides Beta 5499. The data also indicates that with a closer plant spacing, more bolters occurred with Beta 5499.

Table 7. Means and statistical analysis for number of plants in the harvest area with curly top and bolters, Trial 1 2015-2016.

Plant spacing inch	Variety	Curly top	Bolters
		Number in harvest area	
2	Beta 52RR45	4.33	0
2	Beta 5499	0.83	7.83
2	SES 2013	2.50	0
2	SES 2014	2.33	0
2	SES 2016	7.33	0
3.5	Beta 52RR45	4.33	0.83
3.5	Beta 5499	3.00	4.83
3.5	SES 2013	2.00	0
3.5	SES 2014	4.83	0
3.5	SES 2016	6.83	0
5	Beta 52RR45	2.67	0
5	Beta 5499	3.67	3.00
5	SES 2013	2.83	0
5	SES 2014	2.00	0
5	SES 2016	21.17	0
Statistical analysis		P > F	
Plant spacing		0.05	0.05
Variety		0.0001	0.0001
Plant spacing X Variety		0.0001	0.009
C.V. (%)		79.2	147.0
Grand mean		4.7	1.1

2015-2016 Trial 2

Trial 2 was planted October 2, 2015 and harvested June 1, 2016. The only factor that significantly affected root yield, sucrose, extractable sucrose (% , lb/ton, and lb/acre), beet nitrate-N was variety, Table 8. The plant spacing had no effect on any of the parameters reported in Table 8. The means by variety for root yield, sucrose, extractable sucrose (% , lb/ton, and lb/acre), and beet nitrate-N are reported in Table 9. Beta 52RR45 had the greatest root yield, followed by Beta 5499, SES 2016, SES 2013, and the least with SES 2014. Sucrose concentration was the greatest with SES 2013. SES 2014 had a similar sucrose concentration as SES 2013. Beta 5499 had a medium sucrose concentration while SES 2016 and Beta 52RR45 had the least. The variety effects on extractable sucrose concentration and extractable sucrose lb/ton results were similar to the sucrose concentration. The extractable sucrose per acre was greatest with SES 2013 while SES 2014 and SES 2016 had the least. The extractable sucrose per acre for Beta 52RR45 and Beta 5499 were intermediate. The purities while being significantly affected by variety, the difference was not large. The greatest purity was found in SES 2013. The purity decreased from 85.4 % for SES 2014 and SES 2016 to 85.0 and 84.9 for Beta 5499 and Beta 52RR45, respectively. The beet nitrate-N values in general were elevated compared to what the goal should be for sugar beet production in the Imperial Valley. The greatest beet nitrate-N concentration was 213 ppm for Beta 52RR45 while the lowest concentration was for SES 2014 and SES 2013. The important information for Trial 2 is that plant spacing did not affect root yield, sucrose concentration, extractable sucrose (% , lb/ton, or lb acre), purity or sugar beet nitrate-N concentration. The means for all the treatments are reported in Table 10.

Table 8. Statistical analysis for root yield, sucrose, and extractable sucrose for Trial 2 2015-2016.

Source of Variation	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N
	ton/A	%	%	lb/ton	lb/A	%	ppm
Plant spacing	0.49	0.95	0.84	0.84	0.68	0.88	0.90
Variety	0.0001	0.0001	0.0001	0.0001	0.02	0.007	0.006
Plant spacing X variety	0.14	0.47	0.50	0.50	0.51	0.77	0.21
C.V. (%)	5.3	3.9	5.4	5.4	9.1	1.5	30.4
Grand mean	44.3	16.2	12.5	251	11118	85.4	175

Table 9. The effect of variety on root yield, sucrose, extractable sucrose, purity, and beet nitrate-N for Trial 2 2015-2016.

Variety	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N
	ton/A	%	%	lb/ton	lb/A	%	ppm
Beta 52RR45	46.2	15.7	12.0	240	11095	84.9	213
Beta 5499	45.6	16.0	12.3	246	11257	85.0	175
SES 2013	43.6	17.0	13.5	270	11779	86.4	155
SES 2014	40.7	16.7	13.0	259	10593	85.4	149
SES 2016	45.2	15.5	12.0	240	10864	85.4	185

Table 10. The means for root yield, sucrose, extractable sucrose, purity, and beet nitrate-N for all treatments in Trial 2 2015-2016.

Plant spacing inch	Variety	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N
		ton/A	%	%	lb/ton	lb/A	%	ppm
2	Beta 52RR45	44.9	15.8	12.2	243	10934	85.2	211
2	Beta 5499	43.0	16.0	12.3	246	10579	84.9	165
2	SES 2013	43.3	17.3	13.8	275	11926	86.9	126
2	SES 2014	38.3	16.6	13.0	259	9973	85.7	112
2	SES 2016	43.4	15.4	11.9	238	10278	85.4	199
3.5	Beta 52RR45	47.0	15.3	11.7	234	11029	84.7	219
3.5	Beta 5499	46.1	16.2	12.6	253	11698	85.7	159
3.5	SES 2013	42.8	17.2	13.5	271	11615	86.3	180
3.5	SES 2014	42.9	16.9	13.2	264	11380	85.9	143
3.5	SES 2016	46.9	15.5	11.9	239	11256	85.4	194
5	Beta 52RR45	46.7	15.8	12.1	242	11322	84.8	208
5	Beta 5499	47.8	15.8	12.0	240	11495	84.4	200
5	SES 2013	44.8	16.7	13.1	263	11795	86.2	158
5	SES 2014	40.9	16.7	12.7	255	10425	84.5	193
5	SES 2016	45.2	15.7	12.2	244	11057	85.5	163

In Trial 2, additional observations were made, canopy score and bolters, Table 11. The greater the number for canopy score, the less top growth there was. The plant spacing did not affect the canopy score. There was an observation that one variety had a poorer canopy than the rest, SES 2013, Table 12. The number of bolters in the harvest area was affected by variety. Beta 5499 had a significant amount of bolters, Table 11. The plant spacing was not a factor.

Table 11. Means and statistical analysis for canopy score (top growth 1 = best, 5 = poor) and number of bolter plants in the harvest area, Trial 2 2015-2016.

Plant spacing inch	Variety	Canopy score	Bolters
		Score 1 – 5	Number in harvest area
2	Beta 52RR45	2.42	0
2	Beta 5499	2.50	6.33
2	SES 2013	3.17	0
2	SES 2014	2.75	0
2	SES 2016	2.75	0
3.5	Beta 52RR45	2.50	0
3.5	Beta 5499	2.67	5.83
3.5	SES 2013	3.50	0
3.5	SES 2014	2.92	0
3.5	SES 2016	2.67	0
5	Beta 52RR45	2.58	0
5	Beta 5499	2.50	5.83
5	SES 2013	3.50	0
5	SES 2014	2.83	0.17
5	SES 2016	3.25	0
Statistical analysis		P > F	
Plant spacing		0.80	0.98
Variety		0.0001	0.0001
Plant spacing X Variety		0.88	0.99
C.V. (%)		20	132.2
Grand mean		2.83	1.2

Table 12. The effect of variety on canopy score and number bolters for Trial 2 2015-2016.

Variety	Canopy score	Bolters
	Score 1 – 5	Number in harvest area
Beta 52RR45	2.50	0
Beta 5499	2.56	6.0
SES 2013	3.38	0
SES 2014	2.83	0.06
SES 2016	2.89	0

2015-2016 Trial 3

Trail 3 was planted October 14, 2015 and harvested July 5, 2016. The statistical analysis for sugar beet root yield, sucrose concentration, extractable sucrose (% , lb/ton, and lb/acre), purity and beet nitrate-N is reported in Table 13. The only treatment factor that affected these measured parameters was variety. Plant spacing had no effect on root yield, sucrose concentration, extractable sucrose (% , lb/ton, and lb/acre), purity, or beet nitrate-N. Beta 5499 had the lowest root yield, sucrose concentration, extractable sucrose (% , lb/ton, and lb/acre), and purity, Table 14. The greatest root yield occurred with Beta 52RR45. SES 2013 had the greatest sucrose concentration and extractable sucrose (% , lb/ton, and lb/acre), and purity. The sugar beet nitrate-N concentrations were very high. The means for all the factors are reported in Table 15.

Table 13. Statistical analysis for root yield, sucrose, and extractable sucrose for Trial 3 2015-2016.

Source of Variation	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N
	ton/A	%	%	lb/ton	lb/A	%	ppm
Plant spacing	0.44	0.59	0.64	0.64	0.80	0.75	0.80
Variety	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Plant spacing X variety	0.56	0.16	0.41	0.41	0.53	0.65	0.21
C.V. (%)	8.2	3.9	6.7	6.7	12.0	1.8	20
Grand mean	41.5	13.4	9.4	189	7903	80.8	337

Table 14. The effect of variety on root yield, sucrose, extractable sucrose, purity, and beet nitrate-N for Trial 3 2015-2016.

Variety	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N
	ton/A	%	%	lb/ton	lb/A	%	ppm
Beta 52RR45	46.2	12.7	8.9	178	8214	80.7	416
Beta 5499	39.4	12.6	8.3	167	6718	78.4	333
SES 2013	39.9	14.6	10.7	213	8765	82.6	305
SES 2014	40.1	14.3	10.2	205	8279	81.6	276
SES 2016	41.4	12.9	9.0	180	7475	80.6	353

Table 15. The means for root yield, sucrose, extractable sucrose, purity, and beet nitrate-N for all treatments in Trial 3 2015-2016.

Plant spacing inch	Variety	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N
		ton/A	%	%	lb/ton	lb/A	%	ppm
2	Beta 52RR45	44.5	13.1	9.3	187	8342	81.6	373
2	Beta 5499	37.7	12.7	8.6	171	6516	79.0	343
2	SES 2013	38.0	14.7	10.9	218	8352	83.3	289
2	SES 2014	39.0	14.1	10.1	203	7949	81.8	223
2	SES 2016	38.6	13.0	9.0	180	6954	80.3	357
3.5	Beta 52RR45	46.7	12.9	9.0	179	8388	80.7	427
3.5	Beta 5499	42.5	12.6	8.3	165	7087	78.1	357
3.5	SES 2013	41.2	14.3	10.4	207	8605	82.2	316
3.5	SES 2014	40.6	14.4	10.4	209	8566	82.4	284
3.5	SES 2016	41.7	13.0	9.1	182	7603	81.1	314
5	Beta 52RR45	47.4	12.2	8.3	166	7911	79.9	447
5	Beta 5499	38.5	12.3	8.2	163	6592	78.1	302
5	SES 2013	40.5	14.8	10.7	214	9452	82.3	310
5	SES 2014	41.0	14.3	10.1	201	8331	80.8	322
5	SES 2016	44.1	12.8	8.9	178	7867	80.4	389

In Trial 3, canopy score and bolter number were measured. Because of the late harvest, root rot was also evaluated, Table 16. The canopy score was affected by plant spacing and variety, Table 16. In general SES 2014 had a better canopy than the other varieties, Table 17. As the plant spacing increased, the canopy score increased meaning that the amount of canopy was less, Table 18. The number of bolters was only significantly affected by variety. Beta 5499 had bolters in the plot while the rest of the varieties did not, Table 16 and 17. Root rot was not significantly affected by plant spacing while variety did affect the occurrence. Beta 5499 had the most root rot while Beta 52RR45 had the least, Table 17.

Table 16. Means and statistical analysis for canopy score (top growth 1 = best, 5 = poor), number of bolter plants, and number of beets with root rot in the harvest area, Trial 3 2015-2016.

Plant spacing inch	Variety	Canopy score	Bolters	Root rot
		Score 1 – 5	Number in harvest area	
2	Beta 52RR45	3.00	0	3.50
2	Beta 5499	3.00	3.67	7.33
2	SES 2013	3.50	0	7.00
2	SES 2014	1.83	0	1.50
2	SES 2016	3.50	0	7.50
3.5	Beta 52RR45	3.92	0	6.33
3.5	Beta 5499	3.58	3.00	11.33
3.5	SES 2013	3.75	0	8.50
3.5	SES 2014	2.33	0	2.83
3.5	SES 2016	3.42	0	7.67
5	Beta 52RR45	4.00	0	7.67
5	Beta 5499	3.75	2.17	13.00
5	SES 2013	4.00	0	10.17
5	SES 2014	2.75	0	7.67
5	SES 2016	4.08	0	5.83
Statistical analysis		P > F		
Plant spacing		0.002	0.35	0.37
Variety		0.0001	0.0001	0.03
Plant spacing X Variety		0.59	0.34	0.87
C.V. (%)		16.1	130	84
Grand mean		3.36	0.59	7.19

Table 17. The effect of variety on canopy score, number bolters, and root rot for Trial 3 2015-2016.

Variety	Canopy score	Bolters	Root rot
	Score 1 – 5	Number in harvest area	
Beta 52RR45	3.64	0	5.83
Beta 5499	3.44	2.94	10.56
SES 2013	3.75	0	8.56
SES 2014	2.31	0	4.00
SES 2016	3.67	0	7.00

Table 18. The effect of seed spacing on canopy score, number bolters, and root rot for Trial 3 2015-2016.

Plant spacing Inches	Canopy score	Bolters	Root rot
	Score 1 – 5	Number in harvest area	
2	3.00	0.73	5.37
3.5	3.40	0.60	7.33
5	3.72	0.43	8.87

2016-2017 Trial 1

Root yield in Trial 1 was very good in the 2016-2017 growing season, 70.0 ton/acre. Plant spacing significantly affected only the root yield at Trial 1, Table 19. As the plant spacing increased, the root yield also increased, Table 20. The plant spacing did not affect another measured parameter at Trial 1. Variety did affect root yield, sucrose concentration, extractable sucrose concentration, extractable sucrose per ton, extractable sucrose per acre, beet nitrate-N, and number of bolters in the harvest area, Table 19.

Table 19. Statistical analysis for root yield, sucrose, extractable sucrose, purity, beet nitrate-N, and bolters for Trial 1 2016-2017.

Source of Variation	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N	Bolters
	ton/A	%	%	lb/ton	lb/A	%	ppm	Number in harvest area
Plant spacing	0.0001	0.67	0.31	0.28	0.006	0.13	0.54	0.14
Variety	0.0001	0.0002	0.009	0.01	0.10	0.47	0.002	0.0001
Plant spacing X variety	0.72	0.07	0.46	0.47	0.39	0.83	0.86	0.52
C.V. (%)	5.8	3.3	5.9	5.9	7.5	2.1	41.2	46.0
Grand mean	70.0	15.2	11.6	232	16244	84.7	215	4.4

Table 20. The effect of seed spacing on root yield, sucrose, extractable sucrose, purity, beet nitrate-N, and bolters for Trial 1 2016-2017.

Plant spacing	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N	Bolters
Inches	ton/A	%	%	lb/ton	lb/A	%	ppm	Number in harvest area
2.0	66.9	15.2	11.7	235	15707	85.3	210	2.75
3.5	68.9	15.4	11.7	234	16048	84.6	203	3.25
5.0	74.2	15.1	11.5	229	16976	84.3	232	4.10

Beta 5499 had the greatest root yield of 73.6 ton per acre, Table 21. The least root yield occurred with SES 2014 at 65.2 ton per acre. The greatest sucrose concentration, extractable sucrose concentration and extractable sucrose per ton was from SES 2014. Beta 5499 and Beta 52RR45 had the least sucrose concentration, extractable sucrose concentration, and extractable sucrose per ton. When the root yield, sucrose, and impurity information is combined, Beta 5499 and SES 604 have the greatest extractable sucrose per acre. The downfall of Beta 5499 is the significantly larger number of bolters compared to the other varieties in the study. This is similar to observations at other locations.

Table 21. The effect of variety on root yield, sucrose, extractable sucrose, purity, beet nitrate-N, and bolters for Trial 1 2016-2017.

	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N	Bolters
Variety	ton/A	%	%	lb/ton	lb/A	%	ppm	Number in harvest area
Beta 52RR45	70.6	14.8	11.1	223	15720	84.0	307	0.08
Beta 5499	73.6	14.9	11.4	228	16738	84.8	220	17.0
SES 2013	69.3	15.2	11.6	231	15993	84.5	227	0.08
SES 2014	65.2	15.9	12.3	246	15988	85.3	152	0
SES 604	71.6	15.3	11.8	235	16779	85.0	168	4.67

There was an interaction between variety and plant spacing for sucrose at this site, Figure 1. The interaction indicates that the sucrose concentration for each variety was different at each plant spacing. Beta 52RR45 and Beta 5499 had similar sucrose concentrations at all plant spacings while the SES varieties changed sucrose concentrations at different plant spacings. There is no particular reason why these differences occurred and since the extractable sucrose per acre was not affected, there was no economic impact from this interaction.

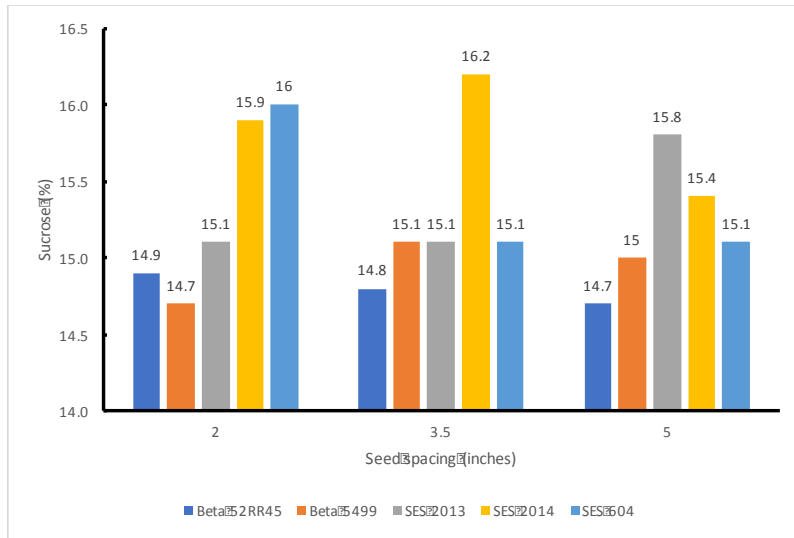


Figure 1. The interaction between variety and plant spacing for sucrose concentration at Trial 1 in the 2016-2017 growing season.

There were no interactions between variety and plant spacing for the rest of the parameters at this site. The means for all treatments are listed in Table 22.

Table 22. The means for root yield, sucrose, extractable sucrose, purity, and beet nitrate-N for all treatments in Trial 1 2016-2017.

Plant spacing inch	Variety	Root yield ton/A	Sucrose %	Extractable sucrose		Purity %	Beet nitrate-N ppm	Bolters Number in harvest area	
				%	lb/ton				lb/A
2	Beta 52RR45	68.6	14.9	11.5	230	15764	85.0	266	0.33
2	Beta 5499	70.0	14.7	11.5	229	16059	85.9	221	19.0
2	SES 2013	66.4	15.1	11.6	231	15354	84.8	231	0.14
2	SES 2014	58.2	15.9	12.2	243	14154	84.7	191	0
2	SES 604	57.1	16.0	12.6	252	16922	86.6	100	6
3.5	Beta 52RR45	68.0	14.8	11.1	222	15050	83.8	301	0
3.5	Beta 5499	73.5	15.1	11.2	225	16506	83.5	225	17.0
3.5	SES 2013	71.6	15.1	11.4	228	16364	84.3	225	0
3.5	SES 2014	64.2	16.2	12.6	252	16163	85.6	126	0
3.5	SES 604	72.4	15.1	11.6	231	16710	85.0	148	4.7
5	Beta 52RR45	75.2	14.7	11.0	219	16524	83.6	346	0
5	Beta 5499	78.3	15.0	11.4	227	17762	84.4	215	14.5
5	SES 2013	74.7	15.8	11.9	236	17675	83.7	218	0
5	SES 2014	70.2	15.4	11.9	237	16642	85.2	171	0
5	SES 604	73.4	15.1	11.4	228	16742	84.2	212	4.0

2016-2017 Trial 2

This statistical analysis for Trial 2 is reported in Table 23. There was a significant interaction between variety and plant spacing for sucrose concentration, extractable sucrose concentration, and extractable sucrose concentration per ton. This indicates that the interaction occurred because of differences in response to the treatments on the sucrose concentration and not the impurities that are accounted for in the extractable sucrose values. Figure 2 and Table 24 shows the interactions. There is no particular reason why these differences occurred and since the extractable sucrose per acre was not affected, there was no economic impact from this interaction.

Table 23. Statistical analysis for root yield, sucrose, extractable sucrose, purity, beet nitrate-N, and bolters for Trial 2 2016-2017.

Source of Variation	Root yield	Sucrose	Extractable sucrose		Purity	Beet nitrate-N	Bolters	Mildew
	ton/A	%	%	lb/ton	lb/A	%	ppm	Number in harvest area Rated on 1 to 9 scale
Plant spacing	0.0001	0.57	0.92	0.92	0.0001	0.69	0.51	0.26
Variety	0.0001	0.0001	0.0001	0.0001	0.0001	0.14	0.06	0.0001
Plant spacing X variety	0.69	0.03	0.04	0.04	0.76	0.41	0.56	0.59
C.V. (%)	5.2	4.1	5.8	5.8	7.6	1.6	46.1	11.6
Grand mean	72.4	14.0	11.2	225	16251	87.8	79	2.3

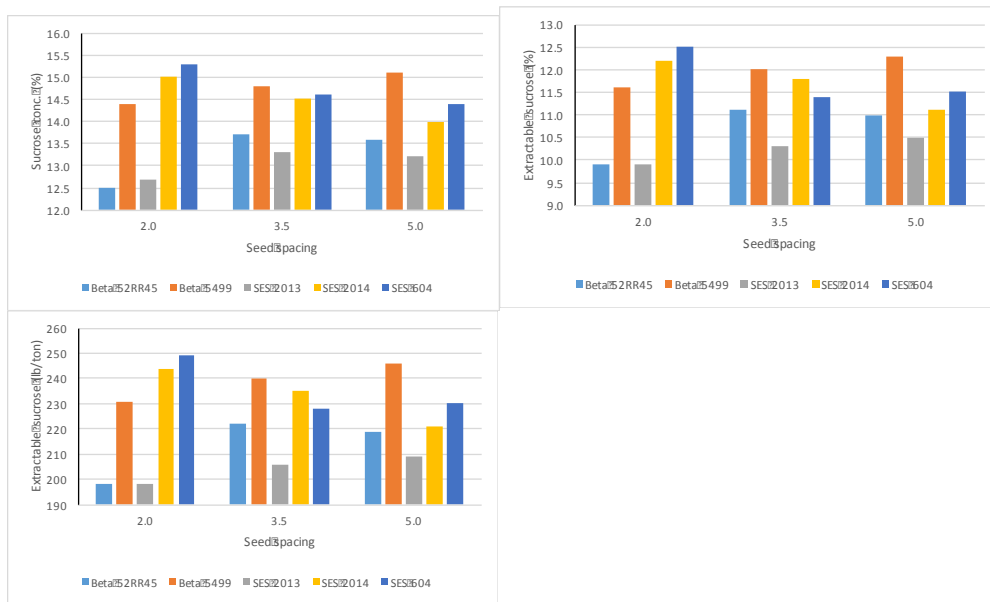


Figure 2. The interaction between variety and plant spacing for sucrose concentration, extractable sucrose concentration, and extractable sucrose per ton at Trial 2 in the 2016-2017 growing season.

Table 24. The means for root yield, sucrose, extractable sucrose, purity, and beet nitrate-N for all treatments in Trial 2 2016-2017.

Plant spacing	Variety	Root yield	Sucrose	Extractable sucrose		Purity	Beet nitrate-N	Bolters	Mildew	
		ton/A	%	%	lb/ton	lb/A	%	ppm	Number in harvest area	Rated on 1 to 9 scale
2	Beta 52RR45	67.5	12.5	9.9	198	13414	87.9	99	0	4.5
2	Beta 5499	67.0	14.4	11.6	231	15488	88.0	72	11.8	5.4
2	SES 2013	65.9	12.7	9.9	198	13069	86.8	105	0	6.1
2	SES 2014	60.8	15.0	12.2	244	14857	89.0	40	0	4.5
2	SES 604	66.0	15.3	12.5	249	16472	88.6	43	1.7	3.0
3.5	Beta 52RR45	72.4	13.7	11.1	222	16085	88.6	81	0	4.0
3.5	Beta 5499	76.2	14.8	12.0	240	18469	88.6	64	10	5.7
3.5	SES 2013	73.6	13.3	10.3	206	15163	86.1	89	0	5.7
3.5	SES 2014	69.5	14.5	11.8	235	16308	88.4	54	0	4.5
3.5	SES 604	79.2	14.6	11.4	228	18059	86.4	105	1.7	3.0
5	Beta 52RR45	76.3	13.6	11.0	219	16720	88.3	111	0	4.3
5	Beta 5499	78.1	15.1	12.3	246	19171	88.5	68	8.8	5.3
5	SES 2013	76.4	13.2	10.5	209	16004	87.8	107	0	5.0
5	SES 2014	71.8	14.0	11.1	221	15911	87.1	77	0	4.0
5	SES 604	82.5	14.4	11.5	230	18927	87.3	71	0.2	2.8

Plant spacing significantly affected root yield, extractable sucrose per acre, and the occurrence of mildew at Trial 2. As the plant spacing increased, root yield and extractable sucrose per acre increased, Table 25. In Trial 2, the root yields averaged 72.4 ton per acre. The amount of mildew observed decreased as plant spacing increased. This could be caused by better air movement in the canopy with the greater plant spacing during the growing season.

Table 25. The effect of plant spacing on root yield, sucrose, extractable sucrose, purity, beet nitrate-N, and bolters for Trial 2 2016-2017.

Plant spacing	Root yield	Sucrose	Extractable sucrose		Purity	Beet nitrate-N	Bolters	Mildew	
			%	lb/ton					lb/A
Inches	ton/A	%	%	lb/ton	lb/A	%	ppm	Number in harvest area	Rated on 1 to 9 scale
2.0	65.8	13.8	11.0	220	14467	87.8	79	3.4	5.1
3.5	73.3	14.2	11.3	226	16572	87.8	75	1.8	4.5
5.0	77.6	14.2	11.4	227	17639	87.7	83	1.8	4.1

Root yield, extractable sucrose per acre, number of bolter per plot, and mildew occurrence were affected by variety, Table 26. SES 604 had the greatest root yield and extractable sucrose yield at this site. SES 2013 and SES 2014 had the least root yield and Beta 52RR45 and Beta 5499 were intermediate. Beta 5499 and SES 604 had the greatest extractable sucrose per acre, SES 2013 had the least extractable sucrose per acre and SES 2014 and Beta 52RR45 were intermediate. SES 604 had the least mildew while the rest of the varieties were significantly greater. As in the other Trials reported, Beta 5499 had a significant number of bolters compared to the other varieties.

Table 26. The effect of variety on root yield, sucrose, extractable sucrose, purity, beet nitrate-N, and bolters for Trial 2 2016-2017.

Variety	Root yield	Sucrose	Extractable sucrose			Purity	Beet nitrate-N	Bolters	Mildew
	ton/A	%	%	lb/ton	lb/A	%	ppm	Number in harvest area	Rated on 1 to 9 scale
Beta 52RR45	72.9	13.5	10.8	217	15830	88.3	95	0	4.2
Beta 5499	73.0	14.7	11.9	238	17369	88.3	69	10.3	5.4
SES 2013	69.6	12.9	10.1	202	14081	86.8	101	0	5.8
SES 2014	68.8	14.4	11.6	232	15934	88.1	59	0	4.3
SES 604	77.6	14.7	11.7	234	18096	87.1	73	0.9	2.9

2017-2018 Trial 1

Trial 1 in 2017-2018 was considered an early harvest site. It was harvested April 18, 2018. The statistical analysis is presented in Table 27. There were no significant interactions between variety and plant spacing. Variety and plant spacing affected stand. The differences in plant stand reflected the spacing treatments that were part of the study, Table 28. We made the spacing differences as part of the treatments.

The differences in stand caused by variety were small, Table 29. The Beta varieties had better stand than the SV varieties. SV 2013 was eliminated for analysis because of poor emergence.

Root yield was affected by plant spacing and variety, Table 27. As plant spacing increased, root yield increased, Table 28. Varieties from least yield to greatest were, SV 2014, B5499, B52RR45, and SV604, Table 29.

Sugar, extractable sucrose %, and extractable sucrose per ton were not affected by plant spacing or variety. Extractable sucrose per acre was affected by plant spacing and variety. As plant spacing increased the extractable sucrose per acre increased, Table 28. These results are similar to the results for root yield.

Purity was not affected by plant spacing, Table 27. Variety did have significant differences in purity between them, Table 29. These differences in purity were not large, 88.17 to 88.89 %.

Table 27. Statistical analysis of plant spacing study – Early Harvest Trial 1 2017-2018.

Source of variation	Stand	Root yield	Sugar	Extractable Sucrose			Purity
	Plants/plot	ton/A	%	%	lb/ton	lb/A	%
Rep	0.59	0.32	0.39	0.14	0.14	0.83	0.04
Variety	0.05	0.0001	0.61	0.63	0.63	0.0001	0.04
Spacing	0.0001	0.04	0.45	0.66	0.66	0.04	0.90
Variety X Spacing	0.20	0.26	0.54	0.63	0.63	0.17	0.47
C.V (%)	7.4	3.7	2.0	2.7	2.7	3.7	0.8
Mean	134	35.5	16.7	13.7	274	9728	88.67

Table 28. The effect of plant spacing on stand, root yield, sugar, extractable sucrose, and purity at Trial 1 in 2017-2018 growing season.

Plant spacing	Stand	Root yield	Sugar	Extractable Sucrose			Purity
	Plants/plot	ton/A	%	%	lb/ton	lb/A	%
2.0	170	34.9	16.7	13.7	274	9544	88.61
3.5	127	35.5	16.8	13.8	275	9765	88.67
5.0	104	36.1	16.7	13.7	273	9876	88.72

Table 29. The effect of variety on stand, root yield, sugar, extractable sucrose, and purity at Trial 1 in 2017-2018 growing season.

Variety	Stand	Root yield ton/A	Sugar %	Extractable Sucrose			Purity %
	Plants/plot			%	lb/ton	lb/A	
B52RR45	137	35.2	16.6	13.7	273	9606	88.87
B5499	137	34.7	16.8	13.8	276	9574	88.89
SV2014	133	34.2	16.7	13.6	272	9313	88.17
SV604	127	38.0	16.7	13.7	275	10421	88.76

2017-2018 Trial 2

The Trial 2 locations was considered the late harvest site in 2017-2018. This site was harvested June 13, 2018, much earlier than planned. This makes it a mid-harvest site. This location had phenomenal sucrose concentrations, good root yields, and good purities. There were no statistical interactions between ariety and plant spacing at this site, Table 30.

Variety and plant spacing affected stand, Table 30, 31 and 32. We made the spacing differences as part of the treatments. The variety differences were small, Table 32. Stands from greatest to least were SV2014, B5499 and SV 604, and then B52RR45. Similar to Trial 1, SV 2013 was eliminated for analysis because of poor emergence.

Root yield was affected by plant spacing, Table 31. As plant spacing increased, root yield increased. Varieties from least yield to greatest were, SV2014, B52RR45, B5499, and SV604, Table 32.

Sugar, extractable sucrose %, and extractable sucrose per ton were affected similarly by variety, Table 30 and 32. B5299 had the greatest sucrose, while SV2014 was intermediate, and B52RR45 and SV 604 had the least.

Extractable sucrose per acre was affected by plant spacing and variety, Table 30. As plant spacing increased the extractable sucrose per acre was increased, Table 31. The greatest extractable sucrose per acre occurred with B5499, with SV2014 intermediate, and B52RR45 and SV 604 with the least, Table 32.

Purity was not affected by plant spacing. Variety did have significant differences in purity between them, Table 32. These differences were not big, 89.65 to 90.65 %.

Table 30. Statistical analysis of plant spacing study – Late Harvest Trial 2 2017-2018.

Source of variation	Stand	Root yield ton/A	Sugar %	Extractable Sucrose			Purity %
	Plants/plot			%	lb/ton	lb/A	
Rep	0.23	0.53	0.63	0.41	0.41	0.69	0.07
Variety	0.04	0.12	0.004	0.002	0.002	0.06	0.006
Spacing	0.0001	0.004	0.58	0.63	0.63	0.003	0.97
Variety X Spacing	0.86	0.90	0.42	0.66	0.63	0.87	0.52
C.V (%)	3.1	8.8	2.1	2.7	2.7	8.7	0.74
Mean	149	50.6	19.2	16.2	323	16353	90.00

Table 31. The effect of plant spacing on stand, root yield, sugar, extractable sucrose, and purity at the Trial 2 in 2017-2018 growing season.

Plant spacing Inches	Stand	Root yield ton/A	Sugar %	Extractable Sucrose			Purity %
	Plants/plot			%	lb/ton	lb/A	
2.0	199	47.4	19.2	16.1	323	15289	89.99
3.5	143	51.2	19.3	16.2	325	16635	90.02
5.0	104	53.3	19.1	16.1	323	17206	90.00

Table 32. The effect of variety on stand, root yield, sugar, extractable sucrose, and purity at the Trial 2 in 2017-2018 growing season.

Variety	Stand	Root yield ton/A	Sugar %	Extractable Sucrose			Purity %
	Plants/plot			%	lb/ton	lb/A	
B52RR45	146	49.0	19.1	16.0	321	15705	89.87
B5499	149	51.8	19.6	16.7	333	17229	90.69
SV2014	152	48.7	19.3	16.1	323	15777	89.65
SV604	149	52.7	18.9	15.9	317	16727	89.86

Summary

Root Yield

1. There was no significant interaction between variety and plant spacing for root yield.
2. Variety significantly affected root yield in 5 of 7 site years. No consistent variety was best for the 5 site years that were affected
3. Plant spacing affected root yield in 4 of the 7 site years. When plant spacing did affect root yield, the increased plant spacing had greater yields.
4. Having a plant spacing at 41,818 plants per acre was the best in this study.

Extractable sucrose per ton

1. Variety affected extractable sucrose per ton at 6 of the 7 site years. At 4 of the 6 responsive sites SV2014 had the greatest extractable sucrose of the varieties.
2. There was no effect of plant spacing at 6 of the 7 sites. One site, 16171, had an interaction between variety and plant spacing for extractable sucrose per ton, Figure 1. The interaction was caused by the B52RR45 and B5499 varieties increasing extractable sucrose with increasing plant spacing while SV2014, the extractable sucrose per ton decreased with increasing plant spacing population.

Extractable sucrose per acre

1. Variety affected extractable sucrose per acre at 6 of the 7 site years. The non-significant site, variety significantly affected root yield and extractable sucrose per ton in opposite ways and thus caused the lack of response for extractable sucrose per acre. At 4 of the 6 responsive sites, B5499 had the best extractable sucrose per acre. At the other two responsive sites B5499 had the least (15163) or intermediate (16172) extractable sucrose.
2. Plant spacing did not affect extractable sucrose per acre at 3 of the 7 site years. At 4 of the 7 site years, plant spacing significantly affected extractable sucrose per acre. At those sites, as the plant spacing increased, the extractable sucrose per acre increased. These extractable sucrose per acre increases were more pronounced at sites with extractable sucrose per acre values above 15,000 lb per acre.
3. There were no variety by plant spacing interactions for extractable sucrose per acre.