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Final Report

Title: Broccoli Heat Tolerance and Varietal Evaluation in Western Oregon

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Abstract:

With the hot summers of recent years causing significant heat damage to broccoli heads within the Willamette valley, varietal screenings for newer and more heat tolerant varieties became necessary. Most commercially available broccoli varieties are bred for production within milder and more climatically stable regions, such as the Salinas Valley of California. Determining which broccoli varieties would be the most climatically suitable to grow here in Oregon is one of the best ways to ensure the long-term viability of the broccoli industry. Over the past four years (2019-2022), varietal screenings have been conducted at the OSU Vegetable farm in Corvallis to evaluate newly released varieties and experimental broccoli lines for suitability to our regional climate. The experimental design incorporated six planting dates (i.e. spaced one week apart) to maximize the potential range of temperature variability the broccoli varieties would see within a single growing season. The evaluation criteria used for this trial was designed to identify the broccoli hybrids which have the most complete range of desirable characteristics for broccoli growers in Oregon. Most of the 40+ broccoli lines screened in the past four years have had one or more detrimental qualities observed within the 6 plantings. The most common of the heat related detrimental qualities observed were irregularities in bead size and a lack of uniformity in head shape and color. Overall, several broccoli hybrids originating from established seed companies such as Sakata and Seminis (Lieutenant, Eastern Crown, Eastern Magic) generally performed well and produced acceptable yield and quality. However, these may lack other desirable field traits such as head exsertion, which allows for ease of mechanical harvesting. Other cultivars with consistent field performance across all four growing seasons, with heads of high quality and acceptable yields, were Kings Crown (Tainong Seed) and Asteroid (HM Clause). Viper and Wolfman, two varieties recently released by Hazera Seeds and screened in our trial for the past two years, have proven to be exceptionally consistent and the most heat tolerant of all the varieties.

Key Words:

Broccoli, Heat Tolerance, Variety Trial, Mechanical Harvesting, Processed Vegetables

Objectives:

The primary goal of this project was to identify heat tolerant broccoli cultivars suitable for processed vegetable production in the Willamette Valley of Oregon. Heat tolerance alone does not make a broccoli variety suitable for commercial processing. More often than not, yield is of paramount concern for growers, while head quality and floret characteristics are the main concerns of the vegetable processors. In consideration of these divergent perspectives, the evaluation criteria of this trial was designed to identify heat tolerant broccoli hybrids with the most complete range of desirable characteristics for broccoli growers and processors in the Willamette Valley of Oregon.

Procedures:

Identifying high performing varieties for our regional climate can be challenging, as weather fluctuates from year to year. Our strategy for examining the climatic suitability of a broccoli was to trial varieties over several seasons with multiple planting dates throughout the growing season. A cultivar would be considered climatically adaptable when it is able to grow and perform well across a wide spectrum of growing temperatures.

Varietal selection:

Selection of the varieties for the heat trial was initiated by contacting known seed company representatives, examining current online seed catalogues and collecting seeds from commercial broccoli lines which purportedly have heat adaptive 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 tolerant to high temperature environments. Cooperating universities and the USDA-NIFA-SCRI funded Eastern Broccoli Project also sent seeds of varieties for evaluation in this trial. It should be noted that some commercially available broccoli varieties were included in all four years of field evaluations, while others were dropped after the first year of field trials, due to poor performance. On the other hand, newly released varieties such as those from Hazera Seeds or Sakata, were unavailable during the initial years and included after acquiring seeds.

Experimental design:

The heat trial was designed to include six different planting dates at one-week intervals to maximize the potential range of temperature variability within a single growing season. Bjorkman and Pearson (1998) reported that 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 the reproductive phase, when the initial enlargement of bud primordia begins. A study conducted more recently estimated this period of vulnerability to heat as occurring approximately 3 weeks before harvest (Siomos, A.S. et al, 2022).

Transplant production:

Broccoli seedlings were grown in the OSU campus greenhouses and transplanted into the field at the University's Vegetable farm in Corvallis after approximately 4 weeks of growth. For each of the weekly seeding dates, 15 seeds of each broccoli variety were planted into seedling trays.

Photo 1 (above) Broccoli Heat Trial as seen on July 29th, 2021

Field preparation, planting and management:

The field was prepared by making 4 bed rows to accommodate the first 3 weeks of broccoli seedlings (three trial rows and a northern border row). Approximately 3 weeks later, another set of 4 rows was prepared in a similar fashion to accommodate the last three broccoli plantings and southern border row. Fertilizer was side-dressed prior to transplanting with a two-row planter, placing 16-16-16 fertilizer at 2 x 2 inches from the seed row at 250 lbs/A. The 10 most vigorous seedlings were then

transplanted into the randomly assigned field plots at a one foot in-row spacing. The weekly transplanting of broccoli into assigned rows typically began in early May and continued until mid-June. Irrigation was applied as necessary throughout the season. An additional input of nitrogen fertilizer (i.e. UREA @ 100lbs N/Acre) was also side dressed next to each planted row after growing in the field for approximately 2-3 weeks.

The trial site was closely monitored for any pest issues and treated as necessary. Insecticide applications for flea beetle were generally needed soon after transplanting and applications for aphid control were done as heads began to form. The weed control program generally used for the site was applying Goaltender@1pt/acre to the bed row with a single nozzle boom 48 hours before transplanting. Weed control thereafter was typically done by hand and/or using an electric wheel hoe. Two Hobo temperature loggers were placed into the trial to record the ambient air temperatures at canopy height for the duration of the trial

Data Collection:

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 determine the variety's propensity for maturing uniformly. Evaluations of broccoli head quality consisted of visually rating each head for: *color uniformity, bead uniformity, head uniformity, head firmness, and head diameter*. The ratings used a 1-9 scale, with 9 as the best rating, 1 as the lowest rating, and 5 being the cut off of acceptable quality for processing. Rating scores of <3 were typically deemed culls, especially when ratings involved more than one of the quality aspects assessed. Beginning in year two, excessive amounts of brown bead on or inside of the broccoli head would result in the head being deemed as a cull, even if other aspects of quality were acceptable, such as head uniformity. With head yield being the main concern of local broccoli farmers, and floretting characteristics the main concern of processors, the weight of each head (i.e. cut to 6in length), the weight of total florets, and the weight of usable sized florets (< 2.5in) was also incorporated into the evaluation criteria. Weights were measured using a digital field scale, while floret cuts were made using a "tomahawk" style tabletop floretter. This floretter was fabricated by the local vegetable processing plant for use in this trial to simulate the cuts made by their industrial sized floretter.

Photo 2. (above) Classic array of heat damage symptoms affecting a large broccoli head.

Accomplishments

Of the 40+ broccoli varieties evaluated during the four years of the heat trial, only a few broccoli varieties consistently produced heads of acceptable quality across the range of temperatures and environmental condition seen in a given year. Many broccoli varieties included in this trial had at least one or more detrimental qualities observed within some of the six plantings. The most common of these detrimental qualities were irregularities in bead size and lack of uniformity in head shape and color (*see Photo2*). Approximately half the varieties evaluated for this trial would fall into a category of what could reasonably be called *semi-tolerant* to heat. The quality of these broccoli heads will vary substantially from one planting date to another due to the unpredictable timing and occurrences of higher than normal temperatures. This is especially relevant when high temperatures occur simultaneously with the broccoli plant's most vulnerable

physiological stage (i.e. transitioning from a vegetative to reproductive phase[1]). Many of these *semi-tolerant* to heat tolerant varieties will demonstrate a kind of "hit or miss" pattern to head quality, and this was apparent throughout the duration of this trial for many of these varieties. Figure 1 (below) is a graph created from overall quality ratings assessed during the 2021 season. An interesting aspect of this graph is the simultaneous decline in the overall head quality of these varieties in the 3rd planting date, followed by a notable upswing in quality the following week, during the 4th planting date. This decline and upswing in quality is likely correlated to a 5-day heat wave of 100°F temperatures occurring between Aug 10th -15th, followed by a rapid cool down between Aug 17th – 23rd with high temperatures only in the upper 70°F's. This suggests that even a relatively short heat wave event can cause a precipitous decline in the quality of broccoli lines that are *semi-tolerant of heat*, resulting in numerous culls and a lower numbers of acceptable heads at harvest. Figure 2 (below) depicts how broccoli varieties classified as *tolerant to heat* perform under the same environmental conditions, and show a remarkable level of consistency regardless of ambient air temperatures. These *tolerant to heat* varieties account for approximately 25% of the broccoli lines examined over the 4 years of trialing. The remaining 25% of the broccoli varieties trialed would be considered as *intolerant to heat*. These *intolerant to heat* varieties demonstrate a low threshold to even moderately warm temperatures and many produced yields of mostly culls and disfigured heads. However, even *intolerant to heat* varieties can occasionally produce a crop of problem free heads (i.e. if the environmental conditions are sufficiently cool during the transition from vegetative to reproductive phase). This was found to be especially true of the later 6th plantings. This is mentioned as a caution to broccoli growers or researchers who are trying out new varieties, as this suggests almost any broccoli will grow well- given the right sequence of temperatures Although it was outside the scope of this heat tolerance trial, evaluating the performance of varieties grown in multiple locations can lead to a better understanding their adaptability. For example, it can be hypothesized that certain broccoli varieties were not as adaptable to different soil types commonly found

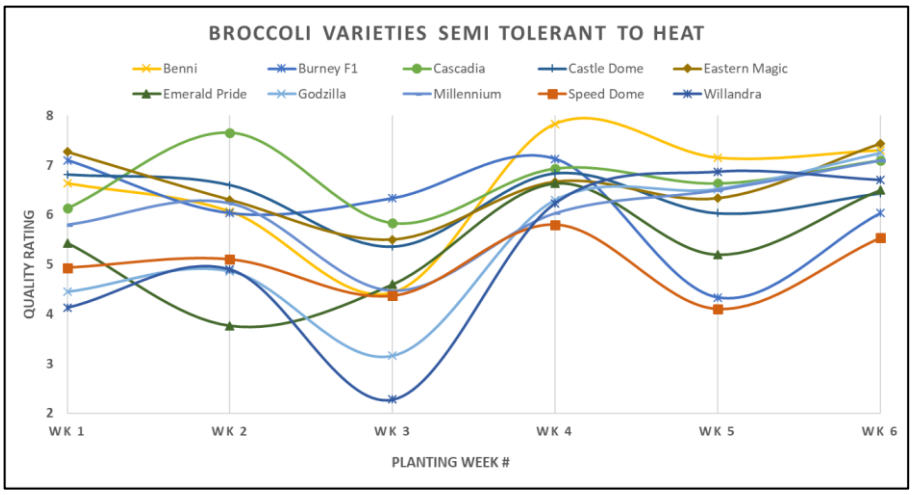


Figure 1- Broccoli varieties semi-tolerant to heat show fluctuations in quality

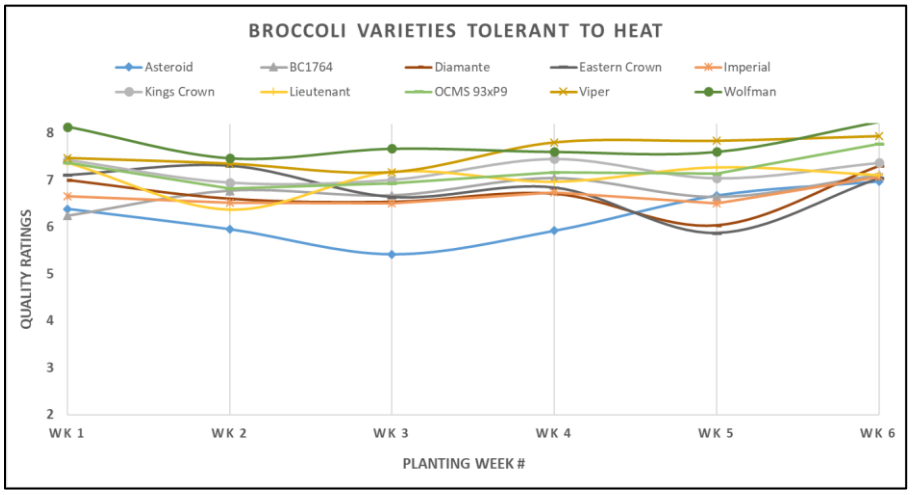


Figure 2- Broccoli varieties tolerant to heat shows quality remain consistent

in the Willamette valley. As a preliminary examination of this theory, two small scale plantings were done near Wilsonville and Woodburn, using the five most heat tolerant lines from previous years. These demo plots, consisting of 15ft rows for each variety, were incorporated into a local commercial broccoli field, and used the agronomic inputs of the larger field to grow. In one of the locations (Wilsonville) two of the most consistent broccoli varieties, Asteroid and Eastern Crown performed poorly, while the adjacent rows of Lieutenant, Kings Crown and Castle Dome grew as normal.

Table 1- Yield Summary for 2019 year

Variety	Head Yield Tons/A	**Variety**	florets <2.5in Tons/A	**Variety**	wt. Culls %
HMX 0207 F1	10.7	Eastern crown	4.2	Stellara	34.8
Stellara	10.4	BH050	3.8	P13 CMS x P19	25.4
Maracaibo RZ	9.5	Eastern magic	3.8	Kariba RZ	24.4
Ironman	9.5	Asteroid	3.5	HMX 0207 F1	24.3
Eastern crown	9.2	Corato F1	3.5	P8CMS x P19	14.5
Eastern magic	9.1	BC1691	3.5	Greenpak28	12.4
Greenpak28	8.9	Ironman	3.5	Hancock	8.8
Kariba RZ	8.9	Imperial	3.5	Willandra RZ	8.4
BC1691	8.8	Eiffel	3.4	Ironman	7.9
Batory	8.8	Kings Crown	3.3	Covina F1	7.8
Covina F1	8.8	Batory	3.3	Batory	7.6
BH050	8.8	Lieutenant	3.3	Darien RZ	7.2
Castle Dome	8.2	Castle Dome	3.2	Maracaibo RZ	7.1
Corato F1	8.1	Covina F1	3.2	Virgo F1	6.8
Lieutenant	8.0	Maracaibo RZ	3.2	Monflor	6.0
Willandra RZ	7.9	Darien RZ	3.0	Corato F1	3.9
Asteroid	7.9	Willandra RZ	2.9	Durapak16	3.9
BC1764	7.9	Hancock	2.9	BH055	3.6
Kings Crown	7.7	BC1764	2.9	BH050	2.6
Imperial	7.6	Durapak16	2.9	Eastern magic	2.3
Hancock	7.5	HMX 0207 F1	2.8	Lieutenant	2.0
Darien RZ	7.5	Greenpak28	2.7	Asteroid	1.8
Eiffel	7.5	Emerald pride	2.6	Imperial	1.7
Durapak16	7.2	Cascadia	2.5	Eiffel	1.5
Virgo F1	7.1	Virgo F1	2.5	BH026	1.1
P13 CMS x P19	6.8	BH053	2.5	Emerald pride	1.0
P8CMS x P19	5.9	BH044	2.5	Castle Dome	0.9
Emerald pride	5.7	Kariba RZ	2.4	Kings Crown	0.7
BH053	5.4	Monflor	2.4	BC1764	0.7
BH026	5.1	BH027	2.4	BH027	0.3
Cascadia	5.1	OCMS 93 x P9 (E	2.3	BC1691	0.0
BH044	5.1	BH055	2.3	Bejo 2971 F1	0.0
BH045	5.0	BH026	2.3	BH044	0.0
BH027	4.8	BH045	2.2	BH045	0.0
Monflor	4.7	P8CMS x P19	1.9	BH053	0.0
BH055	4.6	Stellara	1.9	Cascadia	0.0
OCMS 93 x P9	4.4	Bejo 2971 F1	1.8	Eastern crown	0.0
Bejo 2971 F1	3.7	P13 CMS x P19	1.8	OCMS 93 x P9	0.0

Table 2- Yield Summary for 2020 year

Variety	Head Yield Tons/A	**Variety**	florets <2.5in Tons/A	**Variety**	wt. Culls %
Eastern crown	8.70	Eastern crown	4.02	Ironman	40.2
Eastern magic	8.48	Eastern magic	3.98	Kariba RZ	32.0
Eiffel	7.78	Imperial	3.82	BH050	31.2
Imperial	7.77	Asteroid	3.69	BR6991	30.5
Willandra RZ	7.72	Eiffel	3.59	Batory	29.3
Castle Dome	7.58	Kings Crown	3.47	BC1691	18.0
BC1691	7.48	BR6991	3.42	Eiffel	11.4
Darien RZ	7.06	Willandra RZ	3.40	Darien RZ	10.8
Corato F1	7.01	Castle Dome	3.34	BH053	10.1
Asteroid	6.90	Corato F1	3.28	Hancock	8.8
BC1764	6.90	Lieutenant	3.28	Willandra RZ	8.1
Kings Crown	6.87	Cascadia	3.27	Virgo F1	8.0
Lieutenant	6.80	Darien RZ	3.14	Eastern magic	6.3
Emerald pride	6.35	Emerald pride	2.90	Emerald pride	5.2
Virgo F1	6.16	BC1764	2.87	Lieutenant	4.3
Hancock	6.14	BC1691	2.82	Cascadia	2.3
Cascadia	6.13	OCMS 93 x P9	2.77	Imperial	1.8
BH050	5.85	Hancock	2.63	Castle Dome	1.3
Kariba RZ	5.82	BH053	2.61	Asteroid	0.0
BH053	5.58	BH050	2.54	BC1764	0.0
Batory	5.50	Kariba RZ	2.53	Corato F1	0.0
BR6991	5.39	Virgo F1	2.45	Eastern crown	0.0
Ironman	4.78	Batory	2.38	Kings Crown	0.0
OCMS 93 x P9	4.76	Ironman	2.19	OCMS 93 x P9	0.0

Table 3- Yield Summary for 2021 year

2021 Broccoli lines Heat Varietal Evalation	Yield of Cut Heads acceptable quality Tons/A	Culls unacceptable Tons/A	Culls unacceptable % wt of Yield	Total Florets all sizes Tons/A	Usable Sized Florets < 2.5 inch Tons/A	Usable Sized Florets < 2.5 inch usable % of florets
Asteroid	10.8	0.80	6.9	6.9	3.9	56.1
BC1691	8.1	3.47	30.0	5.7	2.8	49.5
BC1764	9.5	0.00	0.0	6.4	3.8	60.1
Benni	7.0	0.80	10.3	4.8	3.0	62.8
Burney	8.1	2.80	25.6	5.2	3.3	64.1
Cascadia	6.6	0.10	1.5	3.8	3.0	78.1
Castle Dome	11.3	0.54	4.5	9.3	4.7	51.2
Diamante	14.7	0.39	2.6	9.4	6.0	63.8
Eastern crown	12.2	1.00	7.6	7.5	4.8	64.2
Eastern magic	12.3	0.62	4.8	7.6	5.0	65.5
Eiffel	8.6	1.48	14.7	6.3	3.5	56.0
Emerald pride	8.0	0.57	6.6	5.1	3.4	67.1
Godzilla	8.6	1.39	14.0	5.5	3.0	55.1
Imperial	10.2	0.33	3.2	6.6	4.2	63.7
Kings Crown	9.4	0.55	5.5	6.3	3.8	60.6
Lieutenant	10.8	0.35	3.1	7.1	4.2	58.7
Millennium	13.0	1.05	7.5	8.6	5.0	58.6
OCMS 93 x P9	5.3	0.00	0.0	3.3	3.0	91.7
SBC 7576	10.2	0.00	0.0	6.7	3.8	56.7
Speed Dome	7.5	2.08	21.7	4.5	2.8	62.8
Tahoe	6.6	3.03	31.4	4.7	2.8	59.9
Viper	7.0	0.00	0.0	4.6	3.5	75.1
Willandra	6.2	4.14	40.0	4.1	2.6	64.5
Wolfman	7.2	0.00	0.0	4.8	3.4	69.7

Table 4-Yield Summary for 2022 year

2022 Broccoli lines Heat Varietal Evaluation	Yield of Cut Heads acceptable quality Tons/A	Culls unacceptable Tons/A	Culls unacceptable % of Yield	Total Florets all sizes Tons/A	Usable Sized Florets <2.5 inch Tons/A	Usable Sized Florets <2.5 inch usable % of florets
Abrams	9.6	3.4	26.0	6.5	3.5	52.8
Asteroid	10.7	0.3	2.8	7.0	4.0	57.9
BC1764	8.1	2.7	25.2	5.7	3.1	54.2
Benni	10.1	1.5	12.9	7.1	4.0	55.9
Castle Dome	8.6	3.2	27.4	5.8	3.5	59.8
Corato	9.6	2.0	17.2	6.0	4.2	69.9
Diamante	13.4	1.1	7.4	10.2	6.3	61.4
Eastern Crown	10.3	5.2	33.4	6.3	4.0	62.5
Eastern Magic	6.3	6.9	52.5	3.8	2.6	68.2
Eiffel	7.9	2.8	26.3	4.6	2.5	54.4
Emerald Pride	7.4	1.1	12.7	4.5	3.2	70.6
Hancock	8.3	3.1	26.8	5.7	3.1	54.4
Imperial	10.5	2.2	17.2	6.8	4.2	61.2
Kings Crown	8.5	2.0	19.4	5.7	3.5	60.6
Lieutenant	10.0	2.3	18.4	6.8	4.1	59.8
Maracaibo	5.9	5.4	47.6	4.2	2.0	47.9
Millennium	9.2	6.7	42.1	6.2	3.6	57.5
Monflor	7.7	1.1	13.0	4.4	3.6	82.3
SEL-ER8143	6.9	4.7	40.9	3.8	2.2	56.6
Spectre	9.0	3.5	28.1	6.2	3.4	54.5
Tahoe	3.6	8.8	70.9	2.6	1.5	57.4
Viper	8.6	0.5	5.7	5.8	4.1	70.8
Warthog	8.0	4.7	37.1	5.7	3.1	54.9
Willandra	7.6	4.7	38.4	4.9	2.9	58.8
Wolfman	9.8	0.1	0.6	6.6	4.2	64.4

Varietal recommendations:

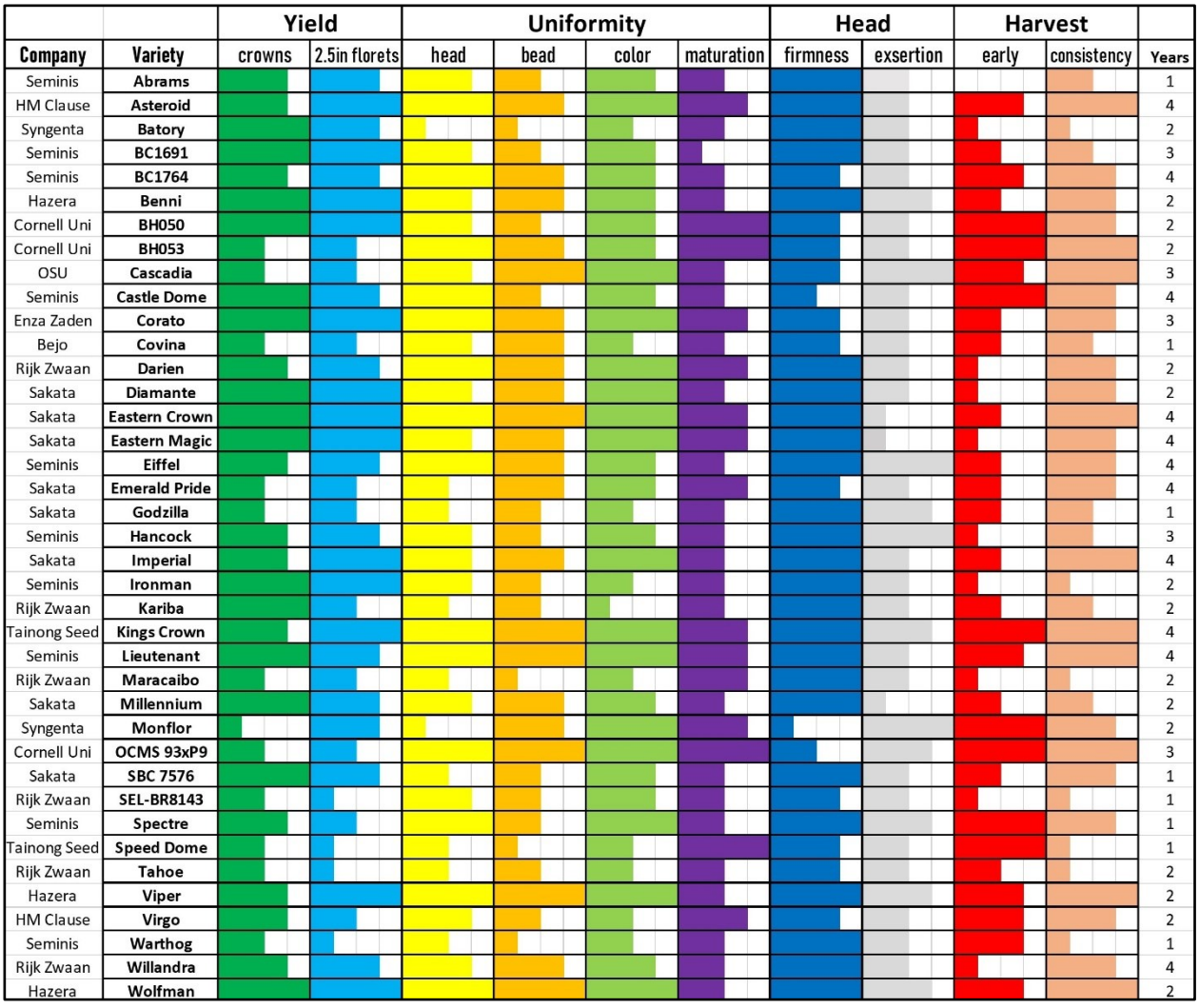
One of the most common questions asked in reference to this type of heat tolerance and varietal trial is: "*what broccoli did the best*?" or "*what broccoli do you recommend*?". Realistically, recommendations can only be made in the context of a grower's priorities and the answer will vary considerably depending on what qualities they feel are the most important. More often than not, it is a combination of several characteristics that narrow down the possibility of recommending a variety. For example, broccoli farmers often consider yield to be the most important factor, but only looking at a chart of the highest yielding varieties would be an over simplification of the varietal selection process. Some of the largest broccoli heads grown in this trial (e.g. 1000-1400 gram heads) were from varieties with the least amount of heat tolerance, with 30-40% of the harvest being deemed culls. The highest yielding variety in both 2021 and 2022 was *Diamante* from Sakata, which does show good heat tolerance and consistency. However, the distinctly round head shape (i.e. impeding proper floret cuts) and habit of growing low to the ground (i.e. making field harvesting difficult) would make it impractical for large commercial field production. In addition, Diamante also had the longest *days to harvest* of all the varieties evaluated. Figure 3 (below) is a summary chart created as a visual aid and guide for this selection process, as it details the most relevant factors a broccoli grower would likely want to know while selecting a variety to plant in western Oregon. This chart is based on the collective results of our field trials in Corvallis over the past four years.

Processed broccoli production:

Recommending a broccoli variety that meets the expectations of farmers and the grading criteria of the processing plant is difficult. Obviously, there is no broccoli currently available which is going to be everything to everyone. Several broccoli varieties evaluated for this trial showed tolerance to temperature variations, but did not produce commercially viable yields at harvest. While other broccoli varieties may have produced high yields in all plantings, they still would be considered impractical at a commercial level because of unfavorable characteristic traits such as poor floretting sizes or lack of any head exsertion.

Photo 3- Mechanical harvesting of broccoli, as seen Sep 14th,2022

Using mechanical harvesting as example, the most desirable traits a grower would typically want is head exsertion and maturation uniformity. Yet the summary chart from this trial (Figure 3) shows no broccoli variety evaluated for this study has both of those qualities. In fact, it can be noticed that head exsertion and maturation uniformity are actually the two rarest traits seen in all the broccoli varieties. When combined with the need for other priority traits such as high yielding and/or floretting into acceptable sizes, it becomes apparent some compromises are needed in the varietal selection process. Mechanical harvesting may be the future of commercially grown broccoli but finding a variety that is completely compatible with it is still currently elusive. During our search for new varieties to use in this heat tolerance trial, it became apparent very few commercial varieties have head exsertion traits. James Myers (OSU broccoli breeder) has observed that selective breeding for head exsertion traits often seems to be negatively correlated with head yield. The secondary problem of uniform maturation of broccoli heads in the field may only be partly related to varietal selection. Several studies have suggested it is also correlated to small physiological differences arising from environmental variations in light and soil fertility (Rogers, 2009). Broccoli varieties recommended for commercial processed broccoli production in the Willamette Valley would need to be field-evaluated by growers in on-farm trials over multiple years. This approach would be recommended, as the data from our heat tolerance trial suggests successfully growing one or two field plantings in a given location, doesn't necessarily guarantee its success in all scenarios.



		Yield		Uniformity				Head		Harvest		
Company	Variety	crowns	2.5in florets	head	bead	color	maturation	firmness	exsertion	early	consistency	Years
Seminis	Abrams											1
HM Clause	Asteroid											4
Syngenta	Batory											2
Seminis	BC1691											3
Seminis	BC1764											4
Hazera	Benni											2
Cornell Uni	BH050											2
Cornell Uni	BH053											2
OSU	Cascadia											3
Seminis	Castle Dome											4
Enza Zaden	Corato											3
Bejo	Covina											1
Rijk Zwaan	Darien											2
Sakata	Diamante											2
Sakata	Eastern Crown											4
Sakata	Eastern Magic											4
Seminis	Eiffel											4
Sakata	Emerald Pride											4
Sakata	Godzilla											1
Seminis	Hancock											3
Sakata	Imperial											4
Seminis	Ironman											2
Rijk Zwaan	Kariba											2
Tainong Seed	Kings Crown											4
Seminis	Lieutenant											4
Rijk Zwaan	Maracaibo											2
Sakata	Millennium											2
Syngenta	Monflor											2
Cornell Uni	OCMS 93xP9											3
Sakata	SBC 7576											1
Rijk Zwaan	SEL-BR8143											1
Seminis	Spectre											1
Tainong Seed	Speed Dome											1
Rijk Zwaan	Tahoe											2
Hazera	Viper											2
HM Clause	Virgo											2
Seminis	Warthog											1
Rijk Zwaan	Willandra											4
Hazera	Wolfman											2

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

Figure 3 (above) ***Summary chart of qualities for selected varieties evaluated during the four years of field trialing. This chart is created as a visual aid for the varietal selection process & uses a rating system of 1 to 4 to predict a variety's propensity to perform well in the given aspects listed (4 being the best score). The consistency column on the right can be considered a surrogate term for a variety's level of heat tolerance. Broccoli with a consistency score of 4 would be considered Heat Tolerant, scores of 2 & 3 would be Semi-Tolerant, and score of 1 being Intolerant of Heat. The last column on the right shows the number of years an individual variety was included in this trial. As an example, some of these varieties may have been dropped from the trial after one year due to poor performance, while others may just be new releases which only became available in the last year or two of the trial. Not all varieties are listed, as some were so intolerant as to not be recommended***

Most Recommended Varieties

Asteroid -Bred by Harris Moran

Purplish green hue suited for crown cuts, bunching and florets with a fairly smooth dome and medium-small beads. Very good consistency and heat tolerance, suitable for many planting dates. Good maturation uniformity. Approximately 88 days from seed to harvest

Eastern Crown - Bred by Sakata

One of the most consistent broccoli hybrids. Heavy yielding with large dome shaped heads & fine medium small beads. Very good heat tolerance and suitable for several planting dates. Very compact plants, often with heads only 12 inches off the ground. Approximately 90 days from seed to harvest.

Kings Crown - Bred by Tainong

Originating from one of the smaller seed companies, Kings crown has proven to be a reliable broccoli to grow in our trials. A good yielding variety with medium to large heads and medium sized beads. Approximately 75 days from seed to harvest

Most Recommended Varieties

Lieutenant – Bred by Seminis

One of the most classic looking of the broccoli hybrids we have evaluated at the research farm, its form makes it well suited for fresh market and commercial production. Very consistent and easy to grow hybrid that has been around for many years. Has good holding abilities. Approximately 80-85 days from seed to harvest.

Viper – Bred by Hazera Seed

One of the most consistent and heat tolerant broccoli we have grown. Original recommended to us by the Eastern Broccoli Project, it has become a standout variety in our trials. Its light purple hue and smooth medium beads would make it suitable for fresh market or commercial settings. Approximately 80 days from seed to harvest

Wolfman– Bred by Hazera seed

Wolfman is a slightly higher yielding, slightly less heat tolerant version of Viper. Very similar in appearance to Viper, it has also proven to be a reliable variety to grow in western Oregon. Approximately 85 days from seed to harvest.

Impacts:

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 declined by 66 %; broccoli production peaked at 15,000 tons in 1987 and about 5,000 tons were processed in 2017. Temperature is increasingly the primary limiting factor in determining the yield and processing quality of a broccoli variety. The recent trend toward warmer summers in Oregon suggests the need for a more heat tolerant broccoli will only increase in the foreseeable future. The identification of heat tolerant broccoli cultivars with commercially acceptable head and floret quality is an important contribution to the ongoing efforts to improve the sustainability of processed vegetable production in the Willamette Valley.

Relation to Other Research:

The Oregon State University vegetable breeding program is currently working on bring in new genetic lines to develop locally adapted, high yielding exserted broccoli varieties suitable for mechanical harvesting.

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1. Björkman, T.; Pearson, K.J. High temperature arrest of inflorescence development in broccoli (Brassica oleracea var. italica L.). J. Exp. Bot. 1998, 49, 101–106.

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3. Jenni, S., Dutilleul, P., Yamasaki, S., and Tremblay, N. 2001. Brown bead of broccoli. I. Response of the physiological disorder to management practices. HortScience 36(7):1224–1227.

   https://journals.ashs.org/downloadpdf/journals/hortsci/36/7/article-p1224.pdf

4. Rogers, G. 2009. Agronomic programme to improve the uniformity of broccoli for once-over mechanical harvesting. Horticulture Australia Project Number: VG06053.

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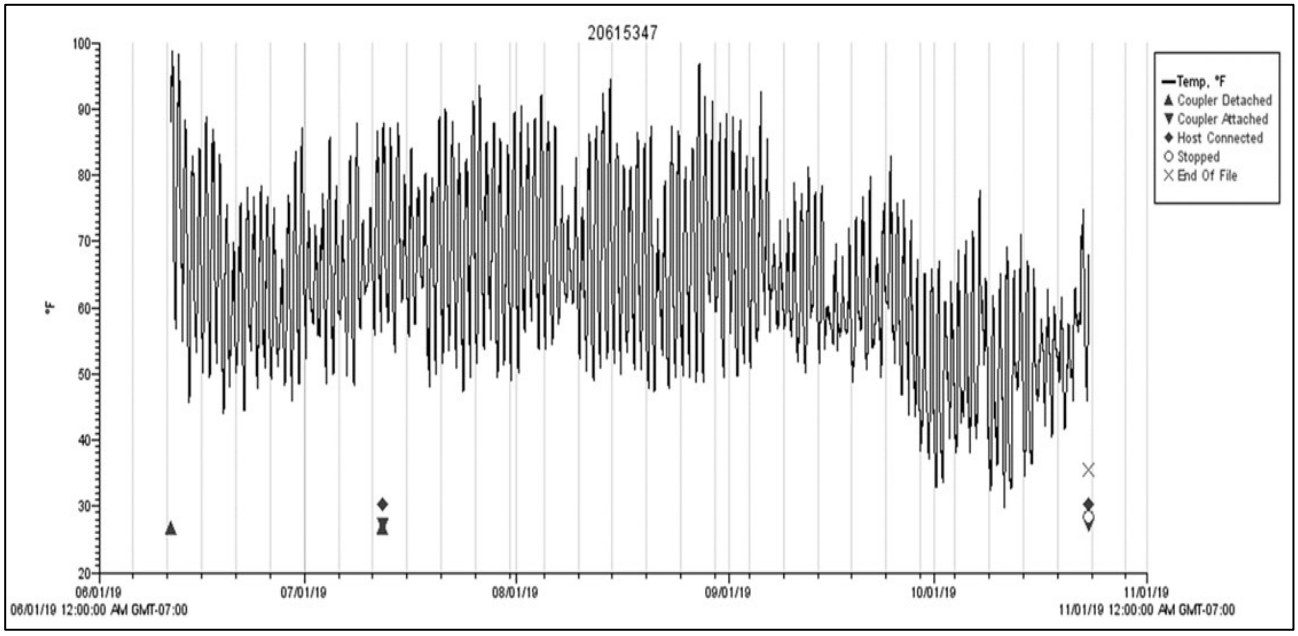
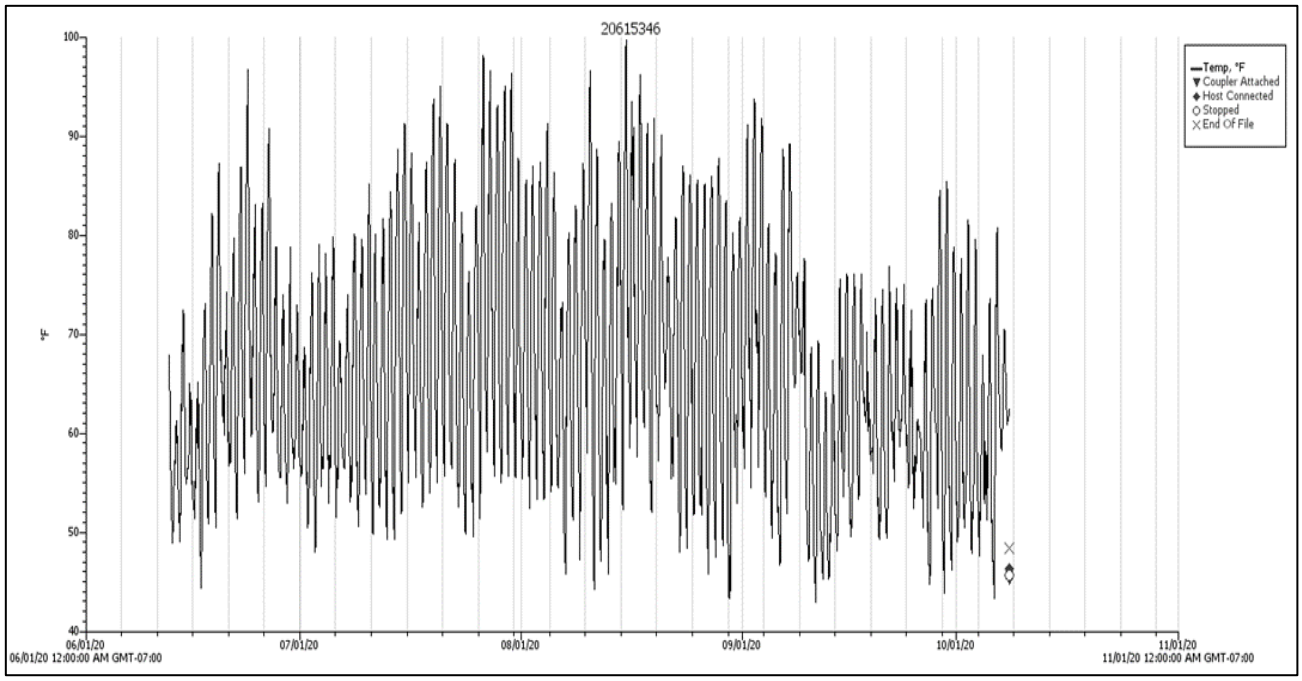
Appendix

Temperature records

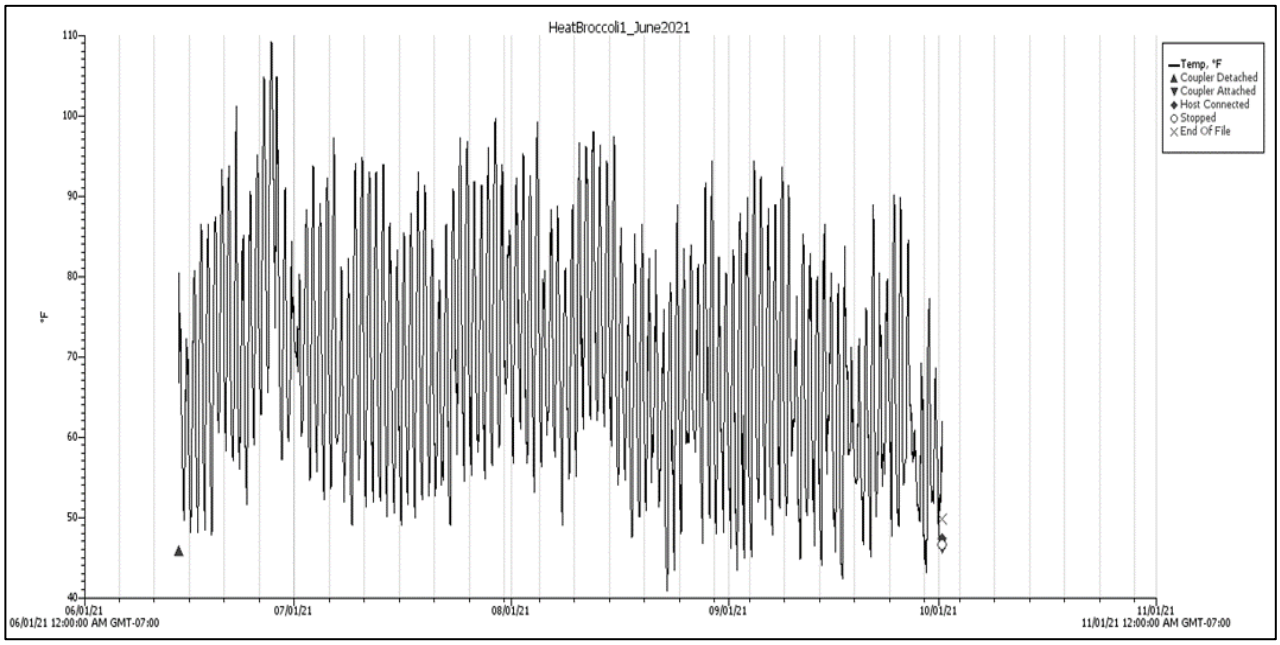


Appendix Graph 1- Temperatures at trial site for year 2019, Hobo Logger

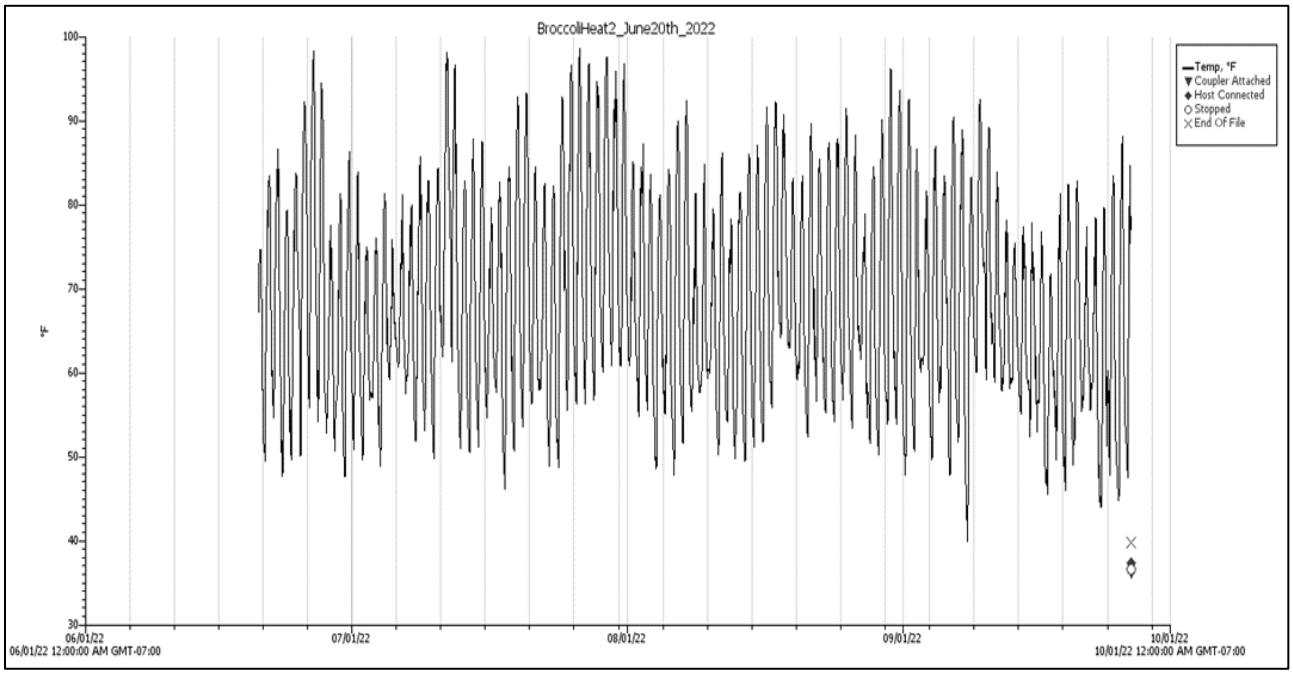


Appendix Graph 2-Temperatures at trial site for year 2020, Hobo Logger

Temperature records, continued



Appendix Graph 3-Temperatures at trial site for year 2021, Hobo Logger



Appendix Graph 4-Temperatures at trial site for year 2022, Hobo Logger

Photos

Photo 1 - "Tomahawk" Broccoli floretter

Photo 2 - Greenhouse seeding of broccoli

Photo 3- Exserted Head Broccoli

Photo 4- Short low growing broccoli

Sample Location	Total Exchange Capacity (meq/100 g)	pH	Organic Matter (%)	Estimated Nitrogen Release (# N/acre)	S* (ppm)	P* (mg/kg)	Bray II P (mg/kg)	Ca* (mg/kg)
Broccoli Site OSU	18.94	6.1	2.64	73	7	60	251	2179

B* (mg/kg)	Fe* (mg/kg)	Mn* (mg/kg)	Cu* (mg/kg)	Zn* (mg/kg)	Al* (mg/kg)
0.34	229	40	2.34	2.18	751

Mg* (mg/kg)	K* (mg/kg)	Na* (mg/kg)	Ca** (%)	Mg** (%)	K** (%)	Na** (%)	Other Bases** (%)	H** (%)
462	189	39	57.52	20.33	2.56	0.9	5.2	13.5

Soil Analysis Report (Brookside Laboratories) Broccoli field site, OSU Vegetable farm

Photo 5 *– Excessive brown beading of heads. One of the more common symptoms of heat related damage, often affecting broccoli heads which would otherwise be considered acceptable. Brown beading to this extent would result in cull designation.*