OPVC CONTINUING PROJECT REPORT: YEAR 2015

1. OPVC REPORT COVER PAGE (maximum 2 pages)

OPVC Project Number:

Project Title: Broccoli Breeding, Evaluation and Seed Production 2015

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2. EXECUTIVE SUMMARY (ABSTRACT): Processors need broccoli with better quality traits than what is available in cultivars developed for California and Mexico fresh markets. Farmers need to reduce labor costs of broccoli production by mechanizing harvest. Most contemporary commercially available cultivars are not suitable for either mechanical harvest or processing. The objective of the OSU broccoli breeding program is to develop broccoli varieties adapted to western Oregon with suitable quality and high yields. The program operates on a one year cycle where cuttings from the field are taken into the greenhouse in the fall where they are rooted and hand crossed and self-pollinated to produce seed for the next generation. Seed is harvested in May and June and used to plant trials for fall evaluation. . In 2015, nine experimental hybrids were planted in a replicated yield trial, which also included two commercial check hybrids and a new exserted commercial hybrid from Seminis. SVO 097BL had the highest net T/A head weight of the trial but was not significantly different than the experimental hybrid S446 x S454. Twenty-two advanced generation inbreds were selfed for seed production and an additional 15 early generation inbreds were advanced a generation. Eleven cytoplasmic male sterile (CMS) selections were backcrossed to various inbreds. A visit was made to a seed company who is evaluating inbreds from the OSU breeding program.

3. FULL REPORT (no maximum)

3.a. BACKGROUND Because of the high labor input into broccoli harvest, much of the acreage of broccoli grown for processing and fresh market has shifted out of the United States to countries where labor costs are lower. Broccoli production in western Oregon continues to face stiff competition, and to be competitive, growers need to produce broccoli more efficiently and affordably. Machine harvest of broccoli could lower production costs. A limitation has been the lack of broccoli varieties suitable to mechanical harvest. From a crop production standpoint, the two key factors in developing varieties that are suitable for mechanical harvest are uniform heading and appropriate plant architecture.

Most commercially available broccoli hybrids are high yielding but have short plants with heavy but poorly exserted heads. Short plants have high fiber in the portion of the stem subtending the head that must be used to achieve a normal-length cut. The lack of height as well as the high fiber makes them unsuitable for machine harvest.

In addition to direct harvest characteristics, processors need broccoli that makes a high quality pack. Florets and stems need to be dark green in color and should be uniform in color and shape; beads should be small, and retained during the blast freezing process. An added benefit to dark green color that we recently discovered is that darker color is associated with higher carotenoid (compounds such as pro-vitamin A) levels. Heat tolerance, and resistance to bacterial head rot, downy mildew, and club root is desirable. Inbred lines from the Oregon State University breeding program have the genetic potential to create hybrids with greatly improved head exsertion and segmentation, better color, and low fiber. The OSU hybrids are suitable for machine harvest, and some inbreds possess some of the already discussed disease resistance characteristics.

Many OSU hybrids are high quality and have shown stable, high yields over several years and it appears now that the major limitation to achieving commercial seed production of hybrids is the scaling up of hybrid seed production using cytoplasmic male sterility or self-incompatibility. There is also a need to derive new inbreds with improved disease resistance

3.b OBJECTIVES

- 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.
- Develop seed production systems using cytoplasmic male sterility (CMS) or self-incompatibility (SI) to produce field scale quantities of F1 hybrid seed.
- Scale up seed production to facilitate wider testing of OSU hybrids.

3.c. SIGNIFICANT FINDINGS OSU broccoli hybrids perform similarly to commercial cultivars in terms of yield and have better processing quality.

3.d. METHODS The broccoli breeding program follows a one year breeding cycle. Cuttings from hybrids and inbreds are brought from the field in the fall and rooted in the greenhouse. Upon flowering during the winter, inbreds are bud pollinated to self-pollinate them and crossed with other inbreds to produce

F_1 hybrid seed. In May and June, selfed and crossed seed is collected and is used to start transplants for planting yield trials and the breeding nursery. After evaluation, the cycle repeats with harvest of cuttings

Table 1. Selection history and pedigrees for advanced broccoli inbreds developed by the OSU vegetable breeding program.

Entry	Former number	Pedigree
S411	88-76-4-1-2	HS179-1/S240-11-8
S438	91-203-2-1-6-3	S352/S240-11-8
S442	91-203-2-3-1-1	S352/S240-11-8
S443	91-203-2-3-1-2	S352/S240-11-8
S445	91-203-2-3-1-5	S352/S240-11-8
S446	91-203-2-3-2-1	S352/S240-11-8
S454	91-232-4-1-2-1	S233/Emerald City
S457	04-3-2-2-3	S454 /S387//S411/S446
S458	04-3-2-3-1	S454 /S387//S411/S446
S460	04-4-1-1-3	S411/S446//S454 /S387
S462	04-4-2-2-1	S411/S446//S454 /S387
S463	04-5-2-2-1	S454 /S446//USVL 089
S465	04-5-2-2-3	S454 /S446//USVL 089
S466	11-1-1-1-2	S446/S460
S468	11-2-1-1-2	S454/RS2
S469	11-2-1-1-1	S454/RS2
S470	11-1-1-1-1	S454/RS2
S471	09-1-1-3-1-2-2	OSU OP Selection
S472	09-1-1-3-1-2-1	OSU OP Selection
S473	09-1-3-1-1-1-1	OSU OP Selection
S474	09-1-1-3-1-1-1	OSU OP Selection
S475	09-1-1-3-1-1-2	OSU OP Selection
(S446/S460)-1-1-1-1	11-1-1-1-1	S446/S460
(S446/S457)-1-1-1	12-1-1-1	S446/S457
(S446/S457)-1-1-2	12-1-1-2	S446/S457
(S454/RS2)-2-1-1	12-2-1-1	S454/RS2
(S463/S446)-1-1-1	12-1-1-1	S463/S446
(S454/S445)-1-1	13-1-1	S454/S445
(S454/S446)-1-2	13-1-2	S454/S446
(S454/S465)-1-1	13-1-1	S454/S465
(S458A/S446)-1-1	13-1-1	S458A/S446
(S458A/S446)-1-2	13-1-2	S458A/S446
(S458A/S446)-1-3	13-1-3	S458A/S446
(S458A/S446)-1-4	13-1-4	S458A/S446
(S462/S460)-1-1	13-1-1	S462/S460
(S454/S446)-1	14-1	S454/S466
(S454/S446)-1	14-2	S454/S446

Hybrid seed production is facilitated on a commercial scale using either self-incompatibility or cytoplasmic male sterility (CMS). The use of self-incompatibility is problematic in a program our size because of a lack of diversity in incompatibility alleles; therefore, CMS seems the best option for commercial hybrid seed production. Table 1 shows pedigrees of inbreds used in the OSU breeding program. As is apparent from this list, many of the inbreds share parentage, which reduces the amount of hybrid vigor that will be achieved in the fall. New inbreds are derived by repeated self-pollination of F_1 hybrids. Four to five generations of selfing is required before inbreds can be tested for hybrid seed production. The Inbreds, experimental hybrids and commercial hybrids grown in the main fall planting are evaluated for head size, shape, and exsertion, segmentation, floret texture and color, maturity and disease resistance. The size of the replicated main fall season trial varies with the number of crosses that can be made (which is a function of the amount of labor available to make hand crosses) but up to 15 of the most promising OSU experimental hybrids and two to four check varieties are included. These are transplanted in one row plots 30 feet in length and replicated four times. Data recorded in addition to yield data includes plant and leaf height, exsertion, dome shape, bead size, head color and uniformity. Heads from entries in the yield trial are taken to the OSU pilot processing plant for blanching and freezing. Frozen material is evaluated at the OSU winter cutting and will be displayed at the NWFPA Expo in Portland in January.

when making a hybrid with a related inbred. Two sources of CMS (Anand and Ogura) have been used in the program. Anand CMS was transferred into broccoli from *Brassica tournefortii*, and has been available as germplasm but has never been used commercially. Ogura CMS came from radish and has the primary means of commercial hybrid seed production in several types of Cole crops. We compared the performance of Anand and Ogura CMS and found that Ogura had fewer flower abnormalities, with showier petals and possibly higher seed set. In 2015, reduced the number of inbreds based on Anand CMS and increased those with Ogura CMS. We now have four inbreds (S462, SW463, S465 and S446) in an Ogura background. CMS lines will be planted as females with fertile inbreds used as males. In the field, males and the associated array of females are grown in isolation or in cages on the Vegetable Farm. Seed production is evaluated based on number of siliques that set at least one viable seed, and weight of seed per female line. Another aspect of commercial scale up is identifying commercial partners who can take our inbreds and produce our hybrids or combine with their inbreds to produce a composite hybrid.

3.e. RESULTS & DISCUSSION *Greenhouse inbred and hybrid seed production:* Cuttings were taken from inbreds and breeding lines grown in the field in 2014 to establish material for crossing and hybrid seed production in the greenhouse during the winter of 2014-2015. A total of nine cross combinations (tables 2 - 3) were obtained. The nine experimental hybrids were planted in a replicated yield trial with four reps, which also included two commercial check hybrids (Arcadia and Emerald Pride) and an exserted commercial hybrid from Seminis (SVO 097BL). Twenty-two advanced generation 15 early generation inbreds were selfed for seed production (table 4).

Aphids were a major problem during August and required several sprays to achieve control.

Yield Trial: Stands were relatively uniform although there was a gradient for maturity across the field, with rep 4 being earlier than rep 1. SVO 097BL had significantly higher net T/A than all other entries in the trial except for S446 x S454. The two check cultivars ranked third and fourth, and four experimental hybrids were not significantly different (Table 2, Figure 1). A cluster of four other experimental hybrid were the lowest yielding in the trial. SVO 097BL appeared to achieve its yields by producing large and heavy stems. This cultivar was not as exserted as was observed in 2014 (Table 3, Figure 2). Days from transplanting to harvest ranged from 62 to 69 days which represents a much narrower range in maturity than what has typically been observed. This may have been due to the relatively warm late summer and fall. Head diameters were generally on the large side, except for the low yield experimental hybrids, which tended to have smaller heads. All of the experimental hybrids as well as SVO 097BL had relatively few leaves on the stem subtending the head.

Except for the taller S460 x S446, canopy heights were similar, but experimental hybrids generally had greater head height compared to the check hybrids (table 3, figure 2). Most entries in the trial had fine to medium bead size and heads of acceptable size. The exceptions were S462 x S454 and S471 x S454 with medium to coarse beads and S465 x S446 with very small heads. In general, experimental hybrids had better color, and were more exserted and segmented than check hybrids (table 3). SVO 097BL had relatively flat heads and light stem color and medium sized beads.

Table 5 shows multi-year net T/A for experimental hybrids dating back to 2003. We also calculated cumulative yield as an average across years, as well as an index for yield relative to the checks Emerald Pride (or Arcadia in 2008 only since Emerald Pride was not grown that year). The index was derived by calculating yield as a percent of the check for each year in which the experimental was tested then averaging the result. This approach compensates for the fact that different hybrids might be tested in

different years, and produces different results compared to yield calculated across years. The hybrids S445 x S454, S446 x S455, S446 x S458, S456 x S446, S456 x S454, S462 x S446 and S463 x S446 stand out as regularly achieving yields greater than the checks. In the majority of these crosses, S446 is one of the parents.

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

Observation Trials: In addition to the advanced inbred lines, 15 selections at S2 to S6 generation of inbreeding were grown and evaluated, and selections were made for the next cycle of self-pollination (table 4). This year, a number plants in early generation selections with soft heads were observed, and we strongly selected against these types when choosing cuttings for further propagation.

Cytoplasmic Male Sterile (CMS) Facilitated Hybrid Seed Production: Eleven selections (three Anand and eight Ogura CMS background) were grown in 2015 (table 6). Backcrossing continued to a set of inbreds that are generally self-compatible. 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 one month. During this time period when presence of honeybees prevented use of pesticides on the plants, an infestation of flea beetles developed and greatly reduced seed set.

4. BUDGET DETAILS

Requested Budget	
1) Breeding (Myers)	
Salaries and benefits	
Faculty Research Assistant, field, full time	$2,287
OPE @ 70%	$1,601
Wages and benefits	
Student Wages	$1,000
OPE @ 8%	$80
Supplies	$348
Land use and greenhouse rental	$1,405
Total	$6,721
2) Processing (Yorgey)	
Salaries and benefits	
Senior Faculty Research Assistant	$2,610
OPE @ 60%	$1,566
Wages and benefits	
Student Wages	$200
OPE @ 8%	$16
Supplies	$108
Total	$4,501
Grand Total	$11,222

Budget Justification: Salary and OPE is requested for a full time faculty research assistant who will commit approximately 6% FTE to broccoli breeding The remainder of salary will come from other sources. For the senior faculty research assistant, approximately5% FTE will be required to process broccoli samples; the remainder of salary to come from other sources. $1,000 is requested for summer undergraduate students to assist in plot maintenance and harvest operations. The SFRA will also supervise an undergraduate student in broccoli processing. Undergraduate student OPE is 8%. Funds for services and supplies includes $348 for field and greenhouse supplies ((fertilizer, pots, labels, stakes, tags, crossing supplies, envelopes, paper bags, etc.). Facilities user charges include land use rental (0.5 acre at $1,259 per acre = $630), and greenhouse rental ($1.55*500 sq. ft. = $775).

Table 2. Maturity, yield and yield parameters for a broccoli yield trial conducted at the OSU Vegetable Research Farm near Corvallis, OR in 2015.

		Field	Heads				Plants		Heads				Head	Hollow	Leaves
Entry	Maturity	wt.	Total	Net	Immature	Cull	Total	Blind	Total	Net	Immature	Cull	Dia.	stems	on head
	days		T/A				No./A		No./A				in.	%	
Arcadia	67	6.2	5.5	5.5	0.0	0.0	16,262	436	15,391	15,101	145	145	5.7	55.0	11.9
Emerald Pride	62	6.1	5.3	5.1	0.2	0.0	15,972	290	15,536	14,084	1,307	145	5.9	42.5	14.3
S446xS454	67	5.8	5.7	5.6	0.0	0.1	16,408	871	15,682	14,810	726	145	5.9	55.0	1.3
S460xS446	69	5.1	5.1	5.0	0.1	0.0	16,262	0	16,262	15,246	871	145	5.9	25.0	1.5
S460xS454	64	3.3	3.1	3.0	0.0	0.1	15,972	290	15,682	15,391	145	145	5.3	35.0	5.1
S460xS462	64	4.3	4.1	4.0	0.0	0.1	16,262	726	15,972	15,101	581	290	5.9	62.5	3.2
S462xS446	64	3.7	3.4	3.2	0.1	0.0	15,536	436	14,810	13,358	1,452	0	5.2	60.0	8.4
S462xS454	62	4.4	4.2	4.0	0.2	0.0	16,988	145	16,553	14,810	1,742	0	5.6	85.0	3.9
S465xS446	69	3.6	3.3	3.3	0.0	0.0	15,391	290	14,520	13,939	581	0	4.7	85.0	7.8
S465xS454	69	3.2	3.0	2.9	0.1	0.0	16,553	290	15,536	14,084	1,452	0	5.1	15.0	4.2
S471xS454	64	4.7	4.3	4.2	0.0	0.0	16,262	290	14,520	13,794	436	290	5.6	70.0	9.0
SVO 097BL	67	7.3	7.1	6.7	0.4	0.0	15,972	871	16,262	13,649	2,614	0	5.9	72.5	3.2
LSD 0.05	0.0	1.0	1.1	1.1	0.1	n.s.	1,272	759	1,633	1,774	751	n.s.	0.4	26.2	4.4

Table 3. Field observation data collected on broccoli hybrids in a yield trial conducted at the OSU Vegetable Research Farm near Corvallis, OR in 2015.

Entry	Leaf Ht.	Head Ht.	Head Shape[z]	Bead Size[y]	Stem color[x]	Exsert-ion[x]	Segmen-tation[x]	Unifor-mity[x]	Branch[w]	Aphids[x]	Overall[x]	Notes
	in.											
Arcadia	25.0	18.0	5	F	3	2	5	7	3	1	3	
Emerald Pride	24.0	18.5	4	F-M	5	3	5	4	3	3	5	Some heads w/ variable bead development
S446xS454	25.0	23.0	5	F	7	8	4	8	3	2	8	
S460xS446	28.0	29.5	7	F	8	9	5	8	5	1	8	Heads small but very uniform & exserted
S460xS454	26.0	24.5	6	F	7	7	7	5	3	1	7	Slightly small heads
S460xS462	24.0	24.5	5	M	7	8	5	5	3	2	5	Some catseye
S462xS446	25.0	22.0	5	M	7	7	3	4	5	3	6	
S462xS454	24.0	23.0	4	M-C	7	7	5	5	5	5	7	Variable bead development - probably from heat
S465xS446	24.0	25.0	6	F-M	7	6	7	5	3	3	7	
S465xS454	23.5	25.0	7	F	7	8	9	7	5	1	7	Small heads
S471xS454	25.0	22.0	4	M-C	5	5	5	5	5	3	5	
SVO 097BL	24.0	21.0	3	M	5	7	7	3	3	3	5	

[z]Scale of 1-9; ≤ 3 = concave, 4 = flat, 5 = slight dome & 9 = extreme domed head. [y]F = fine, M = medium, & C = coarse. [x]Scale of 1-9 where 1 is least and 9 is most extreme. [w]Scale of 1-9 where 1 = no branching & 9 = multiple long branches.

Table 4. Advanced generation broccoli inbreds in the OSU breeding program grown at the Vegetable Research Farm, Corvallis, OR in 2015.

Entry	Plants	Blind	Maturity	Leaf Ht.	Head Ht.	Head Shape[z]	Bead Size[y]	Stem color[x]	Exsert-ion[x]	Segmen-tation[x]	Unifor-mity[x]	Branch[w]	Aphids[x]	Overall[x]	Notes
	no.		days	in.											
S411	16	0	63	21	25	3	M	7	9	7	7	3	3	6	
S438	14	0	63	19	25	4	F-M	5	9	9	7	9	3	5	Soft & loose heads
S442	12	3	67	20	23	4	F-M	5	7	9	7	5	3	5	Loose heads, soft
S443	8	0	63	22	25	4	F-M	7	7	5	5	3	7	5	Soft heads
S445	4	0	74	14	17	3	F	7	6	8	7	3	1	6	
S446	3	0	74	17	20	4	M	7	6	5	7	1	1	7	
S454	19	0	67	18	21	5	M	7	7	7	9	5	1	7	
S457	5	0	60												Very early
S458	14	1	67	22	26	7	M	7	7	9	7	3	1	5	Soft heads
S460	12	1	74	25	28	8	M	5	9	5	7	3	1	9	Large firm heads but catseye
S462	17	0	60	17	18	4	M-C	5	6	3	7	7	1	3	Loose heads
S463	17	0	74	19	22	6	M	5	7	6	8	3	3	8	Large firm heads
S465	17	0	84	21	23	4	M	7	7		5	3	1	3	Late
S466	19	1	74	25	26	5	M-C	7	7	3	7	3	1	5	Soft heads
S468	18	0	74	23	27	5	F-M	7	8	7	7	5	3	8	Large dense heads
S469	23	0	67	22	25	5	M	9	8	7	7	1	1	7	Very small leaves on head
S470	15	0	67	25	30	5	C	7	7	7	5	3	1	3	Soft heads
S471	16	0	74	23	25	4	F	7	6	9	3	3	1	7	
S472	14	0	74	22	25	7	M	5	7	9	7	7	1	7	

Table 4. (Continued).

Entry	Plants	Blind	Maturity	Leaf Ht.	Head Ht.	Head Shape[z]	Bead Size[y]	Stem color[x]	Exsert-ion[x]	Segmen-tation[x]	Unifor-mity[x]	Branch[w]	Aphids[x]	Overall[x]	Notes
	no.		days	in.											
S473	9	0	67	23	20	5	F	7	9	9	5	7	1	6	
S474	24	0	74	21	24	4	F	5	6	9	8	1	3	7	May combine well w/ larger bead domed head
S475	24	1	74	19	23	4	F	7	7	9	9	1	3	7	Very similar to S474
(S446/S460)-1-1-1-1	19	0	74	24	27	5	C	9	8	7	7	3	1	5	Firm heads but coarse beads
(S446/S457)-1-1-1	10	1	74	23	28	6	M	7	7	7	7	3	1	7	Powdery mildew
(S446/S457)-1-1-2	22	0	67	22	25	5	F-M	7	6	5	3	3	1	6	Firm heads, plot quite variable
(S454/RS2)-2-1-1	18	1	67	22	22	4	M	9	7	8	7	5	3	8	$ soft heads
(S463/S446)-1-1-1	7	0	74	20	21	6	M	7	8	8	6	3	1	8	Large firm heads
(S454/S445)-1-1	8		74	18	19	3	F	9	8	9	7	3	1	8	$ soft heads
(S454/S446)-1-2	18	2	67	30	35	5	C	7	8	6	3	$	1	1	Plants $ powdery mildew (heavily infected plot of B. napus 2 rows over)

Table 4. (Continued).

Entry	Plants	Blind	Maturity	Leaf Ht.	Head Ht.	Head Shape[z]	Bead Size[y]	Stem color[x]	Exsert-ion[x]	Segmen-tation[x]	Unifor-mity[x]	Branch[w]	Aphids[x]	Overall[x]	Notes
	no.		days	in.											
(S454/S465)-1-1	21	1	67	22	24	3	F ($)	9	7	9	3	1	1	7	Variable bead size & maturity, soft heads
(S458A/S446)-1-1	23	0	74	24	24	4	F	3-5	6	7	5	3	3	77	Firm, fairly large heads
(S458A/S446)-1-2	18	1	74	23	27	7	F	5	6	8	3	3	3	7	Small but firm heads
(S458A/S446)-1-3	19	0	67	22	25	5	M	9	7	9	3	3	3	5	Soft heads
(S458A/S446)-1-4	22	0	74	15	21	6	C	7	8	3	5	3	3	3	Small coarse heads
(S462/S460)-1-1	19	0	67	20	21	5	F	5	7	7	3	3	3	7	
(S454/S446)-1	13	0	67	22	25	5	M-C	5	8	5	5	3	1	5	Soft heads
(S454/S446)-1	16	0	67	19	20	4	M-C	7	6	5	5	3	3	5	$ for height, bead size, maturity

[z]Scale of 1-9; ≤ 3 = concave, 4 = flat, 5 = slight dome & 9 = extreme domed head. [y]F = fine, M = medium, & C = coarse. [x]Scale of 1-9 where 1 is least and 9 is most extreme. [w]Scale of 1-9 where 1 = no branching & 9 = multiple long branches.

Table 5. Yield data (net T/A) from 12 years of OSU broccoli yield trials, Corvallis, OR.

Entry[z]	2003	2004	2005	2006y	2007	2008	2009	2010	2011	2012[y]	2013	2014	2015	Cumulative yield	Yield relative to Emerald Pride or Arcadia (2008)
	Net T/A														%
S445 x S454	6.1	3.4			3.3	3.6				3.9		1.9		3.7	103
S446 x S454	3.7	4.8		3.7	4.1	2.8	3.6	2.1	3.1			2.1	5.6	3.6	93
S446 x S455								3.9						3.9	111
S446 x S458B												3.5		3.5	121
S446 x S460								3.4				2.7	5.0	3.7	96
S446 x S462								3.4					4.0	3.7	88
S454 x S457								3.1						3.1	89
S454 x S458							2.2		2.6		4.2	1.8		2.7	75
S454 x S459							2.2	2.9						2.6	76
S454 x S460											3.1		3.0	3.1	62
S454 x S462							2.0		2.2	2.7	4.8			2.9	80
S454 x S463									3.5			2.3		2.9	93
S454 x S465									3.3		4.3		2.9	3.5	83
S456 x S446									3.8					3.8	115
S456 x S454							4.3							4.3	134
S459 x S446							2.3							2.3	72
S462 x S446							6.0			3.3				4.7	147
S462 x S460											4.3		4.0	4.2	85
S465 x S411									3.6	1.9				2.8	85
S463 x S446										3.3				3.3	106
S465 x S446										2.5	3.1		3.3	3.0	70
USVL 093 x S446											4.3			4.3	91
S471 x S454													4.2	4.2	82
Arcadia					4.1	3.9		3.1	4.6	3.6	3.9	2.6	5.5	3.9	103
Excelsior	3.9	3.4	2.3	4.5										3.5	90
Regal	5.3	4.2	3.3	3.6	5.2									4.3	108
Emerald Pride	3.4	4.5	4.3	3.9	4.2		3.2	3.5	3.3	3.1	4.7	2.9	5.1	3.8	100
Imperial							3.9	4.0	4.8	4.8				4.4	134
SVO 097BL												2.6	6.7	4.7	111
LSD 0.05	0.9	0.9	0.8		1.0	0.9	1.1	1.0	1.1		1.6	1.0	1.1		

[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 6. Broccoli inbreds with Anand (A) or Ogura (O) cytoplasmic male sterility in the OSU breeding program grown at the Vegetable Research Farm, Corvallis, OR in 2015.

Entry	Plants	Blind	Maturity	Leaf Ht.	Head Ht.	Head Shape[z]	Bead Size[y]	Stem color[x]	Exsertion[x]	Segmentation[x]	Uniformity[x]	Branch[w]	Aphids[x]	Overall[x]	Notes
	no.		days	in.											
(A411*3-1/S463)-2//S463	8	0	67	25	25	4	F	5	7	5	7	5	1	7	
(A411*3-2/S411)-1//S411	16	0	74	22	22	5	M	7	5	7	3	7	3	5	
(A411*3-2/S411)-1//S411	11	2	74	24	24	5	M	9	7	5	5	7	3	7	
(O446*1-1/S462)-1//S462	10	1	67	22	22	3	F-M	5	5	5	3	3	3	5	Still quite variable
(O446*1-1/S462)-1//S462	11	1	67	21	25	5	M	5	7	5	1	5	5	5	Highly variable
(O446*1-1/S462)-3//S462	9	1	67	21	19	6	F-M	7	7	7	5	3	1	7	Variable & poor stand but very large heads
(O446*1-1/S463)-5//S463															
(O446*1-1/S465)-2//S465	14	0	74	21	22	5	F-M	7	7	5	5	3	5	7	Variable height & head characters
(O446*1-1/S465)-2//S465	5	0	81												(LATE)
(O446*6-1-1/S462)-2//S462	8	0	63	21	21	5	F	7	5	5	7	3	5	7	Many leaners in plot
S446OCMS/S446//S446	15	0	74	25	23	5	M-C	9	5	3	3	1	3	3	Variable maturity, head color & head ht

[z]Scale of 1-9; ≤ 3 = concave, 4 = flat, 5 = slight dome & 9 = extreme domed head. [y]F = fine, M = medium, & C = coarse. [x]Scale of 1-9 where 1 is least (worst) and 9 is most extreme (best). [w]Scale of 1-9 where 1 = no branching & 9 = multiple long branches.

Table 7. Commercial broccoli hybrids and OPs grown in an observation trial at the Vegetable Research Farm, Corvallis, OR in 2015.

Entry	Source	Plants	Blind	Maturity	Leaf Ht.	Head Ht.	Head Shape[z]	Bead Size[y]	Stem color[x]	Exsert-ion[x]	Segmentation[x]	Uniformity[x]	Branch[w]	Aphids[x]	Overall (processing)[x]	Overall (fresh mkt)[x]
		no.		days	in.											
Avenger	Sakata	8	0	74	21	15	5	F-M	3	1	3	7	1	3	1	8
Batavia	Bejo	8	0	67	20	15	4	M	5	3	3	7	1	3	1	7
Belstar	Bejo	10	0	81	19	18	6	M	3	5	3	9	1	1	3	7
Diplomat	Osborne	5	0	67	25	16	5	M	5	3	3	7	3	1	3	7
Emerald Crown	Sakata	14	0	71	22	14	5	F-M	5	1	1	7	1	1	1	7
Emerald Jewel	Sakata	14	1	81	25	15	6	F-M	3	1	2	5	1	3	1	7
Green Magic	Bejo	9	0	70	27	19	6	M	5	3	1	9	1	1	3	8
Imperial	Sakata	13	0	74	18	14	6	F	5	1	1	7	1	1	3	9
Nutribud	Nichols	8	0	55	23	19	4	C	7	5	5	1	5	1	3	3

[z]Scale of 1-9; ≤ 3 = concave, 4 = flat, 5 = slight dome & 9 = extreme domed head. [y]F = fine, M = medium, & C = coarse. [x]Scale of 1-9 where 1 is least (worst) and 9 is most extreme (best). [w]Scale of 1-9 where 1 = no branching & 9 = multiple long branches.

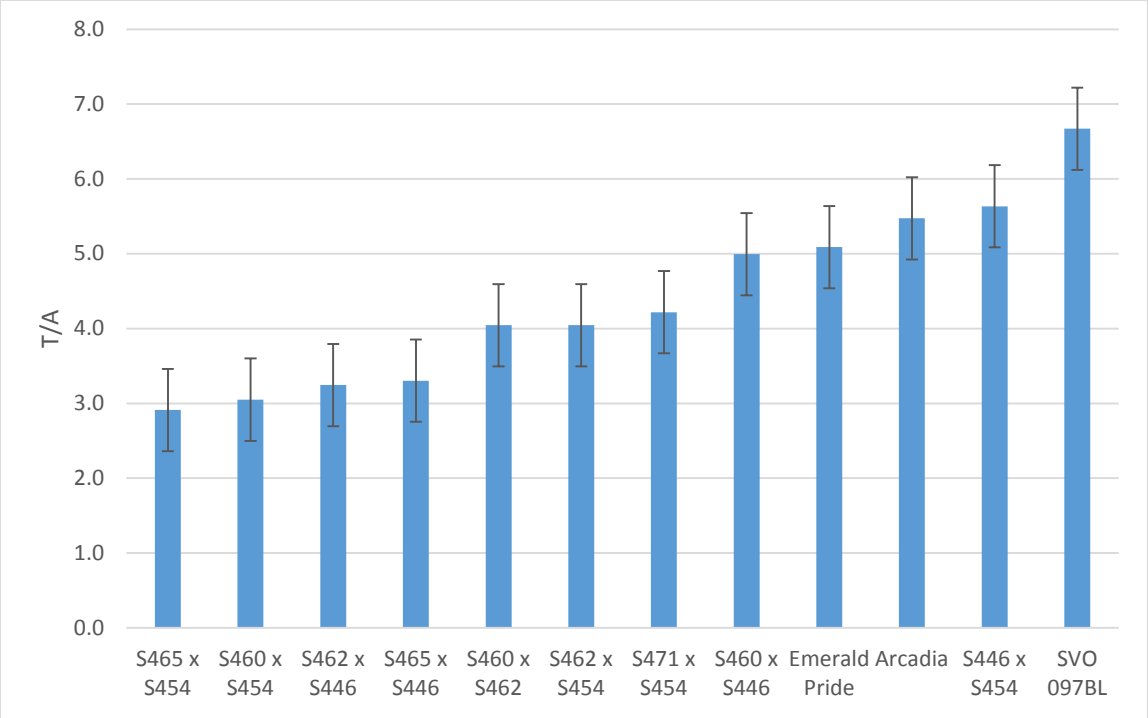

Figure 1. Net T/A yield of experimental broccoli hybrids and checks grown in a yield trial at the OSU Vegetable Research Farm near Corvallis, OR in 2015.

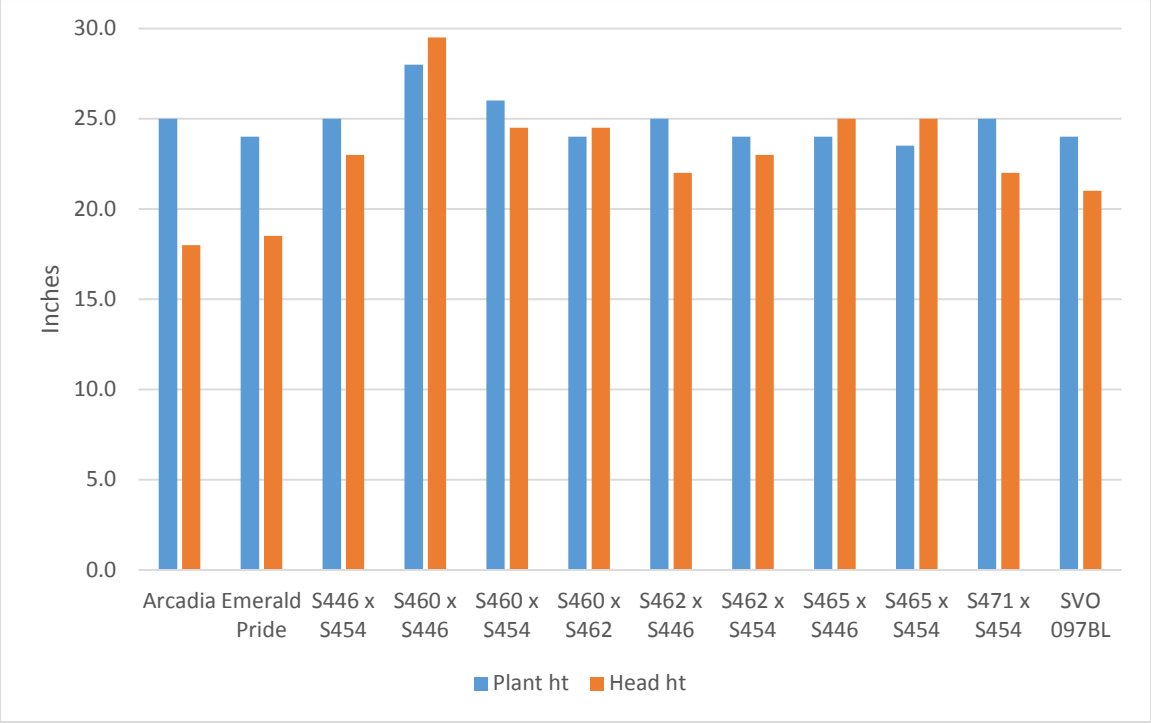

Figure 2. Plant (canopy) height and head height of experimental broccoli hybrids and checks grown in a yield trial at the OSU Vegetable Research Farm near Corvallis, OR in 2015.