Report to the Oregon Processed Vegetable Commission
2013–2014

1. Title: Broccoli Breeding, Evaluation and Seed Production

2. Project Leaders: James R. Myers, Horticulture
Brian Yorgey, Food Science and Technology

3. Cooperators: None

4. Project Status: Terminating 30 June, 2014

Research efforts were focused on testing various inbred combinations for hybrid production and adaptation to Oregon growing conditions. Trials at the Vegetable Research Farm included a yield trial of OSU derived hybrids, and observation trials of OSU inbreds and hybrids. Breeding funds were used for a major portion of the support of a vegetable breeding technician, student labor, supplies, and research farm expenses. Processing funds were used for processing samples of experimental hybrids.

Objectives:

1. Develop broccoli varieties adapted to western Oregon with suitable quality, high yields, and disease resistance including concentrated and uniform yield potential, large heads that are well exserted and have minimal leaf development on stems, firm, uniform florets of dark green color, and fine beads with short pedicels, which are retained after freezing.

2. Develop seed production systems using cytoplasmic male sterility (CMS) or self incompatibility (SI) to produce field scale quantities of F_1 hybrid seed.

3. Scale up seed production to facilitate wider testing of OSU hybrids.

5. Report of Progress:

Greenhouse inbred and hybrid seed production: Cuttings were taken from inbreds and breeding lines grown in the field in 2012 to establish material for crossing and hybrid seed production in the greenhouse during the winter of 2012-2013. A total of 24 cross combinations (tables 1-3) were obtained. Seven hybrids had sufficient seed for a replicated yield trial with four reps, which also included two commercial check hybrids. Twelve inbreds were selfed for seed production (table 4). An additional 14 selections were made in segregating populations and were selfed to inbreed the line (Table 5).

All of the trials exhibited significantly higher levels blind and multishooted plants with the incidence of these being higher in the direct seeded lines relative to the transplanted materials. The large number of blind plants was most likely caused by a substantial radish maggot infestation at the time of planting and emergence.

Yield Trial:

Stands were relatively uniform and percent blind ranged from about 25 – 44%. There were no significant differences in net T/A for the checks and experimental hybrids (table 1, figure 1). Days from transplanting to harvest ranged from 59 to 73 days with two hybr-

ids (S462 x S460 and S465 x S446) being rather late. Arcadia had 28% leaves remaining on the stalk after trimming, and higher than most experimental hybrids. Emerald Pride had an 11% leaf which was similar to many of the experimental hybrids.

The canopy heights were similar, but experimental hybrids generally had greater head height compared to the check hybrids (table 2, figure 2). All entries in the trial had fine to medium bead size and heads of acceptable size. In general, experimental hybrids had better color, and were more exserted and segmented than check hybrids (table 2).

Samples from the yield trial were blanched and frozen in the OSU department of food science pilot plant. They are evaluated in an in-house cutting in early January, and samples are displayed at the Northwest Food Processors Association meetings in mid January.

One novel hybrid combination this year was a cross of S446 x USVL 093. The latter is an inbred developed by Mark Farnham, USDA Brassica breeder at Charleston, SC. While this hybrid was shorter than the others, it still showed acceptable processing characteristics.

Observation Trials:

Additional experimental hybrids that had too few seeds for a replicated trial were grown in a single replicate observation trial (table 3). Hybrids in this table are ranked by overall score. S446 x S454 had the highest overall score. This hybrid has been tested in yield trials in previous years where it has performed well. Newer inbreds that seemed to nick well with S446 or S454 were S460, S462, and S465. Observation trials of inbreds are shown in table 4 ranked by overall score. S454 and S458A had the highest overall ratings.

Fourteen selections at S_2 to S_4 generation of inbreeding were grown and evaluated, and selections were made for the next cycle of self pollination (table 5). The OSU OP materials have been selected under organic production and may be able to set heads with lower fertilizer levels. Other selections are from experimental hybrid combinations that looked particularly good when previously evaluated in yield and observation trials. An important selection criteria this year was for firm heads as a number of selections from previous years had soft heads.

Table 6 shows yield of hybrid cross combinations that have been made since 2000 compared to recurring check hybrids. In general, yields of check hybrids have remained constant over the years, and there seems to have been an increase in yields of experimental hybrids over time.

Cytoplasmic Male Sterile (CMS) Facilitated Hybrid Seed Production:

Fourteen selections of the Anand CMS background and two in the Ogura CMS background were grown in 2013 (table 7). Four inbreds (S411, S445, S446, and S454) are at various stages of backcrossing into these backgrounds. We continued to select for more normal flower morphology in the Anand CMS. Three isolation cages were established at the Vegetable Research Farm. Each cage contained fertile inbred plants in the S445, S446 and S545 backgrounds. Within these cages, CMS lines were grouped to obtain crossed seeds. Honeybees were introduced to the cages at flowering and remained for about six weeks. Seed set on these plants is still being evaluated and will be reported at a later date.

6. Summary:

The seven experimental hybrids tested in a replicated yield trials were similar to the check hybrids in terms of performance. In general, it appears that the OSU inbreds can produce hybrids that are similar to commercial hybrids for most important crop characteristics. The OSU hybrids tend to have more exserted and segmented heads, more uniform bead and stem color. Conversion of inbreds to Ogura CMS background is underway and preliminary efforts to scale up the crossing process were conducted used isolation cages for controlled seed production.

Table 1. Yield data from a hybrid broccoli trial, conducted at the OSU Vegetable Research Farm, Corvallis OR in 2013.[z]

Entry	Harvest (days post-transplant)	No. Plts/ Plot	% Blind Plants	Gross T/A	Young Heads T/A	Culls T/A	Net T/A	Net Heads/A	Head Di-ameter (cm)	% Leaves
Arcadia	63	28.8	32.1	4.2	0.3	0.0	3.9	10,890	11.8	27.6
Emerald Pride	59	29.0	25.0	5.2	0.1	0.3	4.7	12,197	13.5	11.0
S446 x S458A	69	29.3	24.8	4.6	0.1	0.4	4.2	11,180	11.8	4.8
S454 x S460	63	29.8	35.2	3.4	0.3	0.0	3.1	10,309	11.1	16.0
S454 x S462	63	29.5	28.7	5.0	0.2	0.0	4.8	12,487	12.4	11.0
S454 x S465	69	29.8	24.3	4.9	0.6	0.0	4.3	12,197	11.6	10.4
S462 x S460	73	28.5	44.1	4.5	0.2	0.0	4.3	13,068	13.2	5.4
S465 x S446	73	29.8	26.8	3.5	0.3	0.1	3.1	10,890	11.1	10.6
USVL 093 x S446	59	29.3	24.0	5.0	0.3	0.4	4.3	13,068	13.2	4.8
LSD 0.05		1.0	13.3	1.5	0.4	0.3	1.6	2,706	1.2	9.5

[z]Transplanted July 14 in 30' plots, rows 30" apart, 12" between plants. Mean of 4 replications.

Table 2. Observation notes from a broccoli yield trial, Corvallis, 2013[z].

Entry	Plant Ht (cm)	Head Ht (cm)	Head Shape[y]	Bead Size[x]	Stem color[w]	Exser-tion[w]	Segment-ation[w]	Unifor-mity[w]	Branch-ing[w]	Overall[w]	Notes
Arcadia	65	48	6	M	5	5	3	3	5	5	
Emerald Pride	62	39	5	F-M	5	4	2	4	3	4	1/10 hollow
S446 x S458A	62	67	6	F	7	9	9	5	5	7	
S454 x S460	59	55	7	F-M	7	7	6	4	7	6	
S454 x S462	45	54	7	F-M	7	9	7	5	5	8	1 plant stunted from cabbage maggot
S454 x S465	58	67	8	F-M	5	8	6	7	3	7	Small and variable head sizes
S462 x S460	65	70	8	F	9	9	7	3	9	3	Many with multiple shoots
S465 x S446	61	68	9	F-M	9	9	7	1	9	3	Uneven maturity
USVL 093 x S446	51	46	6	M	4	7	6	7	5	7	1/3 part prime (10/10)

[w]Scale of 1-9 where 1 = poor and 9 = excellent.

[x]F = fine; M = medium; C = coarse.

[y]Scale of 1 - 9 where 1 = flat and 9 = extreme dome.

[z]Transplanted July 19 in 30' plots; rows 30" apart, 12' between plants.

Table 3. Notes from an observation trial of broccoli hybrids grown at the Vegetable Research Farm, Corvallis, 2013.[z]

Entry	Head dia (cm)	No. plts	No. Blind	% blind	Maturity (days)	Canopy Ht (cm)	Head Ht (cm)	Head Shape[y]	Bead Size[w]	Stem Color[x]	Exertion[x]	Segment[x]	Branch[x]	Overall Score[x]
S446xS454	15	16	4	25.0	85	55	52	6	F	9	7	7	1	9
S411xS456	15	18	6	33.3	85	66	62	6	M	7	8	7	3	8
S456xS411	14	17	8	47.1	85	66	63	7	M	5	8	7	5	8
S454xS458A	14	6	3	50.0	78	44	48	7	M	7	9	7	1	8
S462xS460	12	1	1	100.0	108	53	55	6	VF	7	8		1	8
S446 OCMSxS446	14	18	7	38.9	98	63	62	7	F-M	7	7	7	1	8
S445xS454	15	7	1	14.3	83	53	56	7	F-M	8	8	9	1	7
S446xS458A	15	8	1	12.5	85	54	59	5	F-M	7	9	9	3	7
S446xS462	12	10	5	50.0	102	59	63	7	F-M	7	7	5	1	7
S465xS446	10	8	6	75.0	103	55	57	6	M	7	7	3	1	7
S454xS462	16	12	4	33.3	83	56	59	6	F	7	9	7	1	6
S454xS465	11	18	6	33.3	85	57	60	8	F	8	9	7	1	6
S446xS465	9	5	4	80.0	108	72	63	7	F	5	6	7	1	5
S454xS460	11	7	1	14.3	83	60	66	8	F	5	9	6	1	5
S465xS454	14	16	7	43.8	83	54	66	6	M-C	3	8	5	1	4
S463xS454	12	7	4	57.1	83	60	50	6	F	7	7	5	1	3

[z]Planted July 9 in 30" rows, thinned to 12" apart.

[y]Scale of 1-9 where 1 = flat and 9 = extreme dome.

[x]Scale of 1-9 where 1 = poor and 9 = excellent.

[w]F = fine, M = medium, C = coarse.

Table 4. Broccoli observation trial, OSU inbreds, Corvallis, 2013.[z]

Entry	Head dia (cm)	No. plts	No. Blind	% blind	Maturity (days)	Leaf Canopy Ht (cm)	Head Ht (cm)	Head Shape[y]	Bead Size[w]	Stem Color[x]	Exertion[x]	Segment[x]	Uniformity[x]	Branch	Overall Score[x]	Diseases
S454	14	13	2	15.4	83	50	57	4	F-M	5	8	7	7	3	8	-
S458B	14	6	3	50.0	99	60	45	7	F	5	7	7	5	1	8	-
S438	14	6	2	33.3	88	45	56	5	M	5	9	7	7	5	7	-
S443	13	4	2	50.0	88	58	54	7	F	3	8	6	5	5	7	-
S445	18	13	7	53.8	85	45	48	4	VF	7	9	9	5	3	7	head rot
S463	13	14	10	71.4	91	52	47	6	F	5	7	7	3	3	7	-
S458A	18	9	2	22.2	91	45	37	4	M	3	7	7	3	3	6	-
S462	17	16	10	62.5	86	40	43	4	F-M	7	9	9	5	3	6	maggot
S411	14	12	8	66.7	91	69	48	5	F	7	7	7	1	3	5	
S459	16	7	6	85.7	106	50	55	8	F	7	8	9	3	1	5	-
S442	12	15	2	13.3	108	55	45	6	F	7	7	9	7	1	3	-
S457	18	7	2	28.6	95	65	50	8	F	9	7	7	7	1	3	-

[z]Planted July 9 in 30" rows, thinned to 12" apart.

[y]Scale of 1-9 where 1 = flat and 9 = extreme dome.

[x]Scale of 1-9 where 1 = poor and 9 = excellent.

[w]F = fine, M = medium, C = coarse.

Table 5. Field evaluation of partially inbred broccoli lines grown in an observation and selection trial at the Vegetable Research Farm, Corvallis, 2013.[z]

Entry	Generation	Head dia (cm)	No. plts	No. Blind	% blind	Maturity (days)	Cano-py Ht (cm)	Head Ht (cm)	Head Shape[y]	Bead Size[w]	Stem Color[x]	Exertion[x]	Segment[x]	Uniformity[x]	Branch[x]	Overall Score[x]
OSU OP POP 1-1-3-1	S_4	15	18	15	83.3	91	60	56	4	VF	8	9	5	7	3	6
OSU OP POP 1-3-1-1	S_4	12	16	6	37.5	78	69	64	8	F-M	9	8	7		5	7
(S445xS463)-1-1	S_3	12	18	7	38.9	86	62	68	8	C	9	9	3	4	3	3
(S445xS463)-2-1	S_3	17	7	1	14.3	88	40	47	4	VF	7	9	9	7	1	5
(S446xS457)-1	S_2	14	17	5	29.4	91	63	60	6	F	5	8	7	3	3	6
(S446xS458)-1	S_2	16	14	4	28.6	91	63	65	7	F-M	5	9	7	3	5	7
(S446xS460)-1-1	S_3	12	12	2	16.7	91	65	57	7	F	5	8	6	3	1	7
(S446xS460)-1-2	S_3	11	58	0	0.0	91	47	38	3	F	6	6	3	7	1	3
(S446xS460)-1-3	S_3	13	15	5	33.3	98	50	42	5	F	6	6	5	3	1	3
(S454xRS2)-1-1	S_3	15	12	5	41.7	78	63	67	7	F	7	9	8	7	1	9
(S454xRS2)-1-2	S_3	11	13	5	38.5	85	44	48	6	M-C	9	8	6	3	1	3
(S454xRS2)-2-1	S_3	13	19	3	15.8	83	56	62	7	F	7	9	7	7	1	8
(S463xS446)-1	S_2	10	15	13	86.7	98	53	48	7	F	5	6	6	1	1	5
(S465xS446)-1-2	S_3	12	21	5	23.8	91	63	45	7	F	3	9	8	5	3	5

[z]Planted July 9 in 30" rows, thinned to 12" apart.

[y]Scale of 1-9 where 1 = flat and 9 = extreme dome.

[x]Scale of 1-9 where 1 = poor and 9 = excellent.

[w]VF = very fine, F = fine, M = medium, C = coarse.

Table 6. Yield data (net T/A) from 14 years of broccoli yield trials, Corvallis, 2013.

	Tons/Acre													
Entry[z]	2000	2001	2002	2003	2004	2005	2006[y]	2007	2008	2009	2010	2011	2012[y]	2013
S411 x S445			3.6											
S411 x S446		3.7		5.3			4.2			4.3	3.3		2.3	
S411 x S447										3.2				
S411 x S449										2.7				
S411 x S454	3.5	4.0	3.3		2.7		4.2							
S411 x S455									5.4	4.2	3.5			
S411 x S457											3.5	3.4[x]		
S445 x S454		4.1	4.3	6.1	3.4			3.3	3.6				3.9	
S445 x S456									3.2					
S445 x S461									1.5					
S445 x S465												2.4		
S446 x S454				3.7	4.8		3.7	4.1	2.8	3.6	2.1	3.1		
S446 x S455											3.9			
S446 x S462											3.4			
S454 x S455									3.1	2.9				
S454 x S456									3.1		2.8			
S454 x S457											3.1			
S454 x S458										2.2		2.6[x]		4.2
S454 x S459										2.2	2.9			
S454 x S460														3.1
S454 x S462										2.0		2.2	2.7	4.8
S454 x S463												3.5		
S454 x S465												3.3		4.3
S456 x S446												3.8[x]		
S456 x S454										4.3				
S459 x S446										2.3				
S462 x S446										6.0			3.3	

Table 6. (continued).

	Tons/Acre													
Entry[z]	2000	2001	2002	2003	2004	2005	2006[y]	2007	2008	2009	2010	2011	2012[y]	2013
S462 x S460														4.3
S465 x S411												3.6[x]	1.9	
S463 x S446													3.3	
S465 x S446													2.5	3.1
USVL 093 x S446														4.3
Arcadia	3.7							4.1	3.9		3.1	4.6	3.6	3.9
Excelsior	2.4	3.8	5.0	3.9	3.4	2.3	4.5							
Legend	3.2		4.7											
Regal	4.0	3.6		5.3	4.2	3.3	3.6	5.2						
Emerald Pride				3.4	4.5	4.3	3.9	4.2		3.2	3.5	3.3	3.1	4.7
Imperial										3.9	4.0	4.8	4.8	
LSD 0.05	0.5	0.8	1.4	0.9	0.9	0.8		1.0	0.9	1.1	1.0	1.1		1.6

[z]Cross and reciprocal combined; crosses involving discontinued inbreds not shown. [y]Uneven number of reps required calculation of LS means and pair-wise comparisons rather than LSD. [x]Entries consisted of three reps, instead of four, requiring the use of a different LSD (1.13) and comparison among only marked entries.

Table 7. Cytoplasmic male sterile selections grown in an observation trial at the Vegetable Research Farm, Corvallis, 2013.[z]

Entry	Head dia (cm)	No. plts	No. Blind	% blind	Maturity (days)	Canopy Ht (cm)	Hd Ht (cm)	Head Shape[y]	Bead Size[w]	Stem Color[x]	Exertion[x]	Segment[x]	Branch[x]	Overall Score[x]
S446 OCMS x S446	14	18	7	38.9	98	63	62	7	F-M	7	7	7	1	8
USVL 0930 CMS x S446	18	15	2	13.3	83	62	58	6	M	8	5	8	1	7
[(CMS13-1xS454)xS454]-1-1 x S454	14	6	2	33.3	88	51	56	8	M	7	3	7	1	7
[(AN24-1A-2xS411)-1xS411]-2-1 x S411	12	12	10	83.3	91	64	51	3	M	7	5	3	1	3
[(AN24-3A-2xS454)-1xS454]-2-1 x S454	11	9	2	22.2	85	54	40	6	M	9	5	3	1	5
[(AN24-3B-2xS445)-1xS445]-1 x S445	24	12	11	91.7	102	42	53	7	F-M	7	9	5	1	3
[(AN25-1A-1xS411)-1xS411]-2-1 x S411	14	11	3	27.3	85	54	47	5	M-C	8	5	7	1	7
[(AN25-1A-1xS454)-1xS454]-3-1 x S454	18	7	2	28.6	95	52	48	6	F-M	6	7	7	3	7
[(AN25-1B-1xS411)-1xS411]-4-1 x S411	14	7	4	57.1	88	63	52	4	M	8	7	3	1	5
[(AN25-1B-1xS454)-1xS454]-1-1 x S454	14	16	5	31.3	85	53	44	6	M	7	8	4	1	6
[(AN25-1B-1xS454)-1xS454]-2 x S454	12	14	10	71.4	91	53	49	8	F-M	5	8	3	1	7
[(AN25-4B-2xS411)-1xS411]-1-1 x S411	13	13	5	38.5	85	57	52	7	M-C		7	5	1	6
[(AN25-4B-2xS411)-2xS411]-2-1 x S411	12	14	5	35.7	88	71	58	5	M	5	7	5	1	6
[(AN25-4B-2xS445)-1xS446]-1 x S446	12	9	4	44.4	95	57	48	5	F	7	5	3	1	5
[(AN25-4B-2xS454)-2xS454]-3 x S454	11	15	3	20.0	85	56	49	6	C	8	7	7	1	5
[(AN25-4B-2xS445)-2xunkown]-2 x S445	15	17	4	23.5	85	57	54	6	M	9	7	5	1	6

[z]Planted July 9 in 30" rows, thinned to 12". [y]Scale of 1-9 where 1=flat & 9=extreme dome. [x]Scale of 1-9 where 1=poor & 9=excellent. [w]F=fine, M=medium, C=coarse.

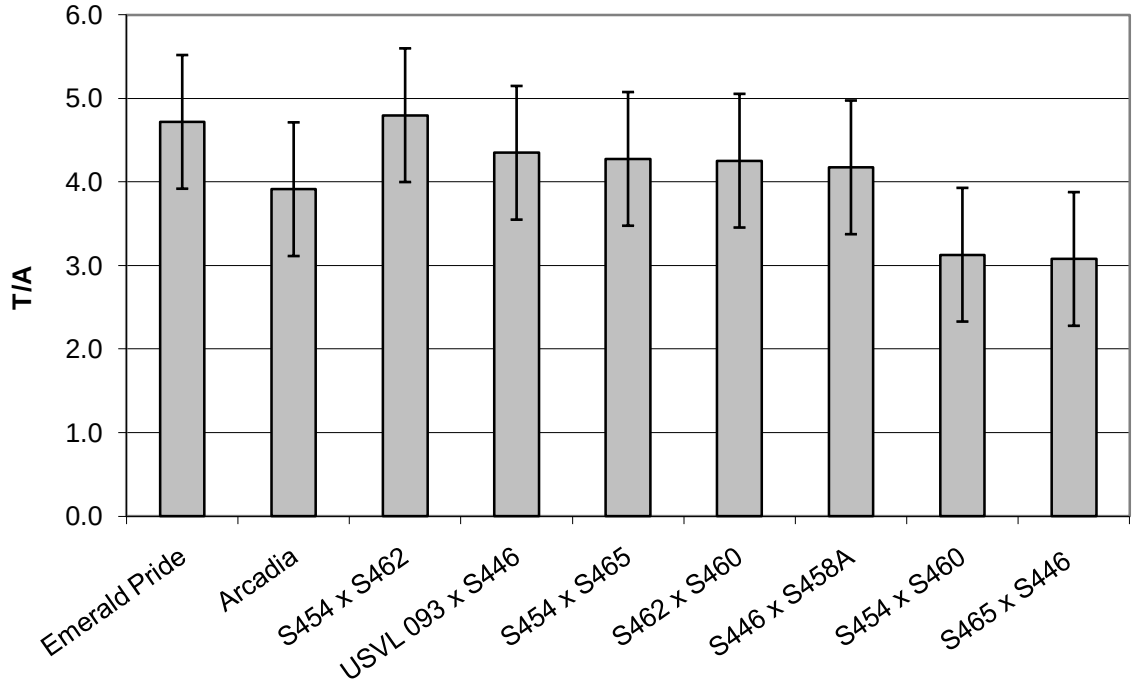

Figure 1. Net T/A from a broccoli yield trial conducted at the OSU Vegetable Research Farm, Corvallis, OR in 2013.

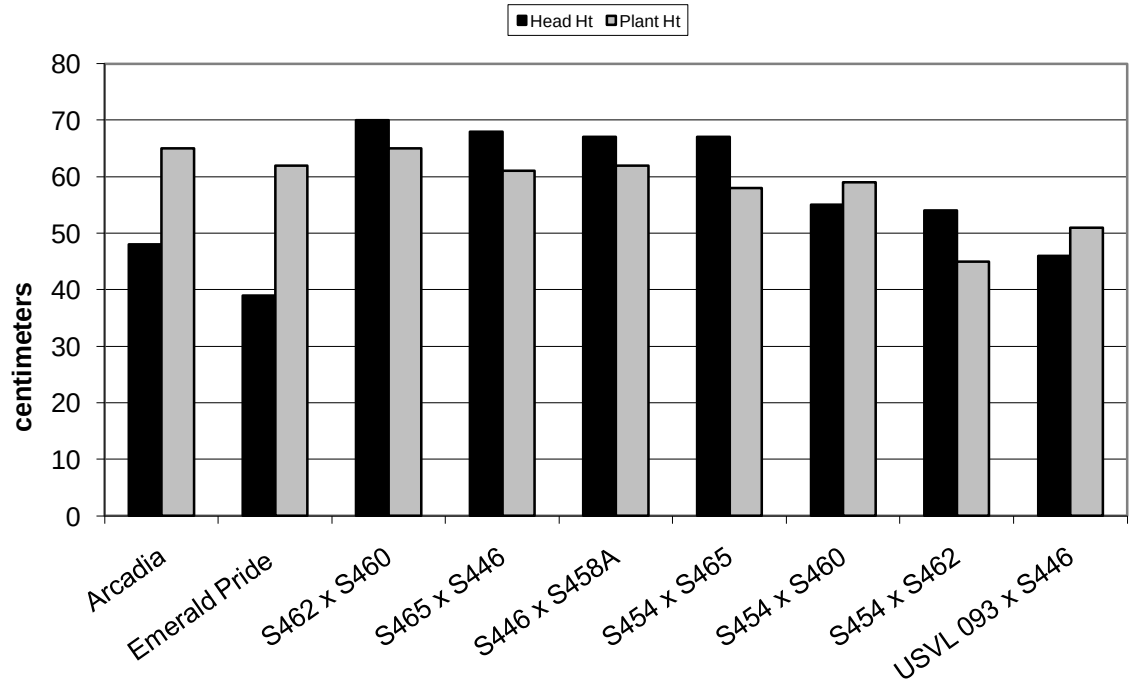

Figure 2. Head (black) and plant (gray) height of broccoli hybrids from a yield trial planted at the OSU Vegetable Research Farm, Corvallis, OR in 2013.