January 2021

Research Reports

for

Oregon Processed Vegetable Commission

Prepared by
Agricultural Research
Foundation January 2021

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Reports

Research/Extension Progress Report for 2020-2021 Funded Projects
Progress Report for the Agricultural Research Foundation
Oregon Processed Vegetable Commission

Title: Identifying heat tolerant broccoli cultivars for the processed vegetable industry

Project Leaders: Alex Stone (Associate Professor), Andy Nagy (Faculty Research Associate)

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Cooperators: Ed Peachey and Jim Myers

Funding History: 1st year

Abstract: With the hot summers of recent years causing significant heat damage to broccoli heads during harvest, it was deemed necessary to screen new broccoli cultivars for tolerance to heat. Temperature is often the main limiting factor in determining whether a broccoli variety can be grown successfully within a particular region, and mounting evidence of global climate change suggests the need for a more heat tolerant broccoli will only increase in the foreseeable future. With most commercially available cultivars being bred for production in mild and stable climatic regions such as the Salinas Valley in California, these types of heat tolerance evaluations become necessary to ensure the long term viability of the broccoli industry in the Willamette Valley. From the perspective of commercial growers and farmers, heat tolerance alone does not make a broccoli variety suitable for large scale field plantings. More often than not, yield becomes of paramount concern for growers, while aspects of head quality and processing characteristics are the main concerns of the vegetable processors. The goal of this work was to identify broccoli hybrids with the most complete range of desirable characteristics, including heat tolerance, for Willamette Valley production.

Key Words: broccoli, heat tolerance, florets, yield, variety, cultivar, selection

Objective: The objective of the heat trial was to assess commercial hybrids and experimental breeding lines for suitability and overall tolerance to the climatic growing conditions commonly found in the Willamette valley.

Procedures: The heat trial was initiated by contacting known seed company representatives, examination of current online seed catalogues and collecting seeds from commercial broccoli lines which purportedly have heat adaptable traits. Contact with representatives of several major seed companies also yielded seeds from yet to be released lines of broccoli which were described as being tolerance to high temperatures environments. Cooperating universities and USDA breeders associated with the USDA-NIFA-SCRI funded Eastern Broccoli Project also sent seeds to be evaluated in this trial. The heat trial was designed to have six different planting dates spaced one week apart to maximize the potential range of temperature variability within a single growing season. Studies conducted by Bjorkman and Pearson (1998) have found there is likely a specific physiological period of time in a broccoli plant's growth wherein excessive heat is the most detrimental to the formation of a broccoli head with desirable characteristics and quality. This 5-7 day period of time occurs when the broccoli plant is transitioning from vegetative growth into a reproductive phase, and the initial enlargement of bud primordia begins.

Having six planting dates maximizes the potential of being able to correlate declines in plant performance with increases in ambient temperatures.

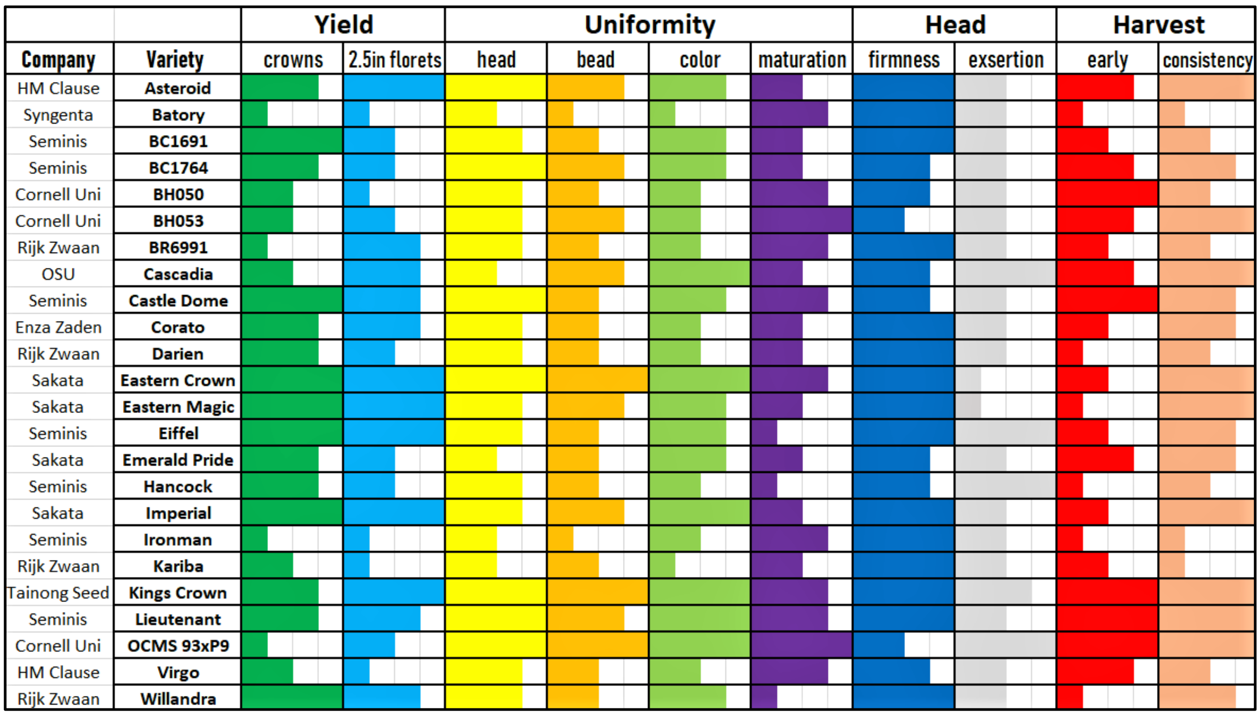
The seeding of each broccoli line was initiated inside the OSU campus greenhouses and approximately 4 weeks later transplanted into the field site at the University's Vegetable farm in Corvallis. For each planting date, 15 seeds of each broccoli variety were started in seedling trays and the best 10 seedlings were then transplanted into the randomly assigned field plots using a transplanter (using one foot in-row placings). The six seeding dates were 10, 16, 23 & 30 May and 6 & 13 June. Two temperature data loggers were placed into the trial to record the ambient air temperatures at canopy height for the duration of the trial. The growth of broccoli and trial site was closely monitored for any pest problems and fertilized with standard agronomic inputs. Each head was harvested individually when it reached a prime stage of maturity and then evaluated for the criteria designated as being relevant to assessing the level of heat damage which occurred for that variety and planting. With each head being harvested individually, the number of days required to harvest a given planting can also estimate the cultivar's propensity for maturing uniformly. Evaluations of broccoli head quality consisted of rating each head for: color uniformity, bead uniformity, head uniformity, head firmness, and head diameter. With yield being of paramount concern for local broccoli farmers, the weight of each head (i.e. cut to 6.0 in length), weight of total florets, and weight of usable florets (< 2.5 in) was also incorporated into the evaluation criteria.

Accomplishments: Several commercial lines performed reasonably well across the given environmental conditions created by having six plantings dates, and scored high in most of the evaluation criteria. A summary table of the 24 broccoli lines trialed, and how they performed within each evaluation criteria can be seen in Table #1 below. Some of these broccoli hybrids were previously described as being tolerant to heat, and originated from established commercial seed companies.

Photo 1 (above) Broccoli Heat trial at OSU vegetable farm: July 20th, 2020

Considerable variation was observed amongst broccoli cultivars for heat tolerance as well as yield. Since no broccoli can be considered the perfect variety for all occasions, and all climates, selecting the best cultivar for growing in western Oregon depends upon production objectives. Growers may consider yield as the main determining factor for variety selection, but this may be at the expense of qualities important for processing. Broccoli hybrids originating from Sakata and Seminis seed companies (e.g. Lieutenant, Castle Dome, Eastern Crown, Eastern Magic) performed well and consistently produced acceptable yield and quality, but may lack other desirable traits such as head exsertion, which allows for ease of field harvesting. Other cultivars with consistent performance across the season, with heads of high quality and acceptable yields, were Kings Crown (Tainong Seed) and Asteroid (HM Clause). These varieties with high performance consistency would also be suitable for smaller scale farmers and backyard growers with little experience with broccoli.

Table 1. Performance of cultivars and breeding lines across diverse criteria: 2020



1	Yield of	crowns	Est. yields of cut heads **for example: "4" score would be more than 8 T/Ac, "3" = 6-7 T/Ac , "2" = 5-6 T/Ac
2	Yield of	2.5in florets	Est. yield weights of usable sized florets >2.5 in (**note: not % of usable sized florets per head)
3	Uniformity of	head	how generally rounded and smooth domed the head is at harvest
4	Uniformity of	bead	how evenly sized the individual beads are on a mature head
5	Uniformity of	color	how evenly colored the surface of the head is
6	Uniformity of	maturation	how evenly the heads will mature through time (i.e. uniform harvest)
7	Head	firmness	how firm the head surface is at maturity (often indicative of resilience)
8	Head	exsertion	how far the mature head protrudes above the vegetative canopy
9	Harvest	early	how short the interval of time is before heads mature
10	Harvest	consistency	how consistently the line performed over all 6 plantings

<u>Impacts:</u> Consumer demand for broccoli has grown dramatically over the last 10 years and continues to expand. During that same 10-year period, Oregon broccoli production has dropped 33%. From a peak of more than 15,000 tons in 1987, only about 5,000 tons is expected to be processed in 2017. This project should increase farm/farmer and processor economic sustainability as the result of increased broccoli production acreage and profitability. It should increase the availability of US-grown broccoli to the consuming public as well as to public schools and federal institutions, resulting in a stronger and more nutritious national and regional food system and contributing to social sustainability.

Table 2. Broccoli head and floret yields

Broccoli lines 2020	Cut Head Yield usable quality Tons/A	Culls T/A	Culls % of Yield	Total Florets all sized Tons/A	Usable Sized Florets < 2.5 inch Tons/A
Asteroid	6.9	0.00	0.0	5.4	3.7
Batory	5.5	2.28	41.4	3.7	2.4
BC1691	7.5	1.64	21.9	5.4	2.8
BC1764	6.9	0.00	0.0	4.7	2.9
BH050	5.9	2.66	45.4	4.3	2.5
BH053	5.6	0.62	11.2	4.0	2.6
BR6991	5.4	2.37	43.9	4.2	3.4
Cascadia	6.1	0.15	2.4	3.6	3.3
Castle Dome	7.6	0.10	1.3	5.2	3.3
Corato F1	7.0	0.00	0.0	4.3	3.3
Darien RZ	7.1	0.86	12.1	4.9	3.1
Eastern Crown	8.7	0.00	0.0	5.7	4.0
Eastern Magic	8.5	0.57	6.7	5.4	4.0
Eiffel	7.8	1.00	12.9	5.6	3.6
Emerald Pride	6.3	0.35	5.5	3.8	2.9
Hancock	6.1	0.60	9.7	4.4	2.6
Imperial	7.8	0.15	1.9	5.8	3.8
Ironman	4.8	3.21	67.2	3.2	2.2
Kariba RZ	5.8	2.74	47.1	3.9	2.5
Kings Crown	6.9	0.00	0.0	4.5	3.5
Lieutenant	6.8	0.30	4.5	4.6	3.3
OCMS 93 x P9	4.8	0.00	0.0	3.0	2.8
Virgo F1	6.2	0.54	8.7	3.9	2.5
Willandra RZ	7.7	0.68	8.8	5.1	3.4

Relation to other research:
Past research to identify heat-tolerant and easy-harvest broccoli varieties was supported by a grant from Western SARE; future work will be supported by the Oregon Specialty Crop Block Grant program.

Research/Extension Progress Report for 2020-2021 Funded Projects
Progress Report for the Agricultural Research Foundation
Oregon Processed Vegetable Commission

Title: Monitoring Soil Moisture and Temperature Impacts on Soilborne *Fusarium* Diseases in Processing Vegetable Cropping Systems

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Cooperator(s):
Two processed vegetable growers within the Willamette Valley

Funding History: Funds were awarded from OPVC in 2019 for $32,409 and in 2020 for $35,000.

Abstract: Sweet corn and snap bean production, amongst other vegetable crops grown in the Willamette Valley of Oregon, are impacted by soilborne diseases caused by *Fusarium* species. The decline in sweet corn yields due to Fusarium crown and stalk node rot as well as root rot in snap bean and sweet corn are well documented in the valley. The widespread presence and increasing disease pressure from *Fusarium* in the soils of western Oregon compels growers to define optimum management practices in order to minimize the impact from *Fusarium* diseases. It may be possible to reduce *Fusarium* diseases and their associated losses in sweet corn and snap bean fields by connecting the physical properties of the soil environment (temperature and moisture) with the levels of *Fusarium* which could then be used to refine cropping practices such as irrigation or crop rotation. We hypothesize that the incidence of *Fusarium* root disease can be predicted by soilborne *Fusarium* populations, soil temperature, and soil moisture levels. Our objectives in this project are to 1) Evaluate the soil conditions as a predictor of *Fusarium* levels in the soil and 2) Evaluate the *Fusarium* disease incidence and severity of crops in monitored sweet corn and snap bean fields.

Key Words: *Fusarium*, sweet corn, snap bean, soil moisture, soil temperature

Objective(s):

Objective 1: Evaluate soil conditions (temperature and moisture) as predictors of *Fusarium* levels in the soil.

Objective 2: Evaluate *Fusarium* disease incidence and severity of crops in monitored sweet corn and snap bean fields.

Procedures:

Objective 1. Evaluate soil conditions (temperature and moisture) as predictors of *Fusarium* levels in the soil.

The number of Fusarium colony forming units per gram of oven-dried soil were very high overall.

We monitored soil temperature and soil moisture throughout the growing season and plan to continue over the fall, winter, and spring, similar to what was done during 2019. Each field had a total of four TDR-315 sensors installed, a pair each at 6” and 12” below the soil surface. The probes are connected to data loggers located at recording stations within the fields, and set to take a reading every 30 minutes. Data were downloaded at regular intervals and used to describe overall field conditions throughout the season. Unfortunately, due to defective sensors, some data are missing, and replacement sensors will be installed this winter. We also completed a basic soil health assessment that included physical, chemical and biological properties of each field’s soil as reference for soil moisture and temperature data and their potential relationship to *Fusarium* levels.

Fusarium population levels in fields were determined in representative soil samples collected approximately every two weeks during the summer cropping months, and monthly thereafter (except for Jan – Feb 2020 while the OPVC budget crisis was sorted out). Twenty 12-inch soil cores were collected in a systematic manner across each of four blocks in each commercial field site. During 2019, two of the sites were cropped with sweet corn and the third site was snap bean; these three fields were subsequently rotated to different crops prior to harvest in 2020. Soil cores collected within each block were combined, bagged and returned to the lab. Soil samples were air-dried until the soil was dry enough to sieve. Three 10-gram subsamples for each block of each field on each sampling date were removed and evaluated for *Fusarium* species by plating serial dilutions onto a *Fusarium*-selective medium. Two to four additional 10-gram subsamples were oven-dried in tins placed at 100°C for 48 hours in order to determine the soil dry weights used for calculating the number of *Fusarium* colony forming units per gram of oven-dried soil. Soil processing and data analyses are still under way for the 2020 sampling.

Objective 2. Evaluate *Fusarium* disease incidence and severity of crops in monitored sweet corn and snap bean fields.

Ten plants were carefully dug from each block (40 plants per field) from each of the monitored fields on each date of plant sampling. Plants were returned to the OSU campus where soil was washed from root balls in the laboratory. The incidence of rot and percentage of the affected underground portion of each plant with rot were determined in visual assessments conducted by Ocamb. We report only on the plants sampled in 2020.

<u>Accomplishments:</u>
Objective 1. Evaluate soil conditions (temperature and moisture) as predictors of *Fusarium* incidence.

Soil physical and biological factors varied across sites, as did the fluctuations in soil temperature and moisture which seem to be related to cropping system. Also, the number of Fusarium colony forming units per gram of oven-dried soil were very high overall.

Comprehensive soil health testing results were accomplished for each field in 2020. Physical, chemical and biological soil characteristics were measured and some key indicators are reported in Table 1. Soil pH was similar in both corn fields and higher in the field planted to beans as it was limed prior to the 2020 cropping season. Comparing the soil particle composition, we notice that Fields 1 and 2 are a similar mix of sand/silt/clay while Field 3 has significantly more clay, and due to both the clay levels as well as site location is likely to have increased periods of winter flooding and prolonged high soil moisture levels in the spring. The amount of potentially mineralizable nitrogen (PMN) was highly variable at the time of sampling and could be due to the effects from timing of sampling as well as the amount and quality of crop residue remaining near the soil surface. The final two soil tests listed for active carbon and respiration describe some aspects of microbial function in the soil. Active carbon is seen as a measure of readily available ‘food’ for microbes, whereas respiration reports the amount of CO_2 evolved from the soil in 24 hours which may indicate the size of the microbial population.

Table 1. Soil Health Testing Results

Field	pH	Sand/Silt/Clay	Potentially Mineralizable Nitrogen (PMN)	Active Carbon	Respiration 24 hours
		(%)	(ppm NO3-N at sample)	(ppm)	(µg CO2-C/g dry soil)
Field 1	7.5	14/66/20	2	235	52
Field 2	6.3	19/63/18	28	324	37
Field 3	6.3	24/44/32	17	616	54

Soil monitoring (Figure 1) showed that Field 1 and 2 had similar overwintering moisture levels while Field 3 had much higher moisture content (as expected based on soil type and location). Interestingly, Field 1, which had grass seed over the summer of 2020, had much less variation in soil temperature throughout the year. The moderate soil temperature and moisture levels may provide ideal conditions for certain soil pathogens over a longer time period than in other systems where we see periods of low soil moisture or higher soil temperatures (July-Sep for Fields 2 and 3). But *Fusarium* spp. are adapted to for survival under more extreme conditions like heat, drought, and flooding, and may even flourish under these conditions relative to other soil microbiota which may be suppressed by the environmental extremes.

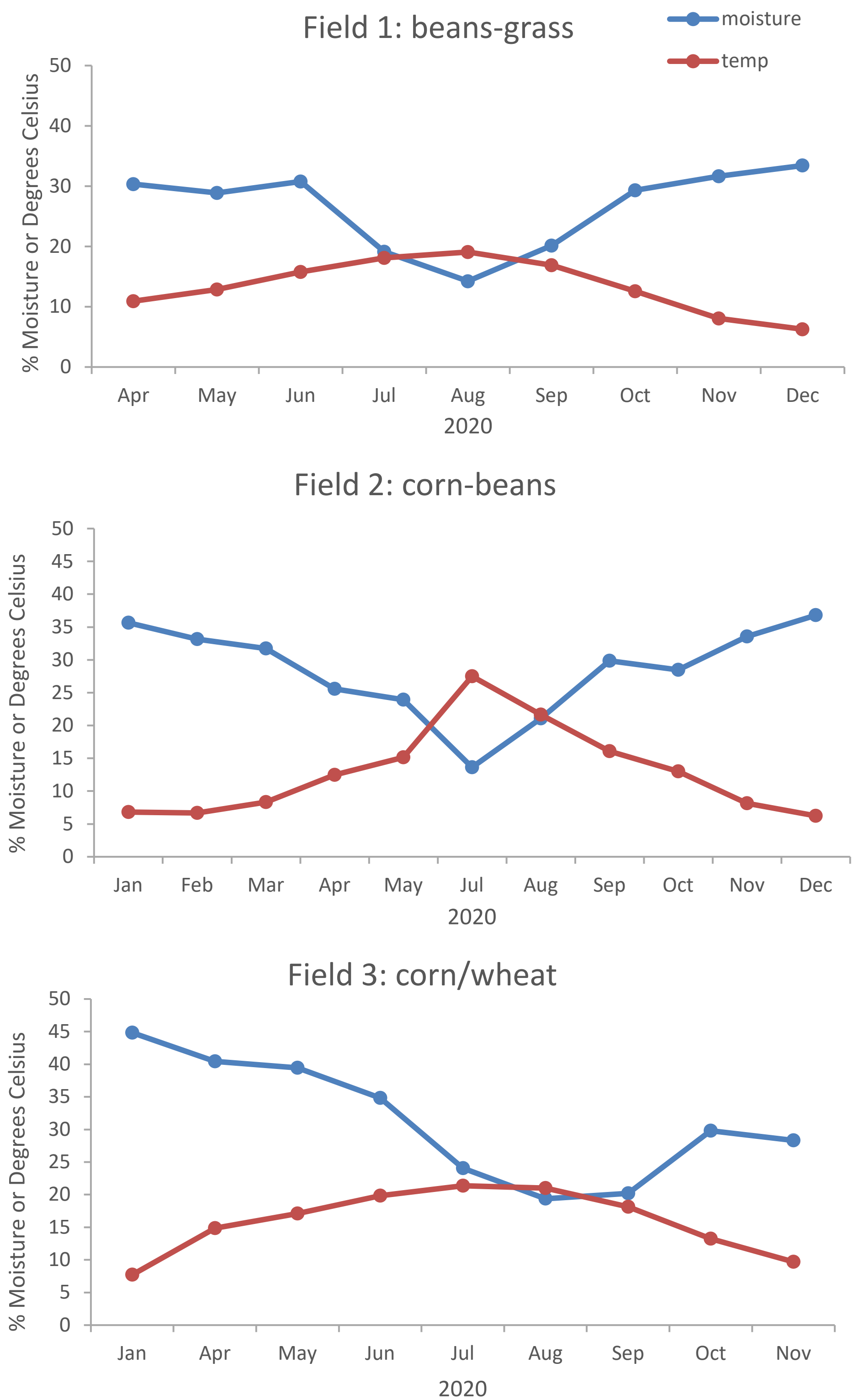

Figure 1. Average soil moisture and temperature in Field 1 (panel A), 2 (panel B), and 3 (panel C) in 2020 by month.

We are reporting the colony forming units of *Fusarium* species recovered from dilutions of 10^{-3} (Table 2) and 10^{-4} (Table 3). The averages from the 10^{-3} dilution levels have lower overall variance among the sample dates for the respective fields, allowing for a more robust comparison among the sampling times within each field. However, the 10^{-4} dilutions' numbers offer a more precise measurement of actual *Fusarium* levels in the soil assayed. *Fusarium* numbers were very high overall, especially in Field 3, which was planted to sweet corn during 2019 and then rotated to wheat in 2020 (Tables 2 and 3). Typically, *Fusarium* colony forming units per gram of oven-dried soil of bulk soil samples associated with diseased and disease-free fields are generally <10,000 and <2,000 CFU/g soil, respectively. The high numbers of *Fusarium* CFUs could explain the relatively severe disease that we observed in both sweet corn and snap bean during the 2019 growing season and then in the subsequent rotation crops during 2020.

Table 2. The number of *Fusarium* colonies/g of oven-dried soil that were obtained in 10^{-3} serial dilutions of soil samples collected on each date.

Date sampled	Mean number of *Fusarium* colony forming units (CFU/g soil)					
	Field 2: Sweet corn 2019/snap bean 2020 [z]		Field 3: Sweet corn 2019/spring wheat 2020 [z]		Field 1: Snap bean-2019/grass seed 2020 [z]	
25-Jun-19			157,407	b		
11-Jul-19	68,437	e	228,125	a	34,503	e
25-Jul-19	49,568	f	237,195	a	60,597	d
8-Aug-19	66,486	e	226,837	a	65,861	d*
22-Aug-19	89,381	cd	181,899	b	76,385	cd*
5-Sep-19	99,112	bcd*				
19-Sep-19	85,044	d*	239,748	a*	141,493	b*
3-Oct-19	96,154	bcd*				
3-Nov-19	109,118	b*	255,692	a*	174,556	a[1]
5-Dec-19	101,201	bc*	179,016	b*	131,765	b
18-Mar-20	65,487	e*	228,667	a[2]	91,159	c
20-Apr-20	129,664	a*	227,653	a	131,579	b

[z] Within each column, means labeled with the same letters are not significantly different (P=0.05) as determined by Fisher's LSD test.

* Soil samples were collected after harvest.

[1] sown to grass for seed.

[2] sown to spring wheat.

Table 3. The number of *Fusarium* colonies/g of oven-dried soil that were obtained in 10^{-4} serial dilutions of soil samples collected on each date.

Date sampled	Mean number of *Fusarium* colony forming units (CFU/g soil)					
	Field 2: Sweet corn 2019/snap bean 2020 [z]		Field 3: Sweet corn 2019/spring wheat 2020 [z]		Field 1: Snap bean-2019/grass seed 2020[z]	
25-Jun-19			358,025	bc		
11-Jul-19	138,643	abc	640,625	a	76,023	d
25-Jul-19	103,746	bc	378,049	b	125,373	bcd
8-Aug-19	97,297	cd	396,166	b	87,613	cd*
22-Aug-19	91,445	cd	183,976	d	67,055	d*
5-Sep-19	94,675	cd*				
19-Sep-19	105,572	bc*	318,612	bcd*	250,746	a*
3-Oct-19	91,716	cd*				
3-Nov-19	152,941	ab*	379,310	b*	301,775	a[1]
5-Dec-19	165,165	a*	229,508	cd*	164,706	b
18-Mar-20	50,147	d*	403,333	b[2]	146,341	bc
20-Apr-20	140,673	abc	450,161	b	154,971	b

[z] Within each column, means labeled with the same letters are not significantly different (P=0.05) as determined by Fisher's LSD test.

* Soil samples were collected after harvest.

[1] sown to grass for seed.

[2] sown to spring wheat.

Objective 2. Evaluate *Fusarium* disease incidence and severity of crop plants in monitored sweet corn and snap bean fields.

Fusarium rot of the roots of wheat, grass seed, and snap bean plants was present in the respective fields that were monitored during 2019-2020. Rot of the adventitious root system of wheat and grass for seed was severe before harvest. Snap bean plants exhibited generally high levels of root rot and virtually all plants sampled had lesions on the lower stem by the time that flower buds were developing on the bean plants.

The grass seed plants (Table 4) that were planted in Field 1 following a snap bean crop exhibited severe root rot by the latter half of June, and root rot progressed as the seed crop matured. A subset of the grass plants sampled on 24 Jun were also examined directly for *Fusarium* presence on the roots via isolations from symptomatic roots. Six plants from each block collected on this date were plated onto a *Fusarium*-selective medium and 21 of the 24 plants assayed were infected with *Fusarium*. Ocamb has informally observed root rot over the past two decades in numerous fields of non-irrigated grass seed crops, which has brought forth many questions and some concerns about the ability of *Fusarium* populations to increase and survive in association with the characteristic fibrous root system (many roots that are similar in size) of grass seed plants. The majority of the individual plant's root mass appears to die and then subsequently regrow from the crown tissues generally twice a year in non-irrigated perennial grass seed fields in western Oregon.

Table 4. 2020 Field 1 - *Fusarium* disease ratings of grass seed crop (snap bean in 2019)

Date	Average overall root rot (%)[z]
24-Jun-20	62 b
8-Jul-20	80 a

[z] Within each column, means labeled with the same letters are not significantly different (P=0.05) as determined by Fisher's LSD test.

The snap bean plants (Table 5) that were planted in Field 2 subsequent to a 2019 sweet corn crop exhibited root rot long before the beans commenced flowering. Three-quarters of the bean plants had stem lesions even at the seedling stage (cotyledons and emerging first trifoliate were visible on the 8 Jul sampling), while about half the root system of individual plants had visible rot on this first plant sampling date. Disease was prominent when plants had 2 to 3 trifoliate leaves on 22 Jul and flower bud development on 5 Aug samplings. Nearly all of the bean plants exhibited lesions on the lower portion of the main stem by 22 Jul, and the stem lesions averaged slightly over three-quarters of an inch in length by this date.

Table 5. 2020 Field 2 - *Fusarium* disease ratings of snap bean (sweet corn in 2019)

Date	Mean % primary root with rot[z]	Average overall root rot (%)[z]	Incidence of lesions on stem base[z]	Length of stem lesion (cm)
8-Jul-20	39 b	47 b	75 b	-
22-Jul-20	55 a	63 a	98 a	1.95
5-Aug-20	55 a	63 a	98 a	1.95

[z] Within each column, means labeled with the same letters are not significantly different (P=0.05) as determined by Fisher's LSD test.

The spring wheat plants (Table 6) that were planted in Field 3 during 2020, following sweet corn in 2019, had minimal root rot on the first sample date but nearly a quarter of the plants had rot of the mesocotyl tissues. By the next sampling date two weeks later, nearly half of the root system on average was rotted and all of the plants' mesocotyl portions exhibited severe rot. A subset of the wheat plants collected on 24 Jun were also examined for direct *Fusarium* presence on the roots and mesocotyl via isolations onto a *Fusarium*-selective medium. Six plants from each block were assayed and all were found infected with *Fusarium*.

Table 6. 2020 Field 3 - *Fusarium* disease ratings of spring wheat (sweet corn in 2019)

Date	Mean % primary root with rot[z]	Average overall root rot (%)[z]	Incidence of lesions on mesocotyl[z]	Mean % mesocotyl with rot
24-Jun-20	17 b	11 b	23 b	-
8-Jul-20	94 a	56 a	100 a	64

[z] Within each column, means labeled with the same letters are not significantly different (P=0.05) as determined by Fisher's LSD test.

Impacts: We anticipate that the data from continual soil monitoring will be the start of a database that will identify potential conditions under which *Fusarium* populations will be higher and the potential risk for disease will be present, posing an increased likelihood of crop loss. In the short term, we can provide grower-cooperators with crop health observations and soil/soilborne descriptive data. We can also begin to characterize the overwhelming presence of *Fusarium* across the Willamette Valley and build support for a broader research effort to address the problem. We anticipate the need to continue soil and plant health monitoring over three seasons to gather data under a wide variety of environmental conditions to use in the development of a predictive risk model. In the longer term, these results will aid growers and field agronomists to adapt crop rotation, irrigation scheduling, and crop disease scouting intervals as needed to minimize crop losses.

Relation to Other Research: Both Buckland and Ocamb work across multiple industries and crop groups that can suffer losses to *Fusarium* and other soilborne pathogens. Often, growers that struggle with crop loss in processed vegetables also grow other crops susceptible to *Fusarium* disease losses and often struggle with other soilborne diseases. Therefore, we have recruited support from the Specialty Seed Growers of Western Oregon to monitor additional fields and are also actively working to secure grant funding to complete a replicated field trial that would test the impacts of soil health management strategies to mitigate soilborne disease presence (*Fusarium* and other pathogens).

Acknowledgements: We would like to thank the Oregon Processing Vegetable commission for the support they provided and also many thanks to Tim Flodquist, Mariah Dietrich, Taylor A. Bates, and Ann Rasmussen for their assistance with collection of plants and soil samples as well as conducting the soil dilution series.

OPVC CONTINUING PROJECT REPORT: PROJECT YEAR: *2019*

1. OPVC REPORT COVER PAGE (maximum 2 pages)

OPVC Project Number:

Project Title: Green Bean Breeding and Evaluation

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Total project request (all years):

Year 1: $29,566 breeding
$7,569 processing
$37,135 total

Contributions from the OSU breeding program

Year 1: $19,639

Other funding sources: None

2. EXECUTIVE SUMMARY (ABSTRACT): Oregon is a major producer of processed green beans, and cultivars are needed that are adapted to western Oregon. The types that have traditionally been used are the bush blue lake (BBL) green beans with high yields, excellent processing quality. On the other hand, they need improvement in plant architecture, and disease resistance (especially to white mold and root rots). Further complicating the breeding process, BBL types are genetically isolated from other green beans which it means that it is difficult to introgress traits from other types of green beans. The primary objective of the OSU green bean breeding program is to develop high yielding and high quality BBL green beans with high levels of white mold resistance. In 2019, two preliminary yield and processing trials of OSU experimental advanced lines were conducted. The first had 36 check and experimental lines of the full sieve to whole bean pod size class, while the second consisted of 61 whole to full sieve checks and experimental lines. A third trial with 25 entries from commercial seed companies in addition to five checks and five OSU extra- very-fine experimental lines were also grown and evaluated. Two white mold disease evaluations were conducted in the field. One was of the remnant stands in the two preliminary yield trials, the other was a replicated fall evaluation of white mold disease. In the early generation nursery, about 700 plots of populations and lines at various stages of inbreeding were grown. In these nurseries, 289 plots were massed and 32 populations were advanced by single pod descent.

3. FULL REPORT (no maximum)

3.a. BACKGROUND Green beans grown for processing in the Willamette Valley contribute about $14 million to the Oregon state economy each year. The industry produces a high quality product with the unique flavor, color, and appearance based on the Bush Blue Lake (BBL) class of green beans. The growing environment in Western Oregon is different from any other green bean production area in the United States. Developing productive varieties that are adapted to this area requires the attention of a substantial breeding effort in Western Oregon. BBL green beans have higher yield potential than those typically bred for the Midwestern U.S. They also have unique flavor and quality characteristics that are hard to match. Another factor contributing to pod quality is that BBL beans typically have the lowest fiber pods (equivalent to Romano beans and much less than most Midwest and fresh market types). A tradeoff of the higher yields is that BBL beans allocate fewer resources to vegetative growth, which can compromise plant architecture and lead to lodging when pod loads are heavy. Lodging and low fiber content contributes to susceptibility to white and gray mold of BBL types.

White mold disease caused by *Sclerotinia sclerotiorum* is a pathogen of more than 400 species of plants including snap bean. Not only does it cause yield loss, but it can adversely affect pod quality and cause rejection of whole lots at the cannery if moldy pods in the lot exceeds 3%. The growing environment in western Oregon is favorable to disease development, especially during the fall when cooler and higher humidity conditions persist. The disease is mainly controlled by fungicide application, which requires precise timing and can be expensive especially if two sprays are required. Biological control also has potential but has not been implemented on a wide scale.

Genetic resistance is the most efficient means of achieving control of white mold disease. Incorporating resistance to white mold transfers the cost of controlling this disease from external inputs to that of the seed, thereby reducing costs to growers and improving quality in the processing plant. While partial resistance is known there are challenges to successful deployment. First, the genetic factors conditioning resistance generally have small individual effect and are strongly influenced by the environment (in this respect, white mold resistance shows many similarities to the genetic control of yield). A number of resistance factors are known but these are in different varieties, many of which are not snap beans. Our recent work involving meta-QTL analysis revealed 17 factors contributing to resistance distributed throughout the bean genome, and in new research, we found in a genome wide association study that 39 regions of the bean genome confer resistance in panels of 146 and 376 snap bean cultivars. We think that these factors are additive – the more resistance factors a bean variety has – the more resistant that variety will be. The challenge is in combining multiple sources of resistance from different genetic backgrounds into the same variety. Screening in the field is expensive and time-consuming so recombination is best facilitated by the use of molecular markers for selection. In addition to physiological resistance, avoidance traits such as maturity, growth habit, lodging, flower number and retention, and canopy porosity influence the overall level of resistance. This requires an approach to plant breeding that emphasizes field scale breeding using replicated plots along with marker assisted selection.

Our program has focused on using several resistance sources. These can be placed into two groups: resistance factors derived from common bean and resistance factors from the related species, scarlet runner bean. Of the common bean germplasm sources, NY 6020 is a snap bean developed by the snap bean breeding program at Cornell University. It has been well characterized genetically and we know that it has two relatively large resistance factors that have molecular markers for selection. This has been the primary focus of our white mold breeding program. Recently, we have screened additional snap bean lines and have discovered several which have useful levels of resistance. We have begun crossing to these to introgress from these resistance sources.

The NY 6020 derived lines are most advanced in the program. With this particular form of resistance we have observed a negative correlation between disease resistance and yield. In the lasts round of crosses, lines with good white mold resistance generally yielded 75 – 85% of susceptible check cultivars. We are now screening the next cycle of crosses that combine this resistance with other sources, while selecting for high yield. In particular, we have a number of crosses to the wax bean 'Unidor' which has shown good white mold resistance. Another parent that we are working with is WM904-20-3, a line we derived from crosses to scarlet runner bean. A third and potentially bountiful source of resistance genes is the dry bean A195. We have created populations from crosses to susceptible snap beans, and these need to be evaluated for resistance, increased, and placed into replicated yield trials. Additional crosses are in earlier generations, and need to be moved along the pipeline. There are over three-hundred advanced lines that need to be evaluated for yield and quality as well as disease resistance.

While the main focus of the program is on improving white mold resistance of the BBL types, other traits including yield, maturity, growth habit, pod size, shape and color, and processing characteristics need to be maintained or improved.

3.b OBJECTIVES

1. Breed improved Bush Blue Lake green bean varieties with:
    a. White and gray mold resistance
    b. Root rot resistance
    c. Improved plant architecture
    d. High economic yield
    e. Improved pod quality (including straightness, color, smoothness, texture, flavor and quality retention, and delayed seed size development)
    f. Tolerance to abiotic stresses

3.c. SIGNIFICANT FINDINGS

- Two preliminary yield trials were conducted about two weeks apart. The first trial had 36 entries while the second had 61 for a total of 97 lines evaluated in 2019. Selected lines were taken to the pilot plant for processing, freezing and subsequent evaluation of product.
- A trial with 35 commercial entries, checks and OSU experimental lines was also evaluated for yield, and quality and product was frozen for processing evaluation.
- Five extra-fine to very-fine experimental snap bean lines 7046, 7047, 7048, 7049 and 7050 were evaluated for the 3rd year in the commercial trial.
- Of the ~700 plots grown in the early generation nursery, 98 were discarded and 289 were harvested by massing all plants in the plot and 32 populations were advanced by single pod descent.
- White mold ratings were obtained on the two preliminary yield trials although disease intensity varied across the field.
- A replicated fall white mold trial with 136 advanced lines was also evaluated.
- In the fall white mold trial, 33 lines with high levels of resistance were identified, and no negative association between yield and resistance was observed.

3.d. METHODS

Varietal Development: The program made crosses among elite lines and the best white mold resistant lines during the winter of 2019 and the F_1s were grown in the field. Breeding lines at various stages of development were evaluated in the field for selection and advancement. Pedigree and single seed descent breeding methods were used to advance and select early generation materials. Seed increase, roguing, and sub-line maintenance of the most promising lines continued. For cultivar maintenance, individual plants within each plot were assessed for presence of any off type variation (strings, oval pods, high fiber pods, off color pod, etc.) and these plants were removed from the plot prior to seed harvest.

Variety Trials: Two preliminary trials for OSU advanced lines were grown. The first planted 13 May had 35 advanced lines and one check cultivar. Plots were 20' in length on 30" rows. Entries were unreplicated so two 5' sections of row were harvested separately to provide a measure of field variability. A second preliminary trial with 59 advanced lines and two check cultivars was planted 28 May. This trial was also unreplicated and was treated in a similar manner to the first trial. Lines were evaluated for growth habit, and yield. Graded samples were evaluated for pod size distribution, smoothness, straightness, color and taste. Samples were processed and frozen for evaluation of the processed product. Samples were evaluated at the Food Science Pilot Plant 8 November, 2019 and then displayed in a cutting at the PNVA meetings in Kennewick, WA on 20 November, 2019.

A trial of commercial entries was planted 19 June with five checks (OR91G, OSU 5630, Sahara, Redon and Crockett) five very- to extra-fine OSU experimental lines and 25 commercial entries from four companies. Plots consisted of a single 20-foot row from which 5-foot sections were harvested two or three times, two – three days apart. Entries were replicated six times, with four reps used for harvest and evaluation. Lines were evaluated as described for the preliminary trials and samples were processed and frozen for evaluation of the processed product. The commercial bean trial is not directly supported by OPVC, but solely through fees charged to commercial companies.

Breeding for White Mold Resistance: Advanced lines were evaluated for white mold resistance in a replicated fall trial. Plots were established in a field with a history of severe white mold. At flowering, plots were watered daily for 30 minutes in the evening to increase leaf wetness duration. Plots were read at harvest maturity with data collected on percent incidence (proportion of plot infected) and severity (proportion of infection on individual plants using a 1 – 9 scale where 1 indicates no infection and 9 is most of the plant with symptoms). A disease severity index was calculated based on the geometric mean of incidence and severity.

3.e. RESULTS & DISCUSSION

Varietal Development: In 2019, we grew about 800 plots in the early generation nursery. Plots consisted of populations and lines at various stages of inbreeding. We also grew out the SnAP (Snap bean association panel) consisting of 376 snap bean cultivars to evaluate for pod and leaf color and photosynthetic capacity. In the early generation nurseries, 289 plots were massed, and 32 populations were advanced by single pod descent (bulking a single pod from each plant in the population). The 289 massed plots represent the next wave experimental lines advancing in the program to be funneled into replicated yield and disease trials. In 2019, we evaluated 97 of these lines for yield and quality and 149 for white mold resistance.

Yield Trials: For the first preliminary trial, most experimental entries fell into the 5 to 6 (full) sieve classes (50-60% 1-4 sieve) with four lines judged to be more of a 4 or 4-5 sieve bean (Table 1). Yield of OR5630 was 8.5 T/A (unadjusted) and was exceeded by 30 of the experimental lines. Around 15 lines showed oval or heart shaped pods and were rejected along with lines that had lighter pod color compared to OR 5630 (Table 2).

In the second preliminary trial, two checks (OSU 5630 and Sahara) were grown along with 59 advanced lines. The majority of these were 5-6 sieve but 18 produced predominantly 4 sieve or 4-5 sieve pods, and one fell into the 2-3 sieve range. OSU 5630 yielded 11.4 T/A but was harvested late, and when adjusted to 50% 1-4 sieve, had a yield of 9.4 T/A. Yield for Sahara was low compared to how this cultivar usually performs at 6.1 T/A (unadjusted; yields of 4 sieve and smaller cultivars are not adjusted in these trials). Yields of experimental lines was also lower in this trial, ranging from 4.9 to 12.1 T/A (Table 3). In March, the OSU Vegetable Research Farm was flooded by the Willamette River. A few days before the event, Diuron herbicide was applied to hazelnuts on the farm. The flooding moved soil particles with herbicide into the land on which the bean plots were planted, which resulted in reduced growth, particularly in low lying regions of the field. This effect was particularly noticeable in the second trial and the effects can be seen in table 3 where yields through the beginning and middle part of the field are lower than those at the ends. Fewer entries in this trial showed unacceptable pod traits (Table 4).

Commercial Green Bean Trial:

Five commercial lines submitted for trial were full sieve (Table 5), but the other ranged from extra fine (2 sieve) types to whole bean (3 & 4 sieve) types along with two Romano beans. Yields ranged from about 4.2 – 13.8 T/A (unadjusted) with Romano cultivars having the highest yields (Table 6). OSU 5630 yielded 9 T/A (adjusted) with several commercial lines exceeding its yield. This was the third year for SV9203GV, a line with BBL attributes, and it continued to show relatively high yields. This trial was in a different location on the farm that was less affected by flood induced herbicide movement. Raw product evaluation notes are found in table 7 and seed size development notes during successive harvests are in table 8. At the November evaluation of processed product at the OSU Pilot Plant, lines in the commercial trial were rated by 11 evaluators on a 0 – 2 scale where 0 = discard, 1 = maybe keep and 2 = definitely save (Table 9). Ratings were based primarily on appearance and flavor. In addition to average score, percent in each of the rating categories (shown as "good", "ok" and "bad") were calculated.

Of the five OSU extra- to very-fine experimental lines in the commercial trial, yields ranged from 4.2 – 7.8 T/A compared to 4 T/A for Redon and 8 T/A for Crockett (Table 6). OSU7050 is an extra-fine type while OSU7049 would be classified as very-fine, and the other lines fall between these two poles. Two (OSU7047 and OSU7049 had pod color equivalent to Redon, while the others had superior pod color (Table 7). In the processing evaluations (Table 9), OSU7047 and OSU7048 were most highly rated by evaluators and were comparable to Crockett in terms of quality and appearance. The majority of evaluators considered all lines to be ok to good. The extra fine materials have not been tested for white mold resistance, but based on pedigree, are not expected to possess resistance to any significant degree.

White Mold Trial: Environmental conditions favored disease development in the first and second preliminary trials although disease was not uniform throughout the nurseries. Therefore, one should regard high incidence and severity as evidence of susceptibility but lack of disease does not necessarily mean resistance due to the possibility of escapes (Table 10). Disease development conditions were more uniform in the fall white mold trial in addition to the trial being replicated, so the data should be a better indicator of resistance. Using this data (Table 11) and that obtained from the yield trials, a set of lines were selected that did not differ significantly from the partially resistant checks (Cornell 501 and NY6020-4), but were significantly different from the susceptible checks (OR91G and OSU5630). Out of 136 lines evaluated, 33 (24%) were retained for testing next year (Table 11). This list will be collated with yield and quality results to identify those with good yields and quality. We plotted disease severity index vs. adjusted yield to see if any relationship could be found between these two parameters. No association was observed, which is good news in that it appears that the former negative relationship between disease resistance and yield has been overcome.

4. BUDGET DETAILS

BUDGET NARRATIVE

1) Breeding (Myers)	
Salaries and benefits	
Faculty Research Assistant	$17,150
OPE @ 69.48%	$11,916
Wages and benefits	
Student Wages	$0
OPE @11%	$0
Supplies	$500
Travel	$0
Land and greenhouse rental	$0
Total	$29,566
2) Processing Evaluation (Yorgey)	
Salaries and benefits	
Senior Faculty Research Assistant	$2,800
OPE @ 61.45%	$1,721
Wages and benefits	
Student wages	$1,575
OPE (@ 11%	$173
Supplies	$1,300
Total	$7,569
Grand Total	**$37,135**

Contributions of the OSU breeding program	
Student Wages	$8,246
OPE @ 11%	$907
Supplies	$500
Travel	$86
Land and greenhouse rental	$9,901
Total	$19,639

Request to OPVC: Salary and OPE is requested for a full time faculty research assistant who will commit 40% FTE to green bean breeding. A senior faculty research assistant will commit approximately 0.05 FTE to processing of entries from green bean trials; the remainder of salary to come from other sources. Undergraduate student wages of $1,575 are requested for the processing program with 11% OPE. OPE for the FRA is 69.48% and that of the SFRA is 61.45%. $500 is requested for materials and supplies for field work (includes stakes, tags, envelopes, paper bags, etc.).

Contributions of the Vegetable Breeding Program: Undergraduate student wages of $8,246 are estimated for the breeding program with 11% OPE. An additional $500 is required to cover field and greenhouse materials and supplies expenses (fertilizer, pots, labels, stakes, tags, crossing supplies). To cover transport of samples from the farm to campus for processing, $86 is estimated. Land use rental at the OSU Vegetable Research Farm consists of five acres at $1,322 per acre and greenhouse rental of 2,123 ft2 at $1.55 per square foot.

Table 1. Performance of first preliminary green bean trial, May 13 planting, OSU Vegetable Research Farm, Corvallis, 2019.[z]

Line	Days to Harvest	Est. Sieve Size	Stand	1.0-2.0	3.0	4.0	5.0	6.0	%1-4 Sieve	Av Tons/Acre	Av Adj Tons/Acre[x]
5630	72	5	74	9.0	14.6	33.7	33.7	9.0	57.3	8.5	9.2
7065	73	5	127	12.9	11.8	23.7	36.6	15.1	48.4	8.2	8.1
7066	74	6	149	11.1	12.7	23.0	31.0	22.2	46.8	11.6	11.2
7067	73	4	138	12.6	16.7	40.4	27.8	2.5	69.7	11.3	11.3
7069	74	6	151	7.5	8.3	26.7	50.8	6.7	42.5	11.3	10.5
7073	72	5	151	9.7	12.6	28.2	39.8	9.7	50.5	8.7	8.8
7080	73	5	166	13.9	10.9	27.7	41.6	5.9	52.5	9.2	9.5
7092	72	5	146	14.3	11.1	23.8	38.1	12.7	49.2	6.2	6.1
7101	73	5	173	10.6	13.5	43.3	22.1	10.6	67.3	9.4	11.0
7107	72	5	177	10.0	9.3	20.0	46.4	14.3	39.3	13.4	12.0
7113	72	5	167	11.3	13.5	35.3	37.6	2.3	60.2	11.7	12.9
7118	73	5	179	9.4	11.1	36.8	39.3	3.4	57.3	10.0	10.7
7120	72	5	158	12.4	12.4	26.4	43.8	5.0	51.2	10.7	10.8
7137	73	4	165	6.2	9.7	55.8	27.4	0.9	71.7	9.9	9.9
7144	73	4-5	157	6.7	8.7	51.9	31.7	1.0	67.3	9.1	10.7
7152	73	5	180	7.6	9.2	27.5	44.3	11.5	44.3	11.9	11.3
7153	73	4	168	9.0	14.0	60.0	17.0	0.0	83.0	9.1	9.1
7162	73	4-5	170	6.9	6.9	27.6	44.8	13.8	41.4	7.8	7.2
7165	74	6	162	10.4	10.4	14.9	26.9	37.3	35.8	11.8	10.2
7194	74	6	178	6.2	10.5	24.1	43.8	15.4	40.7	14.4	13.0
7195	74	6	147	9.4	8.8	24.4	46.9	10.6	42.5	14.3	13.2
7207	74	6	167	12.2	12.2	29.6	37.4	8.7	53.9	10.3	10.7
7223	74	6	155	6.0	6.8	17.9	44.4	24.8	30.8	10.5	8.4
7227	74	6	164	11.5	10.6	20.4	37.2	20.4	42.5	10.2	9.4
7232	74	6	174	6.4	8.3	25.5	46.5	13.4	40.1	13.6	12.2
7235	73	5	162	6.3	8.7	54.0	30.2	0.8	69.0	11.2	13.4
7238	72	5	168	13.1	9.0	22.9	42.7	12.3	45.0	11.0	10.4
7258	74	6	155	10.9	10.1	23.9	48.6	6.5	44.9	12.0	11.4
7264	73	5	82	8.7	13.0	39.1	36.5	2.6	60.9	10.1	11.2
7269	73	5	138	9.3	14.8	37.0	35.2	3.7	61.1	9.8	10.9
7279	74	5-6	132	8.3	11.6	33.1	41.3	5.8	52.9	10.8	11.1
7281	73	5	153	6.9	7.5	20.8	46.5	18.2	35.2	14.5	12.3

Line	Days to Harvest	Est. Sieve Size	Stand	1.0-2.0	3.0	4.0	5.0	6.0	%1-4 Sieve	Av Tons/Acre	Av Adj Tons/Acre[x]
7293	72	5	129	9.4	12.2	31.7	43.2	3.6	53.2	12.3	12.7
7314	72	5	116	10.4	14.2	40.3	32.1	3.0	64.9	11.8	13.6
7323	72	5	111	9.6	12.3	31.6	37.7	8.8	53.5	10.2	10.5
7327	72	4	139	9.4	12.2	31.7	43.2	3.6	53.2	8.5	8.5
7333	72	5	109	12.6	10.7	19.4	35.9	21.4	42.7	9.6	8.9
LSD 0.05										2.8	2.5

[z]Mean of 3 replications; subplots of 5' were harvested from 18' plots in rows 30" apart.
[y]Percent calculated as % of total of 1-6 sieve beans.
[x]Tons/Acre adjusted to 50% 1-4 sieve for full and 5 sieve beans; yields for smaller sieve lines were not adjusted.

Table 2. Notes on first preliminary green bean trial, May 13 planting, OSU Vegetable Research Farm, Corvallis, 2019.

Entry	Pod Length (cm)	Pod Straightness[z]	Pod Cross Section[y]	Pod Smoothness[z]	Pod Color[x]	Notes[w]
5630	17.0	7	r	7	7	3: s, 4: mod, 5: mod, 6: seedy
7065	18.5	5	r	5	5	3: beg, 4: mod, 5: mod, 6: seedy
7066	16.0	3	r-cb	1	5	Extreme 2 tone pods
7067	15.0	5	r-ov	6	4	3: s, 4: mod, 5: m-seedy, 6: seedy
7069	13.0	7	r-cb	5	5	Shorter pods otherwise ok bean
7073	13.5	6	r	6	5 (varies)	3: beg-s, 4: mod, 5: m-seedy, 6: m-seedy
7080	15.5	8	oval-r	8	5	3: s, 4: s-m, 5: mod, 6: seedy-very seedy
7092	13.0	6	r/oval	6	5 (varies)	3: s, 4:s, 5:m, 6: m-seedy
7101	15.0	8	r	8	4	3: s, 4: s-m, 4: seedy, 6: seedy-very seedy
7107	16.0	6	r	7	7	3: s, 4: mod, 5: mod, 6: m-seedy
7113	16.5	4	r	4	4~6	3: beg, 4: s-m, 5: mod, 6: seedy-very seedy, spiny
7118	14.0	8	r; a few oval	8	8	3: beg, 4: s, 5: mod, 6: seedy-very seedy
7120	17.5	5	r	6	6	3: s, 4: s-m, 5: mod, 6: seedy, darker flesh
7137	16.5	9	r	8	4	3: s, 4: mod, 5: mod, 6: seedy
7144	13.0	5	r	4	4	Bumpy, 3: beg, 4: s-seedy, 5: m-seedy, 6: m-seedy
7152	17.0	5	r	6	9	3: s, 4: mod, 5: mod, 6: mod
7153	15.5	8	r	8	8	3: s, 4: mod, 5: mod-seedy
7162	12.5	7	r	6	6	3: s, 4: s, 4: mod, 5: seedy
7165	14.0	1	r	3	7	Dk green pods w/ strong RC
7194	15.0	3	oval - round	5	5	Oval mix - might be possible to select.
7195	13.5	5	r-cb	5	5	Seedy 5 & 6 sv; pods a bit short but otherwise a nice bean
7207	17.0	3	heart	3	5	Oval to heart tendency
7223	16.0	7	r-cb	7	5	Straight & smooth esp. 3 & 4 sv nice bean - matches 5630
7227	16.0	3	r-cb	5	7	Nice bean
7232	15.5	7	r	7	5	Nice quality bean w/ high yields
7235	-	-	-	-	-	-

Entry	Pod Length (cm)	Pod Straight-ness[z]	Pod Cross Section[y]	Pod Smooth-ness[z]	Pod Color[x]	Notes[w]
7238	17.5	3	r	3	6 (varies)	3: s, 4: s-m, 5: m-seedy, 6: mod
7258	15.0	3	h-r	5	3	Too light - heart in smaller sieves
7264	19.0	8	r-ov	8	7	3: s, 4: s, 5: seedy, 6: very seedy
7269	16.5	6	r	6	6	3: s-beg, 4: mod, 5: seedy, 6: seedy
7279	15.0	5	heart	5	5	Slightly smaller sieve
7281	17.0	6	r	8	7 (varies)	Ugly, bumpy, dark green flesh, less seedy, 3: s, 4: s, 5: mod, 6: m-seedy
7293	14.5	6	oval-r	6	6	3: s, 4: mod, 5: mod, 6: seedy
7314	15.0	8	oval	4	5 (varies)	3: beg-s, 4: s, 5: mod, 6: seedy
7323	14.0	7	oval	8	8	3: s, 4: s-seedy, 5: m-seedy, 6: seedy-very seedy
7327	11.5	8	r	6	7 (varies)	Rather oval, 3: beg-s, 4: mod, 5: seedy
7333	15.0	6	oval	5	4	Too many flats, 3: beg-s; many flat, 4: s-m, 4: mod, 6: seedy

[z]Scale of 1 - 9 where 1 is least or worst and 9 is most or best. [y]Cross section: r = round, h = heart, cb = crease-back ov = oval. [y]Scores based on a 1 - 9 scale with 9 darkest. Standard BBL color is rated as 5. [w]s = slightly, m, mod = moderate, dk = dark.

Table 3. Performance of second preliminary green bean trial, May 28 planting, OSU Vegetable Research Farm, Corvallis, 2019.[z]

Line	Days to Harvest	Est. Sieve Size	Stand	1.0-2.0	3.0	4.0	5.0	6.0	%1-4 Sieve[y]	Av Tons/Acre	Av Adj Tons/Acre[x]
OSU 5630	67	6	146	4.0	4.8	23.8	57.9	9.5	32.5	11.4	9.4
Sahara	69	4	178	4.5	7.5	74.6	13.4	0.0	86.6	6.1	6.1
7072	72	4	168	8.8	29.7	54.9	6.6	0.0	93.4	8.5	12.1
7074	69	4	183	3.4	8.0	59.8	27.6	1.1	71.3	7.8	7.8
7076	67	4-5	180	1.3	5.1	48.1	44.3	1.3	54.4	7.3	7.6
7077	70	4	180	3.5	10.6	52.9	28.2	4.7	67.1	7.8	7.8
7079	70	5	170	7.7	3.8	17.3	48.1	23.1	28.8	9.1	7.2
7083	71	5?	112	4.5	4.5	29.9	53.7	7.5	38.8	6.0	5.3
7086	67	4-5	181	3.2	6.3	61.9	28.6	0.0	71.4	6.1	7.4
7087	71	4	159	3.4	10.2	86.4	0.0	0.0	100.0	8.9	8.9
7124	73	6	154	2.3	3.1	13.1	47.7	33.8	18.5	11.9	8.2
7125	73	6	159	2.2	2.2	6.6	45.6	43.4	11.0	12.6	7.7
7130	66	2-3	176	25.6	59.0	15.4	0.0	0.0	100.0	3.5	3.5
7136	71	4?	159	1.4	2.8	40.3	55.6	0.0	44.4	6.8	6.8
7139	70	4	179	2.7	4.1	33.8	56.8	2.7	40.5	6.8	6.8
7140	70	4	160	2.7	8.1	58.1	28.4	2.7	68.9	6.4	6.4
7143	70	4	141	4.5	3.0	41.8	50.7	0.0	49.3	6.4	6.4
7158	71	5	132	2.6	3.9	28.6	57.1	7.8	35.1	7.0	5.9
7159	69	5	144	3.1	6.3	56.3	34.4	0.0	65.6	8.5	9.9
7160	66	5	156	6.4	4.3	27.7	53.2	8.5	38.3	9.0	7.9
7166	70	5	147	6.1	3.0	9.1	53.0	28.8	18.2	6.2	4.2
7168	69	4	165	5.8	9.6	78.8	5.8	0.0	94.2	5.1	5.1
7172	70	4	47	6.9	3.4	17.2	48.3	24.1	27.6	4.9	4.9
7175	70	4	156	5.1	3.4	16.9	54.2	20.3	25.4	5.3	5.3
7176	72	6	153	3.8	5.1	17.7	53.2	20.3	26.6	7.3	5.6
7182	66	6	53	4.8	3.6	12.0	53.0	26.5	20.5	14.7	10.4
7187	71	5-6	171	2.4	4.8	9.6	36.8	46.4	16.8	11.4	7.6
7188	71	5	175	5.3	3.3	11.3	51.3	28.7	20.0	14.6	10.2
7189	71	5	183	3.6	12.6	45.9	34.2	3.6	62.2	10.3	11.5
7192	73	6	170	6.5	6.5	11.9	32.1	42.9	25.0	15.2	11.4
7199	71	5?	149	2.9	5.1	13.7	38.3	40.0	21.7	15.8	11.3
7202	67	6	135	4.8	5.5	13.1	48.3	28.3	23.4	13.0	9.5

Line	Days to Harvest	Est. Sieve Size	Stand	1.0-2.0	3.0	4.0	5.0	6.0	%1-4 Sieve[y]	Av Tons/Acre	Av Adj Tons/Acre[x]
7206	71	5	170	2.5	6.1	34.4	49.7	7.4	42.9	11.8	11.0
7208	73	6	161	3.5	4.1	8.8	31.6	52.0	16.4	15.9	10.5
7221	69	6	150	2.7	1.8	9.0	48.6	37.9	13.5	10.5	6.6
7226	71	4?	180	2.3	2.3	23.8	58.1	13.4	28.5	15.4	12.1
7230	76	5	135	6.2	7.5	26.1	52.8	7.5	39.8	13.9	12.5
7240	71	5	172	5.1	10.1	26.3	48.5	10.1	41.4	9.2	8.4
7241	69	5	181	4.5	9.0	52.3	33.3	0.9	65.8	10.1	11.7
7248	71	5	157	5.0	6.3	15.7	37.7	35.2	27.0	14.3	11.0
7251	70	6	149	2.7	5.5	13.7	37.7	40.4	21.9	12.9	9.3
7260	70	4	165	5.1	17.8	72.9	4.2	0.0	95.8	10.5	10.5
7273	69	5	153	5.7	7.1	28.6	56.4	2.1	41.4	12.1	11.1
7276	71	4?	159	11.8	27.7	49.6	10.9	0.0	89.1	10.5	14.7
7287	70	5	149	5.3	5.3	24.6	64.9	0.0	35.1	16.0	13.6
7290	69	5	124	6.6	3.6	24.1	58.4	7.3	34.3	12.3	10.4
7292	70	5	179	3.0	6.1	37.0	50.3	3.6	46.1	13.8	13.2
7296	66	6	141	9.0	11.1	33.3	44.4	2.1	53.5	13.2	13.7
7297	69	5	173	4.3	4.9	19.5	57.3	14.0	28.7	14.8	11.6
7300	69	5	126	7.2	8.0	31.2	51.4	2.2	46.4	12.4	11.9
7301	70	5	161	3.7	5.5	17.1	48.8	25.0	26.2	15.8	12.0
7305	70	4	173	4.1	7.5	26.5	57.1	4.8	38.1	13.4	11.8
7306	70	5	128	5.9	7.9	28.3	52.6	5.3	42.1	13.4	12.4
7309	71	5	160	3.7	11.0	40.4	41.9	2.9	55.1	11.6	12.2
7312	67	6	163	8.9	8.9	33.3	47.4	1.5	51.1	12.4	12.5
7318	69	5	175	6.8	5.3	21.1	58.9	7.9	33.2	16.6	13.8
7322	71	5	154	7.2	11.2	36.8	41.6	3.2	55.2	11.2	11.8
7324	69	5	118	4.4	6.3	27.0	52.2	10.1	37.7	14.7	12.9
7334	70	5	138	5.1	7.3	21.5	46.9	19.2	33.9	16.1	13.5
7340	71	4	162	5.8	11.7	58.3	20.0	4.2	75.8	10.8	10.8
7341	72	6	137	2.6	2.6	8.6	49.7	36.4	13.9	13.9	8.9
7345	69	5	169	8.3	8.3	27.3	47.9	8.3	43.8	11.0	10.3
7347	71	5	175	5.1	5.1	17.9	46.2	25.6	28.2	13.4	10.5

[z]Mean of 3 replications; subplots of 5' were harvested from 18' plots in rows 30" apart. [y]Percent calculated as % of total of 1-6 sieve beans. [x]Tons/Acre adjusted to 50% 1-4 sieve for full and 5 sieve beans; yields for smaller sieve lines were not adjusted.

Table 4. Notes on second preliminary green bean lines, May 28 planting, OSU Vegetable Research Farm, Corvallis, 2018.

Entry	Pod Length (cm)	Pod Straightness[z]	Pod Cross Section[y]	Pod Smoothness[z]	Pod Color[x]	Notes[w]
OSU5630	16.0	5	r	5	5	Mod seedy 6 sv seedy 5 sv mod seedy 4 sv
Sahara	12.0	7	r	6	6	3 sv: mod, 4 sv: seedy, 5 sv: seedy
7072	12.0	7	o-h-r	7	6	Seedy 5 sv mod seedy 4 sv; oval to heart in smaller sieves, Becomes round in 5 sv.
7074	13.0	4	cb	4	3	3 sv: veg, 4 sv: mod, 5: seedy, 6: seedy
7076	13.0	6	r	7	3	Very seedy 5m & 6 sv; seedy 4 sv. Too light
7077	14.0	5	r-cb	5	4-5	3 sv: mod, 4 sv: m-seedy, 5 sv: seedy, 6 sv: seedy
7079	15.5	3	r	4	4.5	3 sv: beg-m, 4 sv: mod, 5 sv: seedy, 6 sv: seedy
7083	14.5	3	cb	3	4	3 sv: beg, 4 sv: m-s, 5, 6 sv: seedy, waxy look
7086	12.0	7	r	5	4	Low yld but may be due to field location
7087	16.0	7	r	7	4	3 sv: mod, 4 sv: m-sd, 5 sv: seedy, light color, soft pods
7124	15.0	5	r	5	5	Junky 3 & 4 sv. Very seedy 5 &n 6 sv 4 sv mod.
7125	16.0	5	h-r	3	6	Good color but heart esp in lower sv sizes. Very seedy 5 & 6 sv; Junky 3 & 4 sv
7130	11.5	9	r	7	3	Extra fine bean; too light & low yields; very seedy 3n& 4 sv.
7136	14.5	6	r	7	5	3 sv: beg-seedy, 4 sv: seedy, 5 sv: very seedy
7139	13.0	8	r	6	5	3 sv: seedy, 4 sv: very seedy, 5,6 sv: very seedy
7140	16.0	6	r	7	4	3 sv: s, 4 sv: mod, 5 sv: seedy, 6 sv: mod
7143	16.5	7	r	5	4,5	3 beg-m, 4 sv: seedy, 5 sv: seedy-very seedy
7158	16.0	6	ht	6	5.5	3 sv: small, 4 sv: m-sd, 5 sv: m-sd, 6 sv: very seedy
7159	14.5	9	r	8	4	3 sv: mod, 4 sv: seedy, 5 sv: seedy-very seedy
7160	15.0	7	r	7	4	Seedy 4, 5 & 6 sv; light pods and low yields
7166	17.0	3	cb	3	7	3 sv: beg-s, 4 sv: seedy, 5 sv: m-seedy, 6 sv: seedy, ugly pods
7168	13.0	8	ht	9	4	3 sv: small, 4 sv: md-seedy, 5 sv: seedy
7172	15.0	6	r	5	6	3 sv: beg, 4 sv: small, 5 sv: mod, 6 sv: seedy
7175	18.0	5	r	7	4	3 sv: beg-s, 4 sv: s-m, 5 sv: mod, 6 sv: mod, dark color flesh
7176	16.5	3	r	5	5	Very seed 5 & 6 sv.
7182	16.0	7	r	7	5	Very nice bean with high yields, might be on light side. Also $ pod length.
7187	17.0	6	r	4	6-7	3 sv: beg-s, 4 sv: small, 5 sv: mod, 6 sv: seedy

Entry	Pod Length (cm)	Pod Straight-ness[z]	Pod Cross Section[y]	Pod Smooth-ness[z]	Pod Color[x]	Notes[w]
7188	18.0	7	ht	7	7	3 sv: small, 4 sv: mod, 5 sv: m-seedy, 6 sv: seedy
7189	13.0	4	cb	6	5-7	3 sv: mod, 4 sv: mod, 5 sv: m-seedy, 6 sv: seedy
7192	15.5	5	r	5	5	Nice looking bean with high yields seedy to v seedy 5 & 6 sv, mod 4 sv
7199	16.0	5	r-cb	6	6-7	3 sv: beg-s, 4 sv: small, 5 sv: mod, 6 sv: m-seedy
7202	17.0	5	r	5	4.5	Nice bean, only moderately seedy in 5 & 6 sv; color is marginal though
7206	14.0	7	r-oval	8	7	3 sv: beg-s, 4 sv: mod, 5, 6 sv: seedy, 4 sv oval
7208	16.0	3	r	3	5	Very seedy 5m & 6 sv; seedy 4 sv.
7221	20.5	7	r	8	4-5	4 sv: beg-md, 5 sv: md-seedy, 6 sv: seedy
7226	13.0	4	cb	3	7	3 sv: seedy, 4 sv: seedy, 5 sv: seedy-very seedy, 6 sv: very seedy
7230	17.0	4	r	5	8-9	Color varies, 3 sv: 4, 4 sv: 5, 5 sv: 6, 6 sv: 7
7240	14.5	5	r	4	6-7	Bright green!, 3 sv: small, 4 sv: s-m, 5 sv: seedy, 6 sv: mod, sticky; higher sugar?
7241	17.0	7	r-oval	8	3	3 sv: small, 4 sv: mod, 5 sv: seedy, 6 sv: seedy
7248	13.0	3	r-oval (4 sv)	4	7-8	3 sv: beg, 4 sv: small, 5 sv: mod, 6 sv: m-seedy, bumpy
7251	16.5	5	ht	6	6-7	Color varies, 3 sv: beg, 4 sv: small, 5 sv: m-seedy, 6 sv: seedy
7260	12.0	9	r	8	6	3 sv: beg, 4 sv: small, 5 sv: mod
7273	14.5	6	ht	8	5.5	3 sv: flat, beg-s, 4 sv: m-seedy, 5 sv: seedy, 6 sv: seedy-very seedy
7276	13.0	2	cb	1	9	Dark flesh, white seeds, extremely bumpy, 3 sv: small, 4 sv: mod, 5 sv: seedy
7287	15.0	6	ht-occasional oval	8	7	3 sv: beg-s, 4 sv: m-seedy, 5 sv: seedy, 6 sv: very seedy
7290	16.0	7	hr-oval	5	5	3s v: beg-s, 4 sv: mod, 5 sv: seedy, 6 sv: seedy-very seedy
7292	12.5	6	ht	5	8	3 sv: small, 4 sv: s-m, 5 sv: seedy, 6 sv: seedy, one stringy in 5 or 6 sv
7296	16.5	7	r	8	7	Very nice bean w/ high yields; seedy 6 sv, mod
7297	16.0	7	ht	7	3-5	3 sv: s, 4 sv: mod, 5 sv: mod, 6 sv: mod
7300	17.5	6	r	6	4-7	Color varies, string in sv 6, 3 sv: beg-s, 4 sv: s-m, 5 sv: seedy, 6 sv: very seedy
7301	16.0	6	cb	5	7	3 sv: beg, 4 sv: s-m, 5 sv: m-seedy, 6 sv: very seedy

Entry	Pod Length (cm)	Pod Straight-ness[z]	Pod Cross Section[y]	Pod Smooth-ness[z]	Pod Color[x]	Notes[w]
7305	15.5	4	ht-oval, r	4	6-8	3 sv: mod, 4 sv: mod, 5 sv: seedy, 6 sv: very seedy
7306	15.0	7	r-ht	6	8	A couple of stringy in 5 sv, 3 sv: beg-s, 4 sv: mod, 5 sv: seedy, 6 sv: very seedy
7309	13.5	5	r	6	9	3 sv: beg, 4 sv: mod, 5 sv: mod, 6 sv: m-seedy
7312	16.0	5	r/h	7	5	Nice bean with high yields; only moderate seed dev. May need to be single plant selected to increase uniformity
7318	14.5	7	ht-cb	6	7	Sticky; high sugar?, 3 sv: small, 4 sv: mod, 5 sv: m-seedy, 6 sv: seedy
7322	16.0	4	r	6	5-6	Color varies, 3 sv: beg-mod, 4 sv: s-mod, 5,6 sv: seedy
7324	17.0	7	r-cb	5	6	3 sv: beg, 4 sv: mod, 5 sv: m-seedy, 6 sv: seedy
7334	17.5	7	r	7	8	3 sv: small, 4 sv: mod, 5 sv: seedy, 6 sv: seedy-very seedy
7340	17.0	8	r	8	8-9	3 sv: small, 4 sv: mod, 5 sv: mod, partial string in 5, 6 sv
7341	15.0	3	r-cb	5	5	Very seedy 5 & 6 sv; getting pithy; otherwise nice bean w/ good yield
7345	13.5	6	ht	5	3-8	Light color pods mixed in, 3 sv: small, 4 sv: s-m, 5 sv: m-seedy, 6 sv: seedy
7347	12.5	5	cb	5	8+	3 sv: beg-s, 4 sv: mod, 5 sv: m-seedy, 6 sv: seedy

[z]Scale of 1 - 9 where 1 is least or worst and 9 is most or best. [y]Cross section: r = round, ht = heart, cb = crease-back. [x]Scores based on a 1 - 9 scale with 9 darkest. Standard BBL color is rated as 5. [w]Abbreviations: s = slightly, sv = sieve, beg = beginning, mod = moderate, yld = yield

Table 5. Commercial snap bean lines and checks grown in a yield trial at the OSU Vegetable Research Farm in 2019.

Entry	Source	Class/sieve size
91G	OSU Check	6
5630	OSU Check	6
Sahara	Harris Moran (check)	6
SV9203GV	Seminis	5
Tapia	Seminis	Romano
Usambara	Seminis	Romano
Affirmed	Seminis	4
Pierroton	Syntenta	2
R102019	Syntenta	2
R202002	Syntenta	3
R207654	Syntenta	2
SB4734	Syntenta	4
SB4738	Syntenta	4-5
BEX 057	Brotherton	3-4
BEX 069	Brotherton	4-5
ECHO	Brotherton	4-5
BEX 070	Brotherton	4-5
BEX 074	Brotherton	5
BSC 934	Brotherton	2-3
BSCHB15	Brotherton	3-4
1923	Pureline	4-5
PLS 5630	Pureline	6
RR 3002	Pureline	6
RR 3004	Pureline	6
RR 3006	Pureline	6
RR 3009	Pureline	6
7046	OSU	2-3
7047	OSU	2-3
7048	OSU	3
7049	OSU	3
7050	OSU	2
Crockett	Harris Moran (check)	3
Redon	Syngenta (check)	2

Table 6. Performance of commercial green bean lines in a yield trial planted Jun 11 OSU Vegetable Research Farm, Corvallis, 2019.[z]

Line	Days to Harvest	Est. Sieve Size	Stand	Percent Sieve Size[y] 1.0	2.0	3.0	4.0	5.0	6.0	%1-4 Sieve	Av Tons/Acre	Av Adj Tons/Acre[x]
91G	62	6	188.3	3.5	3.5	8.8	35.4	45.1	3.5	51.3	9.6	9.7
5630	63	6	174.8	3.3	3.9	10.0	44.4	36.1	2.2	61.7	8.1	9.0
Sahara	63	4-5	198.5	2.7	14.1	48.3	48.3	30.9	0.0	69.1	6.7	6.7
Crockett	65	3	191.5	4.0	18.3	60.6	17.1	0.0	0.0	100.0	8.0	8.0
Redon	64	2	186.0	28.2	69.4	2.4	0.0	0.0	0.0	100.0	4.0	4.0
SV9203GV	62	6	199.8	2.6	2.6	5.6	24.4	59.7	5.0	35.3	13.6	11.6
Affirmed	65	4	200.0	3.2	5.4	24.7	61.3	5.4	0.0	94.6	4.3	4.3
Pierroton	64	2	200.0	23.8	76.3	0.0	0.0	0.0	0.0	100.0	3.7	3.7
R102019	66	2	200.0	26.2	71.8	1.9	0.0	0.0	0.0	100.0	4.7	4.7
R202002	62	3	199.0	6.1	29.3	60.6	4.0	0.0	0.0	100.0	4.7	4.7
R207654	66	2	197.5	6.3	69.8	24.0	0.0	0.0	0.0	100.0	4.6	4.6
SB4734	63	4	200.0	3.8	8.9	24.8	57.3	5.1	0.0	94.9	6.8	6.8
SB4738	64	5	184.5	2.2	2.2	6.1	34.4	54.4	0.6	45.0	8.3	7.9
BEX 057	66	3-4	198.8	2.2	7.6	39.1	47.8	3.3	0.0	96.7	4.3	4.3
BEX 069	62	5	148.5	3.4	3.0	6.4	34.5	52.7	0.0	47.3	9.3	9.0
ECHO	63	4-5	193.8	3.1	6.3	26.0	56.3	8.3	0.0	91.7	8.6	8.6
BEX 070	65	4-5	184.5	3.4	2.6	12.9	63.8	17.2	0.0	82.8	5.4	7.2
BEX 074	66	5	107.8	3.0	4.0	9.0	20.0	51.0	13.0	36.0	4.8	4.1
BSC 934	64	3	189.0	4.0	14.0	75.3	6.7	0.0	0.0	100.0	7.1	7.1
BSCHB15	66	3-4	189.5	3.7	8.1	42.2	44.4	1.5	0.0	98.5	6.3	6.4
1923	62	6	192.0	2.9	1.9	4.3	25.8	57.9	7.2	34.9	9.6	8.2
PLS 5630	62	6	176.5	4.6	4.2	10.6	38.9	40.3	1.4	58.3	9.8	10.6
RR 3002	62	6	187.5	2.4	4.8	14.3	29.5	41.4	7.6	51.0	9.5	9.5
RR 3004	62	6	194.0	2.7	3.1	6.7	22.3	54.0	11.2	34.8	10.1	8.2
RR 3006	63	6	190.3	1.6	2.3	6.2	21.0	47.1	21.8	31.1	11.7	12.9
RR 3009	62	6	189.8	3.6	4.0	8.9	25.7	49.8	7.9	42.2	13.5	12.5
7046	66	2-3	191.5	4.7	43.0	51.0	1.3	0.0	0.0	100.0	6.8	6.8
7047	63	2-3	200.0	9.4	46.9	40.6	3.1	0.0	0.0	100.0	4.5	4.5
7048	64	2-3	198.5	9.0	56.8	32.4	1.8	0.0	0.0	100.0	5.6	5.6

Line	Days to Harvest	Est. Sieve Size	Stand	Percent Sieve Size[y] 1.0	2.0	3.0	4.0	5.0	6.0	%1-4 Sieve	Av Tons/Acre	Av Adj Tons/Acre[x]
7049	63	3	199.5	2.4	15.1	60.8	21.7	0.0	0.0	100.0	7.8	7.8
7050	66	2	200.0	15.5	77.4	7.1	0.0	0.0	0.0	100.0	4.2	4.2
Tapia	67		189.3								13.8	
Usambara	69		174.8								12.9	
LSD 0.05			11.5								2.6	2.6

[z]Mean of 3 replications; subplots of 5' were harvested from 18' plots in rows 30" apart.
[y]Percent calculated as % of total of 1-6 sieve beans.
[x]Tons/Acre adjusted to 50% 1-4 sieve for full and 5 sieve beans; yields for smaller sieve lines were not adjusted.

Table 7. Notes on a commercial green bean yield trial planted Jun 11 OSU Vegetable Research Farm, Corvallis, 2019.

Line	Pod Length (cm)	Pod Straight-ness[z]	Pod Cross Section[y]	Pod Smooth-ness[z]	Pod Color[x]	Flavor[z] Sweet-ness	Astrin-gency	Perfumi-ness	Notes[w]
91G	17	4	r	5	5	7	9	1	
5630	15	5	r-cb	5	5	5	7	1	
Sahara	12.5	7	r	8	7	3	3	1	Sahara struggled in this trial. Prob. herbicide injury. Low yield, lots of blanks & short pods.
Crockett	12.5	9	r	5	7	7	5	1	Oval mix in 2 & 3 sv
Redon	12	6	r	7	4	7	5	7	
SV9203GV	14	5	r	9	5	5	3	5	Should have started on Friday; slow seed development
Affirmed	13	7	r	7	7	1	3	1	Nice appearance very similar to Sahara
Pierroton	11	5	r	7	4	7	7	1	Tough skin. Viny mix in the field.
R102019	11	8	r	9	3	7	7	9	Nice 2 sv but too light to match BBL
R202002	12	4	r	7	3	7	3	7	Nice 3 sv
R207654	11.5	6	r	7	5	3	1	5	Sl oval in 2 sv.
SB4734	12.5	6	r	9	9	5	7	3	Tough skin, v. dark green shiny pods
SB4738	13	5	r	9	5	3	7	1	Flat mix in 3 sv.
BEX 057	14	5	r	9	5	7	9	1	Long slender 3 sv; some blanking
BEX 069	13.5	7	r	9	3	3	5	3	Tough pods, too light for BBL, Very straight & smooth
ECHO	13	7	heart	3	3	7	5	7	Bumpy pods, particularly as sieve size increases. Heart but becoming more round in higher sieves.
BEX 070	13	7	r	9	3	5	7	3	Too light to match BBL. Lots of Blanks & polywogs.

Line	Pod Length (cm)	Pod Straight-ness[z]	Pod Cross Section[y]	Pod Smooth-ness[z]	Pod Color[x]	Flavor[z] Sweet-ness	Astrin-gency	Perfumi-ness	Notes[w]
BEX 074	14.5	3	r-cb	3	4	7	7	1	Wax & stringy mixes. Lots of battering in grader.
BSC 934	12	7	r	9	5	7	3	7	Light/oval mix, tough skin
BSCHB15	15	8	r	7	3	5	5	1	Very long 3-4 sv, too light to match BBL. A few 5 sv but not enough to weigh.
1923	17	5	r	7	3	5	5	1	Very long pods, slow seed dev.
PLS 5630	16	5	r	5	5	5	7	1	Longer pods & more uniform than 5630
RR 3002	14	4	r-cb	7	5	7	9	1	BBL type, flat mix in smaller sieve size.
RR 3004	12	5	r-cb	5	5	7	7	1	BBL type; ~60% pods showing fiber in beak, but does not appear to have persistent strings
RR 3006	16	5	r-cb	5	4	7	5	1	Strong RC.
RR 3009	16	5	r	5	4	3	5	3	Tough skin, long pods, but little seed dev.
7046	12	5	r	5	5	7	5	5	Tough skin. 1 sv curved and junky and prob not very useful.
7047	11	5	h-r	5	3	3	7	7	Nice 2 sv bean but too light to blend w/ BBL
7048	11.5	6	r	7	5	5	9	1	Maybe color/size mix - 4 sv much lighter and oval.
7049	12.5	9	r	5	4	7	7	7	Nice 3 sv w/ good yields ; color is light to blend w/ BBL types
7050	11.5	7	r	6	5	5	7	3	Nice 2 sv but low yields

Line	Pod Length (cm)	Pod Straight-ness[z]	Pod Cross Section[y]	Pod Smooth-ness[z]	Pod Color[x]	Flavor[z] Sweet-ness	Astrin-gency	Perfumi-ness	Notes[w]
Tapia	15								9 cm/10 seed length; pod depth 1.9 cm
Usambara	16								8.5 cm/10 seed length; pod depth 1.8 cm

[z]Scale of 1 - 9 where 1 is least or worst and 9 is most or best. [y]Cross section: r = round, h = heart, cb = crease-back. [y]Scores based on a 1 - 9 scale with 9 darkest. Standard BBL color is rated as 5. [w]Abbreviations: sl = slight, sv = sieve, prob = probably.

Table 8. Seed development of lines in snap bean yield trial grown at the Vegetable Research Farm in 2019. Seed development rated on a scale of 1 - 9 where 1 = no seed development, 3 = seed development beginning, 5 = moderate seed development, 7 = seedy and 9 = very seedy.

		Sieve size category					
Entry	**Harvest date**	**6**	**5**	**4**	**3**	**2**	**1**
5630	12-Aug	7	7	4	1		
5630	13-Aug	7	7	5	3		
5630	15-Aug	9	7	6	5		
91G	12-Aug	7	7	6	5		
91G	14-Aug	9	8	6	5		
Sahara	13-Aug		6	5	3		
Sahara	15-Aug		7	5	5		
Pierroton	14-Aug					7	4
Pierroton	16-Aug					8	6
1923	12-Aug	8	5	5	3		
1923	13-Aug	9	7	6	3		
7046	14-Aug				4	3	1
7046	16-Aug			7	6	5	
7046	17-Aug			7	7	5	
7047	13-Aug			7	6	5	1
7047	15-Aug			7	6	4	
7047	17-Aug			9	7	5	
7048	12-Aug			9	5	2	1
7048	14-Aug			9	8	5	
7048	16-Aug			9	7	5	5
7049	13-Aug			7	5	3	
7049	15-Aug			7	7	5	
7049	17-Aug			7	7	5	
7050	14-Aug				7	3	3
7050	16-Aug				7	5	4
7050	19-Aug				9	9	6
Affirmed	13-Aug		5	4	3	1	
Affirmed	15-Aug		7	5	3		
BEX 057	14-Aug			4	3	1	
BEX 057	16-Aug		7	5	3		
BEX 057	19-Aug		9	9	6	4	
BEX 069	12-Aug		6	6	3		
BEX 069	13-Aug	7	7	5	3		
BEX 069	15-Aug	9	7	5	3		
BEX 070	13-Aug		7	6	5	4	
BEX 070	15-Aug		7	6	4		
BEX 074	14-Aug		5	5	3	1	
BEX 074	16-Aug	6	6	3	3		
BSC 934	12-Aug			7	5	4	
BSC 934	14-Aug			7	6	4	
BSC 934	16-Aug			9	7	5	
BSCHB15	14-Aug		6	6	5	3	
BSCHB15	16-Aug		7	6	4	3	

Entry	Harvest date	Sieve size category 6	5	4	3	2	1
BSCHB15	19-Aug		9	8	5	4	
Crocket	15-Aug			5	5	3	
Crocket	17-Aug			5	4	3	
ECHO	13-Aug		6	4	2	1	
ECHO	15-Aug		8	5	4		
PLS 5630	12-Aug	7	5	3	1		
PLS 5630	14-Aug	9	9	7	4		
PLS 5630	16-Aug	9	9	7	3		
R102019	14-Aug					5	3
R102019	16-Aug				6	6	3
R102019	19-Aug				9	7	6
R202002	12-Aug			7	7	5	
R202002	14-Aug			8	6	3	
R207654	14-Aug				5	4	1
R207654	16-Aug				7	7	3
Redon	14-Aug				6	6	3
Redon	16-Aug				6	5	3
Redon	19-Aug				9	9	6
RR 3002	12-Aug	7	6	5	3		
RR 3002	14-Aug	8	8	6	3		
RR 3004	12-Aug	7	7	5	3		
RR 3004	13-Aug	7	7	7	5		
RR 3006	13-Aug	7	6	5	3		
RR 3006	15-Aug	9	7	5	3		
RR 3009	12-Aug	7	6	5	3		
RR 3009	13-Aug	9	7	7	5		
SB4734	12-Aug		5	5	3		
SB4734	13-Aug		5	5	3	1	
SB4734	15-Aug		7	6	5		
SB4738	12-Aug		5	5	1		
SB4738	14-Aug	7	6	6	2		
SB4738	16-Aug	9	7	5	3		
SV9203GV	12-Aug	7	6	6	3		
SV9203GV	13-Aug	7	7	7	5		
SV9203GV	15-Aug	9	8	6	4		

Table 9. Ratings by 11 evaluators of commercial snap bean cultivars and breeding lines for visual appearance, quality and flavor at the OSU Pilot Plant in 2019. Blue indicates higher ratings and red lower ratings.

Line	Average Score[z]	Good	Ok	Bad
			%	
Affirmed	1.5	72.7	9.1	18.2
5630	1.5	63.6	18.2	18.2
Crockett	1.4	55.6	33.3	11.1
Sahara	1.5	54.5	36.4	9.1
7047	1.3	45.5	36.4	18.2
7048	1.4	45.5	45.5	9.1
BSC934	1.3	45.5	36.4	18.2
R202002	1.4	45.5	45.5	9.1
SB4734	1.1	45.5	18.2	36.4
BEX057	1.2	36.4	45.5	18.2
PLS5630	1.3	36.4	54.5	9.1
Redon	1.3	36.4	54.5	9.1
7046	1.1	27.3	54.5	18.2
91G	1.1	27.3	54.5	18.2
BEX070	0.8	27.3	27.3	45.5
BEX074	1.0	27.3	45.5	27.3
RR3009	1.1	27.3	54.5	18.2
Usambara	1.0	20.0	60.0	20.0
7049	1.0	18.2	63.6	18.2
7050	0.8	18.2	45.5	36.4
BEX069	0.7	18.2	36.4	45.5
BSCHB15	0.5	18.2	18.2	63.6
R207654	0.7	18.2	36.4	45.5
RR3002	0.8	18.2	45.5	36.4
Tapia	1.0	10.0	80.0	10.0
Echo	0.9	9.1	72.7	18.2
R102019	0.8	9.1	63.6	27.3
RR3004	0.6	9.1	45.5	45.5
SV9203GV	0.5	9.1	27.3	63.6
1923	0.4	0.0	36.4	63.6
RR3006	0.6	0.0	63.6	36.4
SB4738	0.5	0.0	54.5	45.5

[z]Ratings based on a scale of 0 - 2 where 0 = discard, 1 = maybe and 2 = save.

Table 10. White mold incidence and severity for two preliminary snap bean trials grown at the OSU Vegetable Research Farm in 2019.

Line	Trial no.	Pedigree	Incidence (%)	Severity
7264	1	5630/6771	0	1
7279	1	5630/6771	0	1
7327	1	6443/6771	0	1
7220	1	6443/6792	0	1
7250	1	6443/6794	0	1
7090	1	6443/Cornell 501	0	1
7092	1	6443/Cornell 501	0	1
7093	1	6443/Cornell 501	0	1
7101	1	6443/Cornell 501	0	1
7342	1	6793/5630	0	1
7347*	2	6793/5630	0	1
7293	1	5630/6771	1	2
7314	1	5630/6771	1	2
7323	1	5630/6792	1	2
7065	1	5630/Cornell 501	1	2
7066	1	5630/Cornell 501	1	2
7121	1	6443/6743	1	2
7097	1	6443/Cornell 501	1	3
7227	1	6794/5630	1	2
7235	1	6794/5630	1	2
7238	1	6794/5630	1	3
7078	1	Cornell 501/6443	1	2
7103	1	5630/6743	5	3
7153	1	5630/6771	5	4
7281	1	5630/6771	5	3
7067	1	5630/Cornell 501	5	2
7069	1	5630/Cornell 501	5	2
7188	2	6443/6772	5	4
7095	1	6443/Cornell 501	5	2
7115	1	6743/6443	5	4
7117	1	6743/6443	5	3
7208	2	6792/6443	5	2
7223	1	6794/5630	5	2
7260	2	ID Refugee/6443	5	2
7261	1	ID Refugee/6443	5	3
7102	1	5630/6743	10	6
7297	2	5630/6771	10	3
7318	2	5630/6771	10	3
7068	1	5630/Cornell 501	10	3
7120	1	6443/6743	10	3
7122	1	6443/6743	10	5
7211	1	6443/6792	10	3
7212	1	6443/6792	10	3
7333	1	6443/6793	10	3

Line	Trial no.	Pedigree	Incidence (%)	Severity
7100	1	6443/Cornell 501	10	2
7113	1	6743/6443	10	2
7340	2	6792/5630	10	5
7345	2	6793/5630	10	3
7232	1	6794/5630	10	4
NY6020-5	2	Res. check	5	2
OSU5630	1	Susep. check	5	4
OSU5630	1	Susep. check	10	3
OSU5630	2	Susep. check	10	3

[z]Scale of 1 – 9 where 1 = no disease and 9 = dead. *very resistant surrounded by 'hot zone'

Table 11. Best snap bean breeding lines from a fall white mold trial conducted at the OSU Vegetable Research Farm in 2019[z]. Shown are least square means for incidence, severity and disease severity index. Each numeric column is followed by columns for the four checks indicating whether the experimental line is significantly different or not from the check. Abbreviations: ns: not significant, *: significant at 0.01<P<0.05, **: significant at 0.001<P<0.01 and *: significant at P<0.001.**

Line	Pedigree	Incidence (%)	OR 91G	OSU 5630	Cor. 501	NY6020-4	Severity (1-9)	OR 91G	OSU 5630	Cor. 501	NY6020-4	Disease severity index (1-30)	OR 91G	OSU 5630	Cor. 501	NY6020-4
OR91G	Suscep. Check	66.7		ns	***	***	7.0		ns	***	***	21.5		ns	***	***
OSU5630	Suscep. Check	43.3	ns		***	*	5.0	ns		***	*	14.6	ns		***	*
Cornell501	Res. Check	0.0	***	***		ns	1.0	***	***		ns	1.0	***	***		ns
NY6020-4	Res. Check	10.0	***	*	ns		2.0	**	*	ns		4.3	***	*	ns	
OSU7065	5630/Cornell 501	5.0	***	**	ns	ns	1.7	**	*	ns	ns	2.9	***	**	ns	ns
OSU7066	5630/Cornell 501	1.7	***	***	ns	ns	1.3	***	***	ns	ns	1.7	***	***	ns	ns
OSU7067	5630/Cornell 501	10.0	***	*	ns	ns	3.0	**	ns	ns	ns	5.5	**	*	ns	ns
OSU7069	5630/Cornell 501	13.3	**	*	ns	ns	2.7	**	ns	ns	ns	5.8	**	*	ns	ns
OSU7070	5630/Cornell 501	3.1	***	***	ns	ns	1.4	***	***	ns	ns	2.1	***	***	ns	ns
OSU7074	5630/Cornell 501	11.7	***	*	ns	ns	2.7	**	ns	ns	ns	5.5	**	*	ns	ns
OSU7076	5630/Cornell 501	1.7	***	***	ns	ns	1.3	***	***	ns	ns	1.7	***	***	ns	ns
OSU7077	Cornell 501/6443	11.7	***	*	ns	ns	3.3	**	ns	ns	ns	6.1	**	*	ns	ns
OSU7078	Cornell 501/6443	1.7	***	***	ns	ns	1.3	***	***	ns	ns	1.7	***	***	ns	ns
OSU7079	Cornell 501/6443	16.7	**	ns	ns	ns	1.7	**	*	ns	ns	4.7	**	*	ns	ns
OSU7081	Cornell 501/6443	1.7	***	***	ns	ns	1.3	***	***	ns	ns	1.7	***	***	ns	ns
OSU7083	Cornell 501/6443	5.0	***	**	ns	ns	1.7	**	*	ns	ns	2.9	***	**	ns	ns
OSU7086	Cornell 501/6443	6.7	***	**	ns	ns	2.0	**	*	ns	ns	3.6	***	**	ns	ns
OSU7087	Cornell 501/6443	6.7	***	***	ns	ns	1.3	***	***	ns	ns	2.8	***	***	ns	ns
OSU7090	6443/Cornell 501	6.7	***	**	ns	ns	1.7	**	*	ns	ns	3.2	***	**	ns	ns
OSU7136	5630/6771	8.3	***	**	ns	ns	2.0	**	*	ns	ns	3.7	***	**	ns	ns
OSU7139	5630/6771	3.3	***	***	ns	ns	1.7	***	*	ns	ns	2.4	***	***	ns	ns
OSU7140	5630/6771	1.7	***	***	ns	ns	1.3	***	***	ns	ns	1.7	***	***	ns	ns
OSU7187	6443/6772	13.1	**	*	ns	ns	2.4	**	ns	ns	ns	5.6	**	*	ns	ns

Line	Pedigree	Incidence (%)	OR 91G	OSU 5630	Cor. 501	NY6020-4	Severity (1-9)	OR 91G	OSU 5630	Cor. 501	NY6020-4	Disease severity index (1-30)	OR 91G	OSU 5630	Cor. 501	NY6020-4
OSU7211	6443/6792	6.7	***	**	ns	ns	2.0	**	*	ns	ns	3.6	***	**	ns	ns
OSU7220	6443/6792	11.7	***	*	ns	ns	2.3	**	*	ns	ns	5.0	**	*	ns	ns
OSU7223	6794/5630	10.0	***	*	ns	ns	2.7	**	ns	ns	ns	5.0	**	*	ns	ns
OSU7235	6794/5630	13.3	**	*	ns	ns	2.7	**	ns	ns	ns	6.0	**	*	ns	ns
OSU7250	6443/6794	1.7	***	***	ns	ns	1.3	***	***	ns	ns	1.7	***	***	ns	ns
OSU7260	ID Refugee/6443	11.7	***	*	ns	ns	2.0	**	*	ns	ns	4.5	***	*	ns	ns
OSU7261	ID Refugee/6443	6.7	***	**	ns	ns	2.0	**	*	ns	ns	3.6	***	**	ns	ns
OSU7279	5630/6771	1.7	***	***	ns	ns	1.3	***	***	ns	ns	1.7	***	***	ns	ns
OSU7281	5630/6771	3.3	***	***	ns	ns	1.7	***	*	ns	ns	2.4	***	***	ns	ns
OSU7293	5630/6771	3.3	***	***	ns	ns	2.0	***	*	ns	ns	2.8	***	***	ns	ns
OSU7318	5630/6771	11.7	***	*	ns	ns	3.3	**	ns	ns	ns	6.1	**	*	ns	ns
OSU7327	6443/6771	3.3	***	***	ns	ns	1.3	***	***	ns	ns	2.2	***	***	ns	ns
OSU7340	6792/5630	1.7	***	***	ns	ns	1.3	***	***	ns	ns	1.7	***	***	ns	ns
OSU7347	6793/5630	3.3	***	***	ns	ns	2.0	***	*	ns	ns	2.8	***	***	ns	ns

[z]138 total lines in trial, susceptible experimental lines not shown. Incidence is the percent of plot that is infected. Severity of the infection is rated on a scale of 1 - 9 where 1 is disease free and 9 is dead. Disease severity index is the geometric mean of incidence and severity and in this case is based on a scale of 1 to 30 where 1 is highly resistant and 30 is highly susceptible.

OPVC CONTINUING PROJECT REPORT: YEAR 2019

1. OPVC REPORT COVER PAGE (maximum 2 pages)

OPVC Project Number:

Project Title: Broccoli Breeding, Evaluation

PI: James R. Myers
Organization: Oregon State University
Telephone: 541-737-3083
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Address: ALS 4017, Department of Horticulture
City/State/Zip: Corvallis, OR 97331

Total Project Request (all years):
Year 1: $7,541 (breeding)
$4,990 (processing)
$12,532 (total)

Other funding sources: Western SARE

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. One yield trial consisting of 12 entries (three check and nine experimental hybrids) was conducted in 2019. The trial was seeded 05 July and transplanted 01 August. Experimental hybrid production focused on combining the OSU inbreds S471, S473 and S475 with others older and newer inbreds in the program. Yields ranged from 4 to 7 T/A (net) with Imperial and Emerald Pride checks and three experimental hybrids having the highest yields. The three experimental hybrids had more desirable characteristics for processing. We measured floret:stem ratio and usable floret (<2.5") proportion and while Imperial had the highest floret weight, only about 43% were usable without being recut. In general, as yield increased, floret size also increased. S471 does seem to combine well to produce high yields and has favorable quality attributes when combined with some older OSU inbreds. It also is self-fertile making it a good candidate for introgression into a cytoplasmic male sterile background to facilitate hybrid production. An observation trial with 26 advanced inbred lines, 15 early generation segregating inbreds, 16 cytoplasmic male sterile lines in various stages of backcrossing to advanced inbreds, and 7 F_1 hybrids with only enough seed for one replicate were grown and evaluated for horticultural traits in the field. Six isolation plots for hybrid seed production were established at the OSU Vegetable and Lewis Brown farms, with variable seed production with different hybrid combinations. A complementary Western SARE project to facilitate more efficient broccoli production was implemented, and will be reported separately.

3. FULL REPORT (no maximum)

3.a. BACKGROUND

Mechanization has reduced labor costs in many crops, but broccoli and cauliflower remain relatively non-mechanized. Large labor crews are typically needed to harvest these crops. Cost and access to labor are the two biggest problems for broccoli harvest – cost in terms of wages to workers and access in that other crops such as blueberries need labor for harvest at the same time as broccoli. Some progress has been made towards mechanizing the process both in Europe and the U.S., but problems remain in creating a cost-competitive approach. The OPVC was awarded a USDA Specialty Crop Block Grant in 2016 and OSU received a Western SARE project in 2018 to work towards automated broccoli harvest. While machinery is part of the equation, the other two parts are the broccoli plant (genotype) and the production system (environment). The OSU Vegetable Breeding Program has for many years, been working on cultivars that are suitable for mechanized harvest and with traits preferred by processors.

Most broccoli cultivars are not well suited for mechanical harvest. The two key factors in developing cultivars that are suitable are uniform heading and appropriate plant architecture. Most commercially available broccoli hybrids are high yielding but have short plants with heavy and 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. Typical broccoli cultivars also have large leaves near the head that are removed during hand harvest. De-leafing broccoli heads has been a major challenge for machine harvest to date. Exserted head broccoli types are being bred to have fewer and smaller leaves around the head.

In addition to direct harvest characteristics, processors need broccoli that makes a high quality pack. Florets and stems need to be dark green 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 also 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

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 screening methodology for breeding for heat tolerance and identify germplasm with the trait.

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

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

3.c. SIGNIFICANT FINDINGS.

- Trial variability was high this year which manifested as a lack of significance for some traits among hybrids.
- While Emerald Pride and Imperial were among the highest yielding (net T/A), one OSU hybrid (S475/S463) had numerically higher yield and two others (S471/S463 and S471/S481) were similar.
- Floret weights generally followed net T/A head weights but in terms of usable florets (florets that are <2.5"), differences were reduced, with no significant difference between Imperial and the experimental hybrids.
- Imperial had the lowest percent usable florets (43%) whereas six experimental hybrids and Cascadia and Emerald Pride were significantly higher (range of 50-60%).
- S471 is a new inbred to the program that continues to have very favorable attributes in its own right and combines well with some older OSU inbreds. It is also highly self-fertile, making it a good candidate for backcrossing into a CMS background.
- Another new inbred is S475 which has good combining ability with other inbreds.
- A screen of commercial and experimental broccoli materials identified nine hybrids that performed consistently across the season.

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 inbreds and F_1 hybrids for testing.

We continued to derive new inbreds through 4 - 6 generations of self-pollination, and are using these on a small scale to produce F_1 hybrid seed for replicated yield trials. Inbreds lines saved from the 2018 growing season were grown from cuttings in the winter 2019 greenhouse. These were bud-pollinated to perpetuate the line, and crossed to other inbred lines to evaluate combining ability for F_1 hybrid production. Crossing efforts were focused on obtaining enough seed for replicated field trials of new hybrid combinations.

Transplants of inbreds and breeding lines are started from seed produced in the greenhouse and planted in the field. Inbreds and experimental hybrids and commercial hybrids were grown in an observation trial in the main fall planting in the field (Table 1). Plots were evaluated for percent blind (multiple shoots rather than a single head), head size, shape, firmness, exsertion, segmentation, uniformity, floret texture and color, and maturity.

A fall replicated yield trial was established with three commercial hybrids along with 9 OSU experimental hybrids (Tables 2 & 3). The fall yield trial seeded on 05 July was transplanted into the field on 01 August, and used one row plots of 30 feet in length and replicated three times within-row spacing of 12 inches. In addition to observation data, yield data was obtained. Heads from all of the replicate plots were harvested on a single day, trimmed to a 6.5 inch length and weighed. After recording of weight, leaves were stripped from the heads and heads were again weighed. Leaf percent was calculated from this data. Heads were sorted for those that were judged too young and small for the floretting process in the plant, and those that were culls (mostly too mature). A set of 10 heads were evaluated for diameter and hollow stem, and a subset of five heads was floretted and florets and stems weighed separately. Floret and stem weight data was used to calculate a floret:stem ratio. The proportion of florets > 2.5 inches was also determined. Entries in the yield trial were taken to the OSU pilot processing plant for blanching and freezing. Frozen material was evaluated at the OSU winter cutting on 8 November and was displayed at the PNVA meetings in Kennewick, WA on 15 November. Data collected from field observations included total number of plants and number that were "blind", leaf and head height, head shape, bead size, stem color, exsertion, segmentation, uniformity, and branching.

Backcrossing of selected hybrids to place the nuclear genome in the Ogura and Arnund cytoplasmic male sterile (CMS) backgrounds continued (Table 1). We focused mainly on the inbreds S454, S462, S463 and S473 but also initiated backcrossing to S471. Seed production of selected hybrid combinations and CMS backcrossing using a fertile inbred as a male and a CMS inbred as a female were evaluated in the field using six isolation plots (three at the Vegetable Research Farm, and three at the Lewis Brown Farm).

With funding from Western SARE, a broccoli heat trial was also conducted this past summer to evaluate commercial hybrids and experimental breeding lines for tolerance to the climatic conditions commonly found in the Willamette valley. Temperature is often the main limiting factor in determining whether a broccoli variety can be successfully grown within a particular region. Since most commercially available cultivars are bred for production in climatic regions outside of Oregon, the need to identify the hybrids most suitable for use by Willamette valley broccoli farmers is necessary to sustain its long term viability. Mounting evidence of global climate change suggests the need for more heat tolerant broccoli will only increase in the foreseeable future.

The heat trial was initiated by examination of current seed catalogues and collecting seeds from numerous commercial broccoli lines which purportedly have heat adaptable traits. Contact with representatives of several major seed companies also yielded seeds from yet to be released lines of broccoli which were described as being tolerance to high temperatures environments. Cooperating universities and the USDA-NIFA-SCRI funded Eastern Broccoli Project also sent seeds to be evaluated in this trial. With seeds from 38 broccoli lines having been collected, the heat trial was designed with six different planting dates (i.e. spaced one week apart) to maximum the potential range of temperature variability within a single growing season.

The seeding of each broccoli line was initiated inside the OSU campus greenhouses and approximately four weeks later transplanted into the field site at the University's Vegetable farm in Corvallis. For each planting date, 15 seeds of each broccoli variety were started in seedling trays and the best 10 seedlings were then transplanted into the randomly assigned field plots using a transplanter (using one foot in-row placings). The six seeding dates were 10, 16, 23 & 30 May and 6 & 13 June. Two temperature data loggers were placed into the trial to record the ambient air temperatures at canopy height for the duration of the trial. The growth of broccoli and trial site was closely monitored for any IPM related issues and treated as necessary. Each head was harvested individually when it reached a prime stage of maturity and then evaluated for the criteria designated as being relevant to assessing the level of heat damage which occurred for that variety and planting. Evaluations of broccoli head quality consisted of rating each head for: color uniformity, bead uniformity, head uniformity, head firmness, and head diameter. Since yield is often of paramount concern for local broccoli farmers, the weight of each head (i.e. cut to 6in length), weight of total florets, and weight of usable florets (< 2.5in) was also incorporated into the evaluation criteria.

Frozen broccoli samples were evaluated in a cutting by 11 evaluators for appearance, quality characteristics and taste. These were rated on a scale of 0 to 2 where 0 = discard, 1 = maybe and 2 = save. Data were compiled and in addition to calculation of an average score, the percent of the scores in each category was determined.

3.e. RESULTS & DISCUSSION *Greenhouse inbred and hybrid seed production:* Cuttings were taken from inbreds and breeding lines grown in the field in 2018 to establish material for crossing and hybrid seed production in the greenhouse during the winter of 2018-2019. Forty-nine selections were taken for rooting with most of these surviving to be potted for crossing. These were bud pollinated by hand to self the inbreds and produce seed for the 2020 growing season. Most lines are highly inbred but a few are still segregating and showing significant variation in the field. The process was repeated at the end of the 2019 growing season where cuttings of 55 lines were collected and brought into the greenhouse for rooting in November.

Observation Trials: The observation trial included 26 highly inbred lines, four lines still undergoing inbreeding and selection, and 16 Ogura cytoplasmic male sterility (CMS) lines at various stages of backcrossing to selected inbreds (Table 1). These were evaluated at heading for various traits important to processing including number of blind plants, various head characteristics (color, bead size, segmentation) and plant characteristics (head exsertion, branching, uniformity and overall performance). Ten inbreds received overall ratings of 7 or above (Table 1). In addition, seven F_1 hybrids for which there was not sufficient seed for replicated plots were grown for observation. Three received overall scores of 7 or above, while some were discarded because of plot variability or lodging.

Yield Trial:

In the fall trial, three commercial hybrids were grown along with 9 OSU experimental hybrids (Table 2 & 3). S475/S463 had the highest net yield at 7.0 T/A, followed by Imperial (6.8 T/A) and Emerald Pride (6.6 T/A). The checks were not significantly different from all but three of the experimental hybrids (lowest yielding was 4 T/A). Most experimental hybrids had much lower leaf percentages (3.9-14.9%) than Imperial (18.5%). Percent florets were higher this year and ranged from 60-69.5% while usable florets ranged from 42.7 to 58.6%. Imperial had the lowest usable floret tonnage. The data continues to support the observation that overall head weight is more important than proportion of the head that is made up of florets in determining amount of usable product. There is also a positive relationship between head and floret weight, but increasing head weight also results in the proportion of florets that exceed 2.5 in. Whether breeding for smaller floret size while maintaining head weight can be accomplished remains to be seen.

Hybrid/CMS backrossing Seed Production:

Seed production from isolation plots was variable in 2019 (Table 4). Two combinations produced good quantities of seed, one produced only a few seeds and three isolation plots were failures. The differences observed were most likely due to flowering time where later flowering plots during the heat of the summer reduced seed set.

Heat Trial:

Studies conducted by Bjorkman and Pearson (1998) have found there is likely a specific physiological period of time in a broccoli plant's growth wherein excessive heat is the most detrimental to the formation of a broccoli head with desirable characteristics and quality. This 5-7 day period of time occurs when the broccoli plant is transitioning from vegetative growth into a reproductive phase, and the initial enlargement of bud primordia begins. Having numerous planting dates maximizes the potential of being able to correlate declines in plant performance with increases in ambient temperatures.

Of the 38 broccoli varieties trialed, many had some irregularities in bead size and color uniformity within the plantings. These irregularities are generally the most common sign of a broccoli head having been affected by non-conducive temperatures during its growth cycle. Several of the experimental broccoli lines showed tolerance to temperature variations, but failed to produce commercially viable yields at harvest. Complicating the evaluations further, some of commercial lines demonstrated a rather high threshold for fertilizer requirements to produce a broccoli head with no irregularities.

Of the 38 broccoli lines tested this summer for heat tolerance, several commercial lines did performed exceptionally well across the spectrum of environmental conditions and within all six plantings (Table 5). Some of these broccoli hybrids are widely recognized as being tolerant to heat, originating from established commercial seed companies. Others were developed by the same established seed companies, but are yet to be released to the public. While a few others originated from more obscure breeders but performed exceptionally well too. While these materials may have tolerance to abiotic stress, they do not necessarily have the traits required for processing broccoli.

A later planting of these broccoli materials was evaluated for head rot using a 0 – 9 scale where 0 indicates no symptoms and 9 indicates that all heads in the plot had symptoms. Differences were observed (Table 6) but symptom expression was confounded by maturity. Early maturing cultivars were harder hit than later maturing ones because of early rains that decreased later in the fall as late maturing cultivar heads transitioned through their most vulnerable window.

Frozen broccoli evaluation:

Differences in quality of frozen broccoli samples were observed. S471/S479 was preferred by the majority of evaluators followed by Cascadia and Imperial check hybrids and several experimental hybrids. Emerald Pride ranked 8th out of 12 entries in the trial. The main reasons for downgrading samples were large floret and bead size and non-uniform color of florets.

4. BUDGET DETAILS

1) Breeding (Myers)	
Salaries and benefits	
Faculty Research Assistant, field, full time	$2,573
OPE @ 69.48%	$1,787
Wages and benefits	
Student Wages	$1,302
OPE @ 11%	$143
Supplies	$300
Land use and greenhouse rental	$1,436
Total	$7,541
2) Processing (Yorgey)	
Salaries and benefits	
Senior Faculty Research Assistant	$2,796
OPE @ 61.45%	$1,718
Wages and benefits	
Student Wages	$260
OPE @ 11%	$29
Supplies	$187
Total	$4,990
Grand Total	$12,532

BUDGET NARRATIVE

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, approximately 5% FTE will be required to process broccoli samples; the remainder of salary to come from other sources. $1,302 is requested for a summer undergraduate student to assist in plot maintenance and harvest operations. The SFRA will also supervise an undergraduate student in broccoli processing. Undergraduate student OPE is 11%. Funds for services and supplies includes $300 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 $1,322 per acre = $661), and greenhouse rental ($1.55*500 sq. ft. = $775).

Table 1. OSU breeding program broccoli observation trial for inbreds, CMS backcrosses and selected hybrids.

Entry	Days post trans-plant	Plants (no.)	Blind (no.)	Blind (%)	Exsert[z]	Head shape[y]	Branch depth[x]	Bead size[w]	Color[z]	Head Dia. (cm)	Head firm-ness[z]	Uniform-ity[z]	Over-all[z]	Notes
							Inbreds							
S445	75	24	2	8.3	6	5	6	F	9	6.5	9	7	5	V. small florets
S446	75	22	0	0.0	6	7	5.5	M	5	7	9	7	7	Some leaf heads
S454	66	24	4	16.7	8	7	4.5	M	7	6	5	7	7	Chlorotic in leaf margins
S462	66	22	4	18.2	8	5	7.5	M	7	8	6	8	6	V. heading
S463	68	24	4	16.7	7	6	7	F	7	7	8	3	5	Many banded var. head size
S465	85	22	1	4.5	7	7	3	M	7	4	9	5	5	Heads cut w/many improve over time
S466	75	23	2	8.7	7	7	5	M	5	7	9	7	8	Very segmented.
S469	66	24	1	4.2	7	7	5	F-N	7	6	8	7	7	Early heads sl. Small
S471	70	21	2	9.5	7	5	5	M	7	7	7	6	8	
S473	68	25	1	4.0	8	5	9	F	9	7	3	7	6	Nice. But small heads
S474	75	22	0	0.0	7	7	6	<	3	6.5	8	7	6	Many small plants
S475	70	20	0	0.0	9	5	7	F	9	8	8	8	8	Lg. leaves
S479	79	22	0	0.0	7	5	5	F-M	5	8	8	8	8	
S479 - v.s.	72	22	5	22.7	8	5	9	F	7	8	6	5	7	V. different from S479 (volunteer self)
S481	75	15	1	6.7	7	7	9	M	9	7	9	5	7	Leafy heads many 2" heads
S482	79	19	2	10.5	7	7	7	M	7	6	9	7	6	Lots of leaners
S483	75	25	0	0.0	7	7	5	F	9	6	7	7	8	Short stature
S486	70	23	1	4.3	9	6	9	F	7	8	8	9	5	Plots not vigorous
S487	75	22	0	0.0	8	6	6.5	F	7	8	9	7	8	V. little side shoot formation

Entry	Days post trans-plant	Plants (no.)	Blind (no.)	Blind (%)	Exsert^z	Head shape^y	Branch depth^x	Bead size^w	Color^z	Head Dia. (cm)	Head firm-ness^z	Uniform-ity^z	Over-all^z	Notes
S488	70	12	0	0.0	8	7	7.5	M	7	6.5	8	5	6	Var. head size deep branch
S490	70	25	0	0.0	9	7	5.5	F	9	6.5	9	5	5	Var. head size
S462/S474	69	20	2	10.0	8	7	7	M	7	7	7	3	7	Var. mat. Ht. & head size
S463/S473	70	24	2	8.3	7	5	7	M	7	7	5	3	5	Var. mat. Ht. Head size
S471/S483	70	23	2	8.7	5	6	6	M	9	7	8	7	5	Short ht. many small heads
S473/S463-1	70	24	2	8.3	7	6	8	F	9	7.5	8	5	7	Tall plots var. head size
S473/S463-2	68	25	5	20.0	7	5	8	M	7	7	8	5	7	Some v. tall plots
S475/S463-1	70	20	6	30.0	5	6	4	F-M	5	6	9	7	5	Lots of head rot
S475/S463-2	72	23	0	0.0	6	7	6	m	7	7	7	5	7	Short var. head size some nice heads
S475/S463-3	70	24	1	4.2	6	6	7	M	5	8	8	3	7	
S471/S483	70	20	0	0.0	5	5	6	M	7	8	9	5	7	
S483/S471-1														
S483/S471-2	70	25	1	4.0	6	6	7	m	9	7	8	5	7	
F1 Hybrids														
S471/S486	68	25	0	0.0	8	6	7	M	9	10	8	7	9	Same massive heads >12"
S471/S490	70	22	0	0.0	7	5	8	F-M	7	5	8	5	3	Heads size from 3-10"

Entry	Days post trans-plant	Plants (no.)	Blind (no.)	Blind (%)	Exsert[z]	Head shape[y]	Branch depth[x]	Bead size[w]	Color[z]	Head Dia. (cm)	Head firm-ness[z]	Uniform-ity[z]	Over-all[z]	Notes
S471/S492	70	12	0	0.0	8	6	6	F-M	7	7	9	8	8	Nice hybrid sold stems
S475/S486	70	18	0	0.0	7	5	7	F-M	7	7	9	4	5	Some nice heads but var.
S475/S490	70	25	0	0.0	6	6	7	M	7	8	9	6	7	Sl. Later stands well
S473/S490	70	24	3	12.5	9	5	8	M	9	6	5	5	3	Lots of lodging
S473/S463	72	25	4	16.0	7	6	7	M	9	6	9	5	5	Some lodging
Cytoplasmic Male Sterile backcrosses														
A463/S463	72	21	4	19.0	7	6	5	M	5	6	7	5	5	Lots of b?
O446	74	35	2	5.7	7	7	5	M	7	5	9	5	7	Var. ht. & head size
O446*2-1/S462-1/S454	68	16	1	6.3	9	6	7	M	7	7	9	7	7	Lots of leaners
O454-1*2	68	22	2	9.1	7	6	5	M	7	5	5	3	5	Var. ht. lots of lodging
O454-2*2	70	19	5	26.3	7	5	7	M	7	7	7	5	7	Taller than last some lodging
O462-1*4	68	22	3	13.6	7	7	6	M	7	6	8	5	5	Lots of lodging (the worst)
O463-1*2	74	23	3	13.0	5	7	6	M	7	6	9	8	6	Some late small heads stands well
O463-3*2	72	23	5	21.7	5	5	6	M	7	6	8	5	3	Lots of lodging
O463-4*3	78	25	7	28.0	5	7	5	M	7	6	9	5	5	Lots of br?
O473-1*2	72	24	3	12.5	7	5	6	F-M	7	7	7	7	7	Tall, stands well small florets
O473-2*2	72	18	3	16.7	5	5	7	F	9	7	9	5	5	
O473-3*2	72	24	3	12.5	9	5	7	F	9	8	9	5	7	Better than last
O473-4*2	72	23	2	8.7	7	5	7	F	7	6	7	5	5	Lots of leaners
O462-2*4	68	23	2	8.7	8	6	8	F	7	7	5	5	5	Lots of leaners

Entry	Days post trans-plant	Plants (no.)	Blind (no.)	Blind (%)	Exsert[z]	Head shape[y]	Branch depth[x]	Bead size[w]	Color[z]	Head Dia. (cm)	Head firm-ness[z]	Uniform-ity[z]	Over-all[z]	Notes
OS473-4*1/ S471	72	14	0	0.0	7	6	7	F	9	7	9	7	8	Some lodging most closely resembles S471
OS473-1*3-2/S471	68	12	1	8.3	9	5	7	F	9	8	8	5	7	Large heads some leaners

[z]Scale of 1-9 where 1 = lowerst (worst) and 9 = highest (best); [y]Scale of 1-9 where <3 = concave, 5 = flat, 7 = moderate dome & 9 = extreme domed head; [x]Scale of 1-9 where 1 = shallow and 9 = deep branching; [w]vf = very fine, f = fine, m = medium & c = coarse beads.

Table 2. Yield and yield component data from a fall trial of processing broccoli cultivars and experimental hybrids grown at the OSU Vegetable Research Farm in 2019.

Entry	Total T/A	Head wt. T/A	Heads/A	Young T/A	Young no./A	Cull wt. T/A	Cull no./A	Net T/A	Net no./A	Leaves (%)	Florets (%)	Usable florets (%)	Floret T/A	Usable floret T/A
Cascadia	4.8	4.1	15100.7	0.11	1549	0.00	0	4.0	13552	14.9	67.0	56.8	3.3	2.8
Emerald Pride	7.5	6.9	16262.3	0.09	581	0.00	0	6.8	15681	8.5	65.1	51.0	5.1	4.0
Imperial	8.2	6.7	14907	0.19	2130	0.00	0	6.6	12778	18.5	69.5	42.7	5.9	3.5
S454/S471	5.2	4.8	15100.7	0.06	581	0.02	194	4.7	14326	7.3	62.4	52.2	3.7	3.1
S454/S475	5.4	5.0	15681.3	0.05	774	0.06	194	4.9	14714	9.0	63.3	53.8	3.6	3.0
S471/S463	6.8	6.3	16455.7	0.00	0	0.00	0	6.3	16456	7.6	67.9	51.8	5.3	4.1
S471/S479	5.9	5.6	14132.7	0.00	0	0.06	194	5.5	13939	5.1	61.4	48.0	4.0	3.2
S471/S481	7.3	6.7	15875	0.05	387	0.07	194	6.6	15295	8.3	65.8	50.2	5.1	3.9
S471/S483	5.6	4.9	16262.3	0.14	1936	0.00	0	4.8	14326	12.4	66.9	58.6	4.0	3.5
S473/S486	6.0	5.5	15488	0.17	1936	0.04	194	5.2	13358	10.2	60.0	49.6	3.3	2.8
S475/S463	7.3	7.0	16455.7	0.03	387	0.00	0	7.0	16069	3.9	66.1	50.7	4.8	3.7
S475/S483	4.8	4.4	14326.3	0.12	1162	0.00	0	4.2	13165	10.2	63.0	55.2	3.5	3.0
LSD 0.05	1.4	1.7	ns	0.12	1325	ns	ns	1.7	3019	8.5	4.9	8.0	1.4	1.0

Table 3. Observation data from a fall trial of processing broccoli cultivars and experimental hybrids grown at the OSU Vegetable Research Farm in 2019. See table 1 footnotes for explanation of scales.

Entry	Blind (%)	Leaf ht. (in)	Head ht. (in)	Head shape	Color	Exsertion	Segment	Uniformity	Branch	Hollow stem (%)	Head Dia.(cm)	Head rot (incidence)	Head rot (severity)
Cascadia	0.0	27.0	22.0	6.7	3.7	6.3	4.7	3.7	5.3	87	13.9	0.0	0.0
Emerald Pride	3.4	26.0	16.3	4.3	5.3	4.3	5.3	3.3	3.0	60	16.7	3.7	4.0
Imperial	4.7	30.3	15.3	6.7	3.0	2.3	2.3	3.3	3.0	43	17.1	0.0	0.0
S454/S471	7.4	26.7	23.0	5.0	3.7	6.7	6.0	4.3	3.3	97	16.0	0.3	1.0
S454/S475	4.8	28.0	23.3	4.7	4.0	6.7	5.7	4.0	3.7	90	15.2	0.3	2.7
S471/S463	4.5	28.0	23.7	5.3	4.0	6.7	5.0	4.7	3.7	87	16.4	0.3	1.3
S471/S479	9.5	29.3	24.7	5.0	4.3	6.7	6.0	4.7	4.0	97	16.0	0.3	1.7
S471/S481	4.7	29.3	24.3	4.3	3.7	6.0	5.3	4.0	4.7	97	17.2	0.0	0.0
S471/S483	7.0	26.7	23.0	5.3	4.0	6.3	4.7	4.7	4.0	83	15.2	0.3	1.7
S473/S486	7.9	30.7	26.7	5.0	4.0	7.7	5.3	4.3	3.3	90	16.4	0.0	0.0
S475/S463	1.1	27.3	23.3	5.7	3.3	6.0	5.7	4.0	4.3	57	17.5	0.7	1.0
S475/S483	8.9	27.3	22.3	5.7	3.7	6.3	5.7	4.3	4.3	90	15.3	0.3	1.0

Table 4. Seed production from field isolation plots at the OSU Vegetable Research and Lewis Brown farms in 2019.

Female	Male	Seed wt. (g)	Notes
O446/S471	S471	19.4	3 rows female, 2 rows male. Females started from seed, males from cuttings. Only males in flower 7/3
O463-1*1	S463	0	2 rows female, 3 rows male. Good nick and spotty seed set 7/3
O473-2*1	S473	10 (seeds)	1 row each, pretty good nick 7/3. Spotty seed set.
O462-1*3-1	S471	14.7	
O446	S475	0	Poor growth - late flowering and no seed set
O446	S479	0	Poor growth - late flowering and no seed set
S471	self	22.9	O446/S471//S471 cross
S471	self	4.4	O462-1*3-1/S471 cross

Table 5. Commercial and experimental broccoli lines which performed well across all six of the planting dates of the Heat trial this summer at the OSU Vegetable Research Farm in 2019.

Variety Name	Company of Origin
Asteroid	HM Clause
BC1691	Seminis
BC1764	Seminis
Eastern Crown	Sakata
Eastern Magic	Sakata
Eiffel	Seminis
Imperial	Sakata
Kings Crown	Sieger Seed Co
OCMS 93 x P9 (B034)	Cornell Univ.

Table 6. Head rot ratings for commercial broccoli lines planted with the fall observation trial grown at the OSU Vegetable Research Farm in 2019z.

Hybrid/Inbred	Head Rot Rating
Asteroid	5
Batory	0
BC1691	0
BC1764	7
Bejo 2971 F_1	3
BH026y	8
BH027	8
BH044	5
BH045	9
BH050	7
BH053	7
BH055	8
Cascadia	3
Castle Dome	6
Corato F_1	3
Covina F_1	1
Darien RZ	0
Durapak16	0

Hybrid/Inbred	Head Rot Rating
Eastern crown	4
Eastern magic	5
Eiffel	0
Emerald pride	7
Greenpak28	6
Hancock	0
HMX 0207 F_1	0
Ironman	0
Kariba RZ	2
Kings Crown	6
Lieutenant	8
Maracaibo RZ	0
Monflor	8
OCMS 93 x P9 (B034)	3
P13 CMS x P19	5
P8CMS x P19	6
Stellara	2
Virgo F_1	4
Willandra RZ	1

zRating scale of 0 – 9 where 0 = no symptomatic heads and 9 = all heads showing symptoms. yBH lines from USDA-Charleston are inbreds.

Table 7. Ratings of processed broccoli appearance, quality and flavor by 11 evaluators of three commercial broccoli and nine experimental hybrids conducted at the OSU Pilot Plant in 2019. Blue indicates higher ratings and red lower ratings.

Hybrid	Average Scorez	Good	Ok	Bad
			%	
S471/S479	1.5	54.5	36.4	9.1
Cascadia	1.1	36.4	36.4	27.3
Imperial	1.1	36.4	36.4	27.3
S454/S471	1.2	36.4	45.5	18.2
S454/S475	1.1	27.3	54.5	18.2
S471/S463	1.1	27.3	54.5	18.2
S473/S486	0.7	27.3	18.2	54.5
Emerald Pride	0.7	18.2	36.4	45.5
S471/S483	1.0	18.2	63.6	18.2
S475/S483	1.0	18.2	63.6	18.2
S471/S481	0.7	9.1	54.5	36.4
S475/S463	0.7	0.0	72.7	27.3

zRatings based on a scale of 0 - 2 where 0 = discard, 1 = maybe and 2 = save.

Research/Extension Progress Report for 2019-20 Funded Projects
Progress Report for the Agricultural Research Foundation
Oregon Processed Vegetable Commission

Title: Effect of Planting Arrangement on Snap Bean Yield

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Funding history: 2019-20: $5,394 2020-21: $7,000

Abstract Nonchemical weed control strategies are in short supply in snap beans, particularly strategies that target weeds within the seed row. Recent work demonstrated the limitations of propane flaming and organic herbicides for weed control in stale seedbeds. There was very little improvement in weed control with propane flame or organic herbicides, and the stale seedbed system needed to make flame useful reduced snap bean yield by nearly 10 percent. The vegetable industry is evolving quickly, and new tools are now available to assist with in-row weed control. The Robovator©[1] uses electronic guidance to discriminate between weeds and crops and then activates small sweeps to remove weeds between plants. The Robovator effectively controls weeds in many widely spaced crops such as lettuce and broccoli, but may not be suited for crops like snap beans unless modifications are made to the planting arrangement of snap bean seeds. Results from this project indicate that 'hill' planting may be possible without significant reductions in yield. A simple linear regression of population versus snap bean yield across hill-planted and conventionally planted snap beans indicated that there may be opportunities to maximize pod yield while accommodating the sweeps of robotic in-row weeders such as the Robovator.

Key words Cultivation, non-chemical weed control, plant spacing, plant population, Robovator.

Objective The objective of this proposal was to measure of the effect of in-row snap bean seed arrangement on snap bean yield. We hypothesize that snap bean seeds can be aggregated into 'hills' to increase the area of access by mechanical weeders such as the Robovator, and that snap bean yield will not be impacted when using these compressed in-row seed arrangements.

Procedures

The experimental site was at the OSU Vegetable Research Farm on a Chehalis silty clay loam soil. After final tillage, rows were made on 19-Jun that were on 30-inch centers with a John Deere Max Emerge planter. Fertilizer (12-10-10) was banded next to the bean row at 350 lbs/a. Plots were 3 rows wide (7.5 ft) and 15 feet long, and each treatment was replicated 4 times in a randomized complete block experimental design. To create different in-row seed spacings and arrangements, soil was removed from the seed row to a depth of 1.5 inches. Snap beans (var. 5630) seeds were then arranged in the seed row as listed in Table 1 and shown in Figure 1. Seeds were aggregated into hills with several seed populations and distances between seed hills that could theoretically be cultivated with a mechanical weeder such as a robovator.

The plot was lightly irrigated after snap bean seeds were placed in the row and covered with soil, then the soil rolled to improve seed-to-soil contact. Select herbicide was applied at the first triolifate of snap bean growth to control crabgrass and other grasses, and Raptor and Basagran herbicides were applied at the 2nd trifoliate to control broadleaves. Urea fertilizer was broadcast at the 2nd triofliate at 50 lbs N/a to

[1] http://www.visionweeding.com/robovator/

improve snap bean growth. Snap beans were harvested from 8.2 feet of row on 22-Aug and graded. Pods averaged 58% 1-4 sieve at harvest.


Fig. 1. Seed 'hill' in Tr. 3 with 8.5 inches between seed hills and ½ in between seeds (139000 seeds/a).

Accomplishments

In general, when snap bean seeds were separated by ½ inch distance within the row, snap bean yield increased as the distance between hills declined (Table 1, Figure 2). When compared to 'nonhill' treatments (seeds evenly spaced in standard plantings), snap bean yield was greater than or equal to 'nonhill' treatments (Figure 2 and 3). The one exception was Tr 3 at a population of 139,000 seeds/acre that did not follow the general trend. The cause of this anomaly is unclear.

In contrast to the trend for seeds separated by ½ inch, when seeds were separated by ¾ inch in seeds hill within the row, yields may have declined as the spacing between hills decreased from 8.25 inches to 6.75 inches between hills (Table 1, Figure 2).

A simple linear regression of seed density at planting versus yield indicated that seed density was somewhat correlated with snap bean yield, but trends differed between planting in hills and in standard plantings (evened spaced seed planting) (Figure 3). This indicates that there may be opportunities to maximize seed yield by revising plant spacing in the row or by planting seeds in hills. Whether these adjusted plant spacings will improve the ability of machines like the Robovator to control weeds is the next question to address.

Impacts

Controlling weeds in snap bean is high priority for growers because of the costs associated with yield loss due to competition and dockage. Truckloads may be docked if weeds are picked up with mechanical harvest, and removing weeds in the field by hand or cultivation is expensive.

Currently weeds are managed in conventional plantings of snap beans with PRE and POST herbicides, and occasionally cultivation if soil type allows. In organic systems, crop rotations, cover crops, cultivation and hand hoeing and pulling are all used in concert to reduce competition and contamination potential. Weeds still persist in the seed row and continue to reduce yields and contaminate product.

Current cultivation strategies do not provide effective in-row weed control. RTK and other guidance systems allow closer cultivation with lower risk of damage to the crop, but weeds still persist in a 3-inch or larger band in the row.

Planting snap beans in hills may provide the opportunity to reduce weed density in the row, assuming that new cultivation equipment such as the Robovator can navigate seed hills. This research also indicates that it may be possible to reduce seed cost by adjusting in-row seed arrangement.

Relation to Other Research

This project complements other ongoing research in row crops that is evaluating both chemical and nonchemical strategies to control weeds in processed, fresh market and vegetable seed crops. Future research will expand to measure the impact of 'hill planting' on bean yield and weed control at both 24 and 30 inch row spacings. The long-term goal is to evaluate efficacy of the Robovator in hill-planted snap beans.

Table 1. Effect of snap bean in-row seed arrangement on pod yield and grade.

	Plant arrangement					Snap bean harvest				
Tr.	Seeds/foot of row	Target plant stand	Distance between seeds	Length of 'seed hill'	Distance between 'seed hills'	Plant stand	Plant biomass	Pod yield	Avg. plant wt	Grade
		no/a	*----------------------- inches------------------*			*no./a*	*------- tons/a ------*		*lbs*	*% 1-4 sieve*
1	6	105000	0.5	2.5	9.5	89000	8.3	8.7	0.43	57
2	7	122000	0.5	3	9	91000	8.6	9.3	0.46	55
3	8	139000	0.5	3.5	8.5	106000	8.5	8.4	0.38	55
4	9	157000	0.5	4	8	116000	9.5	9.9	0.39	55
5	10	174000	0.5	4.5	7.5	126000	9.6	10.0	0.36	57
6	6	105000	0.75	3.75	8.25	94000	9.0	9.2	0.45	62
7	7	122000	0.75	4.5	7.5	99000	8.7	8.8	0.41	55
8	8	139000	0.75	5.25	6.75	122000	8.4	8.8	0.32	58
9	6	105000	1	5	7	92000	8.3	8.2	0.42	57
10	6	105000	2.0	*Even spacing*		91000	8.1	8.3	0.41	56
11	7	122000	1.7	*Even spacing*		95000	8.2	8.5	0.40	64
12	8	139000	1.50	*Even spacing*		116000	8.4	8.8	0.34	56
13	9	157000	1.33	*Even spacing*		124000	9.2	9.5	0.34	58
14	10	174000	1.2	*Even spacing*		113000	8.1	8.4	0.34	61
FPLSD (0.05)						*18000*	*ns*	*1.3*	*0.06*	*ns*

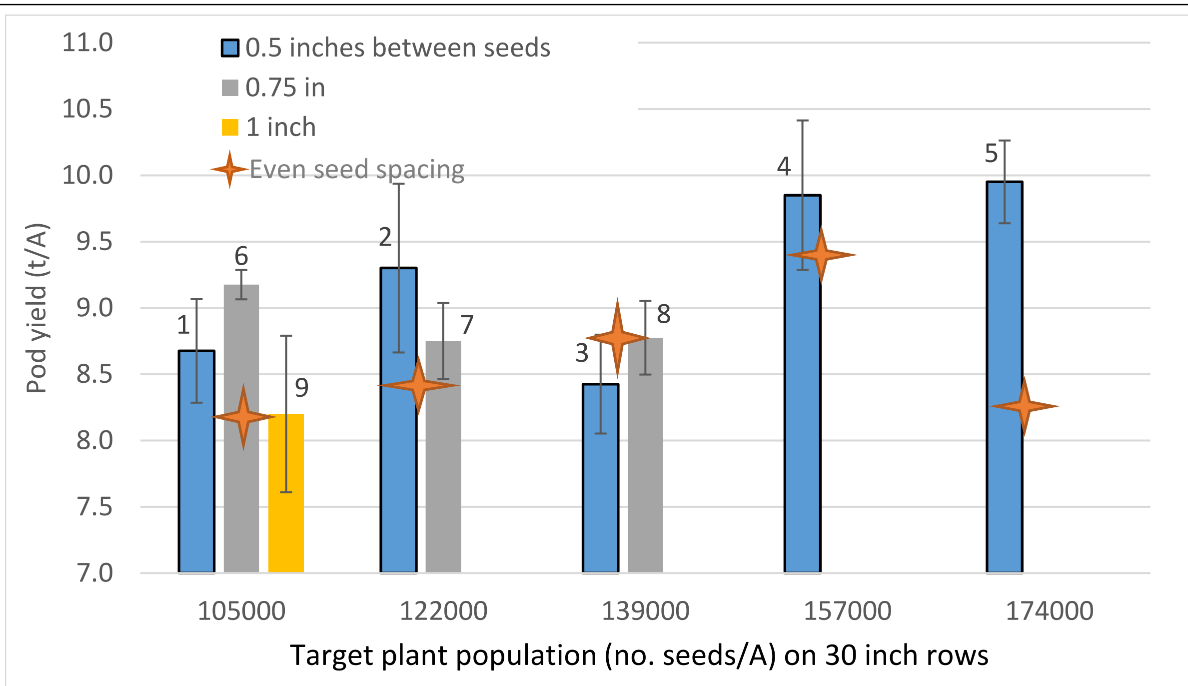

Figure 2. Effect of seed spacing within the row and plant population on pod yield. Stars represent the yield of snap beans in treatments with evenly spaced seeds. N=4, + SE. Numbers correspond to treatments listed in Table 1.

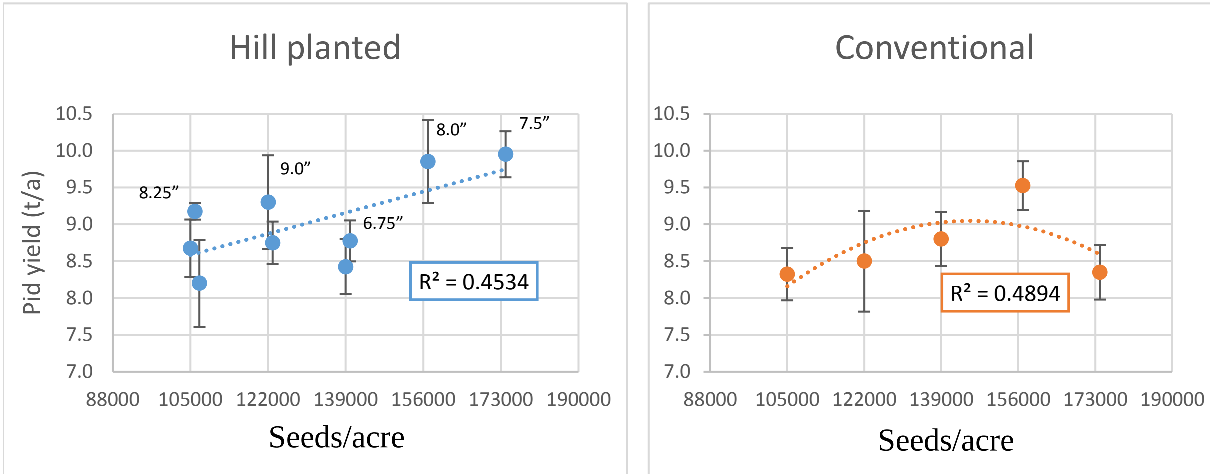

Figure 3. Effect of 'hill' and 'conventional' planting strategies on snap bean yield. Numbers are the distance between hills, or the effective area that could possibly be cultivated with the Robovator.

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Title: Monitoring and Reporting Insect Pests in Cole Crops and Sweet Corn (VegNet)

Project leaders: Jessica Green and Ed Peachey
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FUNDING HISTORY	**2019**	2018	2017	2016
	$19,714	$20,392	$20,154	$21,465

ABSTRACT

Agricultural professionals in the Willamette Valley have come to depend on VegNet as a leading and reliable management tool. This regional program provides activity data for common insect pests of broccoli, cauliflower, sweet corn, and snap beans. Weekly reports are sent via email, and comparative analysis between sites and years can reveal trends that directly affect pest management priorities. Growers and crop consultants then use the data to maintain or intensify field-scouting efforts and make informed spray decisions. The regional nature of the service provides landscape-level comparisons, and allows producers to determine if there is a concern for their crop or location. Data has been collected in the same manner since 1996, which allows us to calculate and compare historical averages for each pest that is currently monitored. When pheromone traps detect an increased level of adult moths compared to historical averages, we use growing degree-day estimates and knowledge of the species' phenology to estimate timing of egg laying and the potential for subsequent crop damage by larvae. The program operates on an email subscription platform; each week between May and September, subscribers receive a summary of data trends and how they might affect vegetable crop production. Monitoring is an essential first step to integrated pest management (IPM), and the utility of having an insect pest monitoring network applies to a wide range of Ag industry professionals. Pest activity in 2019 was minimal overall, except for the notable outbreak of cabbage looper.

KEYWORDS: insect, monitoring, vegetable pests, IPM, Extension, newsletter, cutworm, looper

OBJECTIVES

1. Continue operation of a regional pest monitoring and reporting network for damaging crop pests including black cutworm, variegated cutworm, diamondback moth, cabbage looper, 12-spot beetle and others.
2. Conduct a preliminary survey for swede midge, an invasive crucifer pest that has been moving westward since 2015.

PROCEDURES

OBJ. 1 - Field sites were determined based on previous grower cooperation history, location, and planting schedule. At each site, 'Texas cone' traps were placed and baited with species-specific pheromone lures. Yellow sticky traps and wing traps were used in similar fashion, depending on the crop monitored. Traps remained in place for the duration of the season or until crops are harvested. Data were collected weekly from (May 6th to September 16th).

OBJ. 2 - A Jackson trap was placed in a field suspected of swede midge activity last year. A yellow sticky trap was used to specifically look for adult midges. Both traps were placed at the field edge. Sampling for maggot activity was proposed but not actualized, due to time constraints and the overall improbability of presence in Western Oregon (see Accomplishments section).

ACCOMPLISHMENTS

OBJ. 1 - Regional pest monitoring and reporting -

Insect pest activity is unpredictable and often cyclical in nature. It can be influenced by annual weather patterns, host plant phenology, natural enemy levels, and many other factors. For some species, there is a clear pattern of number of generations, timing of peak flights, etc. Other pests seem to vary widely year-to-year and activity peaks may overlap, which makes analysis, and subsequent prediction of crop damage difficult.

Table 1 provides a summary of activity trends for each pest monitored by VegNet. The most notable trend of 2019 was the outbreak of cabbage looper. Looper counts were abnormally high early in the season, and remained so throughout. Loopers have multiple, overlapping generations, and without doing a full analysis of activity data, there seems to be 3 'peak times' when counts of adults in traps can be expected. This pattern is consistent in each year that we have experienced an outbreak.

Cutworms and armyworms continue to be a major concern for other commodities in this region. Historically, the VegNet program has monitored only for bertha armyworm (*Mamestra configurata*), but it may be time to adjust strategy as other, non-target species dominate the traps. We worked with Extension personnel in Tillamook County to continue a trapping and reporting project in pastures, and found increased activity in 2019 compared to 2018. More information about that effort can be found here: http://blogs.oregonstate.edu/cutworm/tillamook-ext-data__trashed/2019-2/. As suspected, glassy cutworm (*Apamea devastator*) was very prominent in traps, but it is unclear if eggs and larvae were actually in vegetable fields. *A. devastator* has a wide host range and overwinters as partially mature larvae, very similar to winter cutworm (*Noctua pronuba*). A comprehensive monitoring and research plan for winter cutworm is being planned by the new OSU Extension Field Crop Entomologist (hired in 2019).

OBJ. 2 – Swede Midge Monitoring –

In 2018, broccoli plantings throughout the Willamette Valley suffered from poor stand establishment, abnormal root growth, and girdling. A collaborative investigation of potential causes was conducted, including surveying growers and submitting samples to the OSU Plant Clinic. A blog post was made about the issue (http://agsci-labs.oregonstate.edu/vegnet/2018/08/13/whats-wrong-with-the-broccoli/), but cause remains inconclusive.

Partially, this is what fueled the 2019 objective to examine fields for swede midge (Diptera: Cecidomyiidae). Both maggots and adults are extremely small (3 mm and 2 mm, respectively). Another hindrance is that pheromone lures are very expensive and have a short efficacy. We did set a trap at a mid-Valley site known to have 'issues' in 2018, but no adults were detected, and the trap was destroyed unexpectedly.

Progress was made, however, by just learning more about this pest and the potential for occurrence in Western Oregon. We have collected over 15 references about this pest and will continue to mention it to others who perform field sampling in brassica vegetables and field crops.

Table 1. Summary of insect pest trends of 2019 compared to recent history.

Common and Latin name of insect	Crops affected	**2019** activity	Historic trends	Notes
Aphids (*M. persica,)*	varies by species	not monitored	not monitored since 2014	invasive species in PNW, vector transmission
Alfalfa looper (*Autographa californica)*	brassicas, snap beans, spinach	very low activity	very low activity in 2018	
Armyworms (*Mamestra configurata, Apamea* spp., *Spodoptera praefica*)	brassicas, bell peppers, small grains, pastures, *	collaborative project in Tillamook Cty. continued, higher than 2018	Bertha armyworm only species historically monitored by VN	may be related to rainfall in southern regions of N. America
Cabbage looper (*Trichoplusia ni*)	brassicas, snap beans, spinach	Outbreak levels, 400-1,200 moths per day in individual traps	2008 and 2017 were outbreak years, 2018 low, similar to 2011	regulated by a baculovirus, other factors unknown
Cabbage white butterfly (*Pieris rapae*)	brassicas	much lower than average	2004 and 2011 outbreak years. 2018 varied widely by site	activity seems to have declined overall
Corn earworm (*Helicoverpa zea*)	sweet corn, tomatoes, *	very low activity, past 2 years	2016-17 very similar to each other, above average	pattern consistent, good model for predictive estimates
Cutworm, black (*Agrotis ipsilon*)	sweet corn, snap beans, *	relatively normal seasonal average, some weeks high at certain sites	2012-2015 huge increase vs. 1996-2011. Early peaks differ yr to yr	early migrations are mostly males (?) needs confirmed, affects at-plant decisions
Cutworm, variegated (*Peridroma saucia*)	sweet corn, mint, *	very low activity, only detected in S. valley	currently evaluating	
Diamondback moth (*Plutella xylostella*	brassicas	varied by field	2016 outbreak year	
Rootworm beetles (*Diabrotica undecimpunctata* and *D. virgifera*)	snap beans, sweet corn, squash, cucumbers, *	average compared to recent years, but high	12S steadily increasing since 2014	Highly mobile, moves from grass to veg, Western corn rootworm established

* = plus other, additional documented host plants. Many of the pests we monitor are generalist feeders

IMPACTS

Subscribers to the VegNet program immediately gain a competitive edge by receiving advance warning of potential pest problems as they occur. We like to think that "detection yields protection" if the program is used as intended – as one component of an IPM plan for processed vegetable growers. Reports during critical timing of certain pests (corn earworm at silking, black cutworm at planting, diamondback moth at button stage) are especially useful for growers and crop consultants. Industry representatives (especially Valley Agronomics) continue to be our largest portion of engaged subscribers. Other, existing, recognizable subscriber subgroups to VegNet include master gardeners, retail nurseries, and private family farms.

RELATION TO OTHER RESEARCH / EXTENSION

The strength of this program lies in its regional nature and the historical data sets that have developed over 23 years (1996-2019). We've made contact with a geodata specialist who could help us develop interactive maps, which could be useful to test research hypotheses like variance in date of first catch, relation to environmental factors, and latitudinal arrival patterns of long range migrants.

We will continue to strengthening relationships with vegetable and specialty seed organizations, private industry field crop consultants, and OSU Extension programs (Master Gardener, small farms, dairy). Our overall goal is to work towards collaborative solutions to insect pest issues in Oregon.