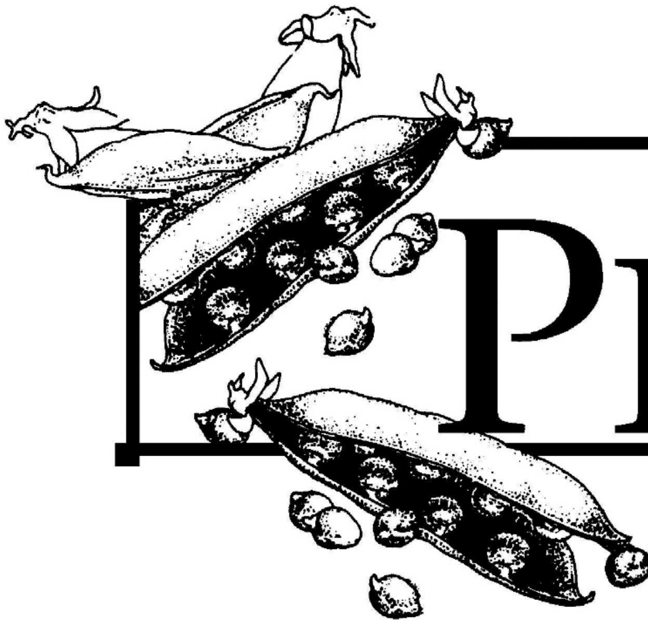
UNIVERSITY
OF DELAWARE



PEA

VARIETY TRIAL RESULTS

2024

Emmalea Ernest

University of Delaware
Carvel Research and Education Center
16483 County Seat Highway
Georgetown, DE 19947

Acknowledgements

The author wishes to thank the following people and companies for their support, interest and work on the 2024 Pea Variety Trial.

Participating Seed Companies
Pure Line Seeds, Inc.
Brotherton Seed Co., Inc.
Crites Seeds, Inc.
Seminis Vegetable Seeds
Syngenta

Seed of standard varieties was provided by collaborating vegetable processor, The Pictsweet Company.

Thank you to the farm staff at the University of Delaware Research & Education Center, Georgetown, for their assistance in planting and irrigating the trial, as well as maintaining the viner.

Thank you to my 2024 student summer crew, Arely Arriaga-Gonzalez, Lily Hearn, Ketsia Murat, Brayden Hearn, Twyla Beachy and Sam Cooke. Lyndsie Mikkelsen, Extension Vegetable & Fruit Agent also assisted with the trial.

2024 University of Delaware Pea Variety Trial

Emmalea Ernest
University of Delaware
Elbert N. and Ann V. Carvel Research and Education Center
16483 County Seat Highway
Georgetown Delaware 19947
(302) 856-7307
emmalea@udel.edu

Introduction

The 2024 Pea Variety Trial was conducted at the University of Delaware Research and Education Center. The aim of the trial is to evaluate varieties and identify those best adapted to the region. Yield, quality and maturity are important characteristics that can vary for any one variety between production regions. Similar trials have been conducted on the Georgetown research farm since 1994. This year's trial was planted on April 10, 2024.

Materials and Methods

Planting and Crop Management

There were 25 varieties in the trial, which was located in Field 6-C at the University of Delaware Research Farm in Georgetown, DE. The field was limed and potassium was applied according to soil test results prior to planting. The trial was irrigated as needed and grown under standard commercial management practices. Weed control in the trial was very good.

Insecticide: Diazinon 3 qt/A applied and incorporated April 8, 2024

Planting Date: April 10, 2024

Herbicide: Pursuit @ 2 oz/A + Dual Magnum @ 1.2 pt/A with N-SUL 33 (27-0-0-6) at 28 gal/A (80 lbs/A of N) April 11, 2024

Planting: The trial was planted using an Almaco drill with 9 rows spaced 8 inches apart. Seeding rate was 8 to 9 seeds per foot of row.

Plot Design: Plots were arranged in a randomized complete block design with 3 replications.

Pre Harvest Data

The date of first flower and peak flowering was noted for each plot.

Harvest Procedure

Each variety was harvested as near to a tenderometer reading of 100 as possible. Pre-harvest samples were taken two to three days prior to reaching this maturity level whenever possible (Table 11). A viner breakdown on June 10 caused a backup in harvest that resulted in more varieties than usual being harvested at high tenderometer readings. All three replications for each variety were harvested on the same day.

Plants were pulled from a 6 x 25 foot section of the plot (150 ft^2). The vines were weighed and fed into a stationary FMC viner. Shelled peas were collected and cleaned (removing leaves, stones, and other trash). The clean, shelled peas were weighed. A 700 g sub-sample was put through a size separator that segregated peas into the following sizes according to their diameter: 12/32 inch or greater (#4 sieve size); between 11/32 and 12/32 inch (#3 sieve size); between 9/32 and 11/32 inch (#1 and #2 sieve size); and peas smaller than 9/32 inch (trash). After each size was weighed, peas with sieve sizes 1 through 4 were recombined into a bulk sample with the smallest (trash) peas removed. Three tenderometer readings were taken from this bulked sample. The average is reported.

Ten plants were sampled from each variety and the following measurements were taken: vine length; number of nodes setting pods; number of pods per plant; pod length; and peas per pod. Statistics for pod length and number of peas per pod were calculated based on ten pods that were randomly selected from the ten sampled plants.

Varieties in the 2024 Pea Variety Trial

Variety Name*	Reported Heat Units	Supplier
Eldorado (check)	1110	Pure Line
Sherwood (check)	1160	Seminis
PLS 534 ‘Short story’	1200	Pure Line
SV3628QH	1205	Seminis
M-14 (check)	1220	Pure Line
SVQH2015	1250	Seminis
SVQF2070	1300	Seminis
Ambler	1300	Crites
PLS 613-89	1320	Pure Line
Idalgo	1340	Syngenta
Portage (check)	1340	Crites
DGL0062 'Kudo'	1346	Syngenta
EXP773	1360	Brotherton
SVQB2566	1470	Seminis
PLS 602	1475	Pure Line
CS-468AF	1520	Crites
Eden	1520	Crites
Dancer (check)	1520	Pure Line
PLS 595	1550	Pure Line
BSC737	1560	Brotherton
EXP710	1560	Brotherton
CS-441AF	1600	Crites
SV6844QG (check)	1600	Seminis
Obigo	1634	Syngenta
EXP649	1650	Brotherton

*Gray highlighted cells indicate afila varieties.

Discussion of Trial Results

The results of this trial are summarized in eleven tables and one chart. In most tables the variety means are listed in descending order. Means followed by the same letter are not significantly different as determined by Fischer’s protected LSD with 5% error (α=0.05). The LSD value, p-value for the effect of the independent variable and the coefficient of variation (CV) are included at the bottom of each table.

The trial was planted on April 10. Harvest began on June 3 with the earliest varieties, Sherwood and Eldorado. The latest maturing variety was SV6844QG, harvested on June 17. The season was warmer and dryer than the 1991-2020 temperature and precipitation means for UD's Georgetown Research Farm, see table below for departures from average, which are based on calculations done by the Delaware Climate Office for April 2024, May 2024 and June 2024.

Departures from 1991-2020 Average Temperature and Precipitation for UD's Carvel Research & Education Center, Georgetown, DE

Month	Departure from Average Temperature (°F)	Departure from Average Precipitation (inch)
April 2024	+2.3	-2.2
May 2024	+1.7	-0.3
June 2024	+2.5	-2.8

Chart 2 is a summary of the season's weather showing daily highs, lows and precipitation events. Irrigation was applied as necessary via an overhead linear irrigation system. Although temperatures were higher than average, daily highs mostly remained below 85 ºF.

All seed used in the trial was treated with insecticide and Diazinon was applied two days before planting. Stand emergence in the trial was very good and seedcorn maggot damage was not apparent. Weed control in the trial was excellent.

Table 3 reports the net and gross yields adjusted to a tenderometer reading of 100. The adjustment calculation procedure is based on the method described by Pumphrey *et al.* (see Appendix A: Adjusting Pea Yields to a T-Reading of 100). Briefly, the adjustment factor (Y) is the percent of yield at a T-reading of 100 for the T-reading at harvest (X).

$$Y = -1059.1 - 8.405X + 200X^{½}$$

and

$$\text{Yield adjusted to a T-reading of 100} = \frac{\text{Yield at T-reading } X}{(Y/100)}$$

The net yield is calculated by subtracting the percent of peas smaller than 9/32 inch, trash, (as determined by sizing of a 700 g sub-sample) from the gross yield.

Yields in the 2024 trial were average compared to what has been observed in the past 20 years for April-planted trials. Average yield for the previous ten April trials (2005-2022) is 3394 lbs/A for all varieties trialed and the average yield for the 2024 trial was 3391 lbs/A. However, this year's average yield is the highest since 2012.

Six varieties that are being used by regional processors were included in the trial as checks: Eldorado, Sherwood, M-14, Portage, Dancer and SV6844QG. The check varieties are highlighted grey in tables 1-11. The highest yielding variety in the trial was SVQF2070 and net yields for the following nine varieties were not significantly different than SVQF2070: SVQB2566, CS-468AF, Portage, EXP649, CS-441AF, SV3628QH, SV6844QG, Ambler, and EXP773. The check varieties Portage and SV6844QG were among the highest yielding varieties.

EXP773 was among the highest yielding varieties in the 2022 Delaware pea trial. The other top yielding varieties had not been tested in previous Delaware trials.

Sherwood was the highest yielding early variety, but was not significantly different than Eldorado, the other very early variety in the trial. Short Story was later than Eldorado and Sherwood and had significantly lower yields that both Sherwood and Eldorado.

SV3628QH, SVQB2566 and Ambler had similar maturity to the check variety M-14 but had significantly higher yields.

Most varieties produced majority sieve size 3 peas (Table 4). SV6844QG produced a significantly percentage of sieve size 4 peas (37%) than all the other varieties, which may have been partially due to later than ideal harvest. The following varieties produced 20-30% size 4 peas: Idalgo, Portage, Eldorado and CS-468AF. Varieties with majority sieve size 1 & 2 peas were PLS 613-89, PLS 602, SVQH2015, Dancer, and BSC737. Of these smaller sieve varieties, PLS 613-89 had the highest yield and it had significantly higher yield than SVQH2015, DSC737 and Dancer.

Pre-Harvest Data
Table 1: Flowering Data

Variety	First Flower		Full Flower	
	DAP	Heat Units	DAP	Heat Units
Eldorado	33	667	36	733
Sherwood	34	689	37	755
SV3628QH	37	733	43	878
Short Story	37	755	40	821
M-14	37	755	42	847
Ambler	40	798	44	913
EXP773	40	821	44	945
SVQH2015	40	821	44	945
Kudo	40	821	45	945
Portage	40	821	44	945
PLS 613-89	40	821	44	945
Idalgo	41	847	45	978
SVQB2566	43	913	46	1012
SVQF2070	43	913	46	1012
CS-468AF	44	945	47	1045
EDEN	44	945	50	1133
PLS 602	45	978	49	1079
PLS 595	46	1012	48	1079
CS-441AF	46	1012	51	1133
Obigo	46	1012	49	1107
BSC737	47	1012	51	1133
EXP649	47	1012	51	1155
SV6844QG	47	1045	51	1155
EXP710	48	1045	51	1155
Dancer	48	1079	51	1133

Harvest Data

Table 2: Weight of Vines from 150 ft^2 Harvest Area (lbs)

Variety	Vine Weight (lbs)	
CS-441AF	123	a
Short Story	113	ab
CS-468AF	111	abc
PLS 602	107	bcd
EXP649	104	bcde
PLS 595	101	bcdef
SVQH2015	100	bcdef
Idalgo	100	bcdefg
SVQF2070	100	cdefg
EXP773	99	cdefgh
Dancer	96	defghi
SVQB2566	92	efghij
EXP710	91	efghijk
Eden	91	efghijkl
SV6844QG	89	fghijkl
Obigo	87	ghijklm
M-14	86	hijklm
PLS 613-89	86	ijklm
Portage	85	ijklm
SV3628QH	83	ijklm
Ambler	80	jklmn
Sherwood	79	klmn
Eldorado	78	lmn
BSC737	74	mn
Kudo	69	n
p-value	***<0.0001***	
LSD	**13.1**	
CV	**8.6**	

Table 3: Gross Yields and Net Yields (% Trash Subtracted) Adjusted to a Tenderometer Reading of 100, T-Reading at Harvest

Variety	Gross Yield (lbs/A)		Net Yield (lbs/A)		T-Reading @ Harvest	
SVQF2070	4758	a	4694	a	175.8	b
SVQB2566	4511	ab	4461	a	182.1	a
CS-468AF	4500	ab	4444	a	124.2	f
Portage	4370	abc	4316	ab	136.1	e
EXP649	4352	abc	4197	abc	109.0	j
CS-441AF	4381	abc	4186	abc	102.7	l
SV3628QH	4245	abcd	4158	abcd	107.6	jk
SV6844QG	4097	abcde	4058	abcd	166.8	c
Ambler	4118	abcde	4019	abcde	111.6	hij
EXP773	4245	abcd	3992	abcde	92.3	m
Sherwood	3769	bcdef	3612	bcdef	113.9	ghi
Eden	3590	cdefg	3480	cdefg	125.4	f
PLS 613-89	4005	abcde	3478	cdefg	138.7	e
Obigo	3476	defgh	3420	defg	143.6	d
PLS 595	3365	efghi	3298	efgh	116.1	g
EXP710	3134	fghij	3002	fghi	107.8	jk
Eldorado	3188	fghij	2995	fghi	104.3	kl
PLS 602	3538	defg	2895	fghi	115.4	gh
M-14	2873	ghijk	2754	ghi	110.9	ij
Kudo	2691	hijk	2625	hi	163.4	c
SVQH2015	3112	fghij	2604	hi	90.4	m
BSC737	2636	ijk	2413	i	103.0	l
Idalgo	2411	jk	2389	ij	165.2	c
Short Story	2209	k	1662	jk	89.2	m
Dancer	2170	k	1627	k	93.2	m
p-value	***<0.0001***		***<0.0001***		***<0.0001***	
LSD	**796.0**		**748.1**		**4.48**	
C.V.	**13.5**		**13.4**		**4.0**	

Table 4: Pea Size (% peas by weight in each class) and Tenderometer Reading at Harvest

Variety	% #4		% #3		% #1 & #2		% Trash		T-reading at Harvest	
SV6844QG	37.4	a	53.2	abc	8.5	o	1.0	g	166.8	c
Idalgo	28.7	b	53.2	abc	17.2	mn	1.0	g	165.2	c
Portage	26.1	bc	57.0	ab	15.7	n	1.2	g	136.1	e
Eldorado	21.5	cd	44.6	fg	27.9	ijkl	6.0	de	104.3	kl
CS-468AF	21.0	d	55.2	abc	22.6	lm	1.3	g	124.2	f
EXP649	19.4	de	53.6	abc	23.5	klm	3.6	efg	109.0	j
SV3628QH	16.8	def	51.1	bcde	30.0	hijk	2.1	efg	107.6	jk
PLS 595	15.7	efg	57.3	a	25.0	jkl	2.0	efg	116.1	g
Sherwood	14.4	fgh	50.2	cdef	31.4	ghij	4.1	efg	113.9	ghi
SVQB2566	12.9	fghi	53.0	abc	33.0	ghi	1.1	g	182.1	a
EXP773	12.3	fghi	49.1	cdef	33.0	ghi	5.6	def	92.3	m
EXP710	12.0	fghi	46.8	defg	36.9	g	4.3	efg	107.8	jk
Ambler	11.6	ghij	58.1	a	27.8	ijkl	2.4	efg	111.6	hij
Obigo	10.1	hij	53.0	abc	35.2	gh	1.6	fg	143.6	d
M-14	9.3	ijk	52.3	abcd	34.3	ghi	4.2	efg	110.9	ij
Eden	8.9	ijk	42.3	g	45.7	f	3.1	efg	125.4	f
SVQF2070	8.6	ijk	57.2	a	32.8	ghi	1.3	g	175.8	b
CS-441AF	6.7	jkl	40.9	g	48.0	f	4.4	efg	102.7	l
Kudo	5.1	klm	46.0	efg	46.4	f	2.5	efg	163.4	c
BSC737	4.4	klm	31.3	h	55.8	de	8.6	d	103.0	l
Short Story	3.5	lm	21.9	i	49.5	ef	25.1	a	89.2	m
SVQH2015	1.7	m	17.1	ij	64.6	bc	16.5	bc	90.4	m
Dancer	0.9	m	15.8	j	58.2	cd	25.1	a	93.2	m
PLS 602	0.5	m	11.7	j	69.9	ab	17.9	b	115.4	gh
PLS 613-89	0.3	m	11.4	j	75.4	a	12.9	c	138.7	e
p-value	***<0.0001***		***<0.0001***		***<0.0001***		***<0.0001***		***<0.0001***	
LSD	**4.95**		**6.03**		**10.8**		**39.5**		**4.48**	
CV	**24.3**		**8.5**		**6.7**		**4.1**		**4.0**	

Table 5: Tenderometer Reading at Harvest

Variety	Tenderometer Reading		Standard Deviation of T-Reading
SVQB2566	182.1	a	3.7
SVQF2070	175.8	b	3.9
SV6844QG	166.8	c	5.6
Idalgo	165.2	c	4.9
Kudo	163.4	c	14.0
Obigo	143.6	d	3.7
PLS 613-89	138.7	e	9.3
Portage	136.1	e	4.4
Eden	125.4	f	6.2
CS-468AF	124.2	f	8.8
PLS 595	116.1	g	6.8
PLS 602	115.4	gh	2.3
Sherwood	113.9	ghi	6.6
Ambler	111.6	hij	1.8
M-14	110.9	ij	3.8
EXP649	109.0	j	4.0
EXP710	107.8	jk	5.0
SV3628QH	107.6	jk	2.7
Eldorado	104.3	kl	1.5
BSC737	103.0	l	3.6
CS-441AF	102.7	l	3.6
Dancer	93.2	m	2.6
EXP773	92.3	m	4.1
SVQH2015	90.4	m	2.4
Short Story	89.2	m	2.6
p-value	***<0.0001***		
LSD	**4.48**		
CV	**4.0**		

Plant Characteristics Based on a 10-Plant Sample

Table 6: Vine Length in Centimeters

Variety	Vine Length (cm)	
SVQH2015	82	a
Kudo	81	ab
CS-441AF	77	abc
Eden	75	bcd
Dancer	74	cde
PLS 595	73	cde
Idalgo	71	def
Eldorado	71	defg
Portage	70	efgh
EXP710	69	efgh
BSC737	69	efgh
Obigo	68	efghi
EXP773	68	fghi
SVQB2566	67	fghi
SV6844QG	67	fghi
M-14	66	fghi
SVQF2070	65	ghi
PLS 602	65	hi
CS-468AF	65	hi
PLS 613-89	63	ij
SV3628QH	59	jk
Short Story	59	jk
Ambler	57	k
Sherwood	55	k
EXP649	54	k
p-value	<0.0001	
LSD	5.4	
CV	9.1	

Table 7: Number of Pods per Plant

Variety	Pods/Plant	
Kudo	6.3	a
Eldorado	5.4	ab
Dancer	5.2	abc
Ambler	4.7	bcd
PLS 613-89	4.5	bcde
SVQB2566	4.2	bcdef
Idalgo	4.2	bcdef
PLS 602	4.1	cdefg
Sherwood	4.1	cdefg
BSC737	4.0	cdefg
Eden	4.0	cdefg
Short Story	3.9	defgh
SV3628QH	3.8	defghi
CS-468AF	3.7	defghi
Portage	3.7	defghi
PLS 595	3.3	efghi
SVQF2070	3.3	efghi
EXP649	3.1	fghi
SVQH2015	3.1	fghi
CS-441AF	3.1	fghi
EXP773	3.0	fghi
SV6844QG	3.0	fghi
Obigo	2.9	ghi
M-14	2.7	hi
EXP710	2.6	i
p-value	<0.0001	
LSD	1.20	
CV	35.6	

Table 8: Number of Pod-Bearing Nodes per Plant

Variety	Nodes w/ Pods/Plant	
PLS 613-89	3.3	a
Kudo	3.2	a
Ambler	3.0	ab
Eldorado	2.9	abc
Sherwood	2.6	bcd
Portage	2.5	bcde
Short Story	2.4	cdef
PLS 602	2.3	defg
EXP773	2.3	defg
Eden	2.3	defg
Idalgo	2.3	defg
SV3628QH	2.2	defgh
SVQH2015	2.2	defgh
SVQB2566	2.2	defgh
BSC737	2.1	defgh
EXP649	2.1	defgh
Dancer	2.1	defgh
PLS 595	2.0	efghi
CS-468AF	2.0	efghi
CS-441AF	1.9	fghij
Obigo	1.8	ghij
M-14	1.8	ghij
EXP710	1.7	hij
SVQF2070	1.5	ij
SV6844QG	1.4	j
p-value	<0.0001	
LSD	0.56	
CV	28.3	

Table 9: Average Number of Peas/Pod

Variety	Peas/Pod	
PLS 595	8.2	a
EXP710	7.7	ab
Dancer	7.4	abc
PLS 613-89	7.2	abcd
CS-441AF	7.1	abcd
Eden	6.8	abcde
SV6844QG	6.8	abcde
SVQH2015	6.7	bcde
CS-468AF	6.5	bcdef
PLS 602	6.3	bcdefg
SVQF2070	6.3	bcdefg
Short Story	6.2	cdefg
Idalgo	6.2	cdefg
Obigo	6.2	cdefg
SVQB2566	6.0	cdefg
M-14	6.0	cdefg
BSC737	5.9	defg
EXP649	5.9	defg
Ambler	5.8	defg
Sherwood	5.8	defg
Eldorado	5.6	efgh
Portage	5.1	fgh
EXP773	5.0	gh
SV3628QH	4.2	h
Kudo	4.2	h
p-value	<0.0001	
LSD	1.45	
CV	26.5	

Table 10: Average Pod Length (cm)

Variety	Pod Length (cm)	
PLS 595	8.9	a
Idalgo	8.6	a
Dancer	8.6	ab
Kudo	8.5	ab
CS-441AF	8.3	abc
PLS 613-89	7.9	bcd
EXP710	7.9	bcd
EXP649	7.7	cde
Short Story	7.5	def
Eden	7.4	defg
SV6844QG	7.3	defg
BSC737	7.2	defgh
SVQF2070	7.1	efghi
CS-468AF	7.1	efghi
Obigo	7.0	fghij
Portage	7.0	fghij
M-14	7.0	fghij
Sherwood	6.9	fghij
PLS 602	6.8	fghij
Ambler	6.8	fghij
Eldorado	6.7	ghijk
EXP773	6.6	hijk
SVQH2015	6.5	ijk
SVQB2566	6.4	jk
SV3628QH	6.0	k
p-value	<0.0001	
LSD	0.71	
CV	11.0	

Trial Maturity Data

Table 11: Tenderometer Readings Leading Up to and Including Harvest

Variety	Reported Heat Units	Observed Heat Units	T-Readings Up to and Including Harvest by Date and Accumulated Heat Units														
			1251	1284	1317	1356	1393	1425	1459	1489	1516	1545	1578	1616	1650	1680	1714
			3 Jun	4 Jun	5 Jun	6 Jun	7 Jun	8 Jun	9 Jun	10 Jun	11 Jun	12 Jun	13 Jun	14 Jun	15 Jun	16 Jun	17 Jun
Sherwood	1160	1210	**114***														
Eldorado	1110	1250	**104**														
SV3628QH	1205	1310	86	95	**108**												
Short Story	1200	1340	86	**89**													
Ambler	1300	1370			84		**112**										
M-14	1220	1370		87	88		**111**										
SVQB2566	1470	1400									**182**						
Kudo	1346	1400					100			**163**							
PLS 613-89	1320	1420					96			**139**							
EXP773	1360	1430			76		92										
SVQH2015	1250	1430					90										
SVQF2070	1300	1430					91				**176**						
Idalgo	1340	1430					90				**165**						
Portage	1340	1430					92			**136**							
CS-468AF	1520	1450					71				**124**						
PLS 602	1475	1475									**115**						
PLS 595	1550	1475									**116**						
BSC737	1560	1500									**103**						
Obigo	1634	1500										119	**144**				
CS-441AF	1600	1510								91	**103**						
Eden	1520	1520										110	**125**				
Dancer	1520	1540									**93**						
EXP649	1650	1550										98	**109**				
EXP710	1560	1560										94	**108**				
SV6844QG	1600	1650										84	78				**167**

*Bold numbers indicated the day on which the variety was harvested and are an average of three samples from each of three replications

Chart 1: Adjusted Net Yield (lbs/A) by Heat Units Accumulated at T-Reading of 100

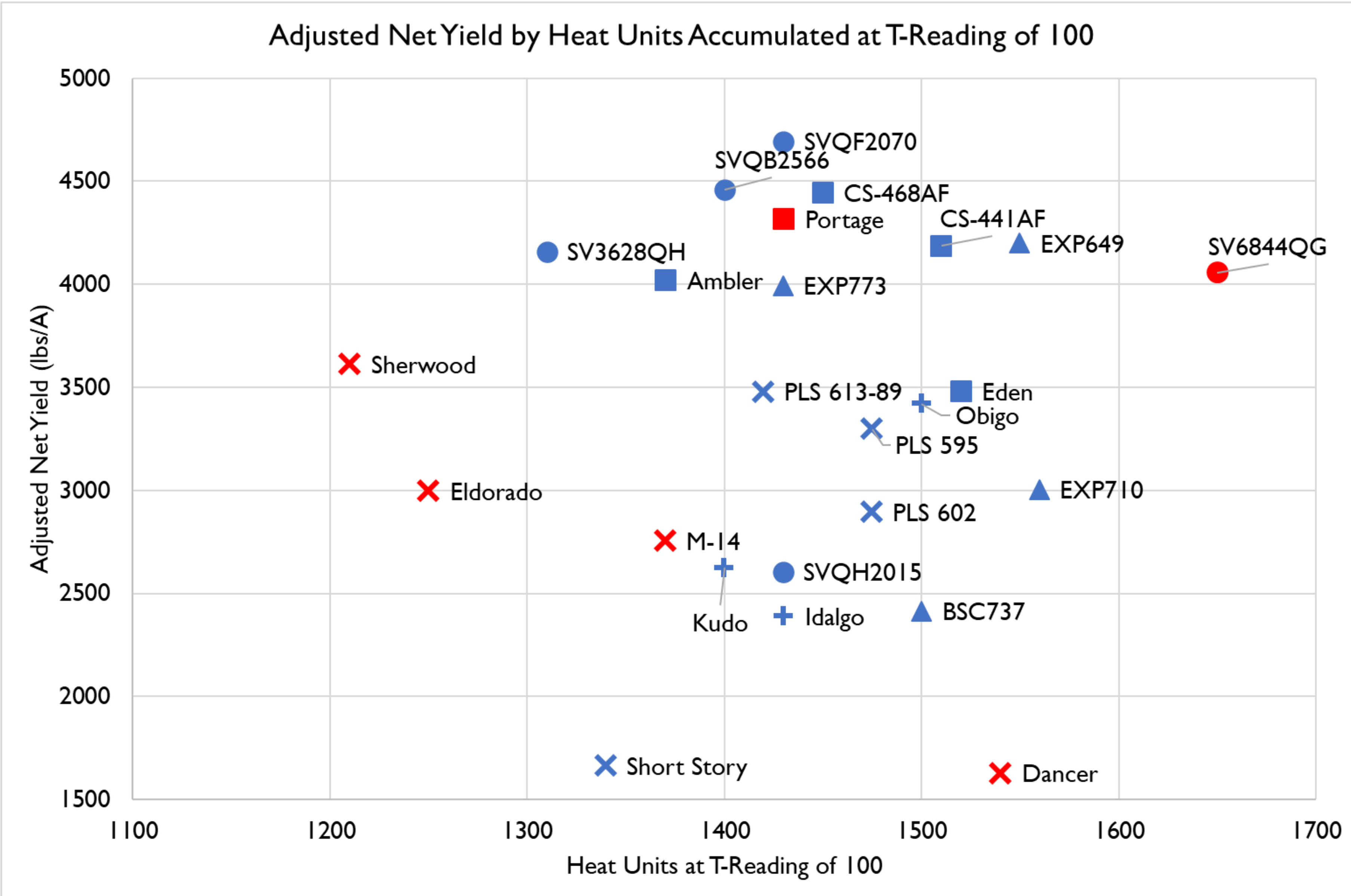


Chart 2: 2024 Pea Trial Temperature and Rainfall

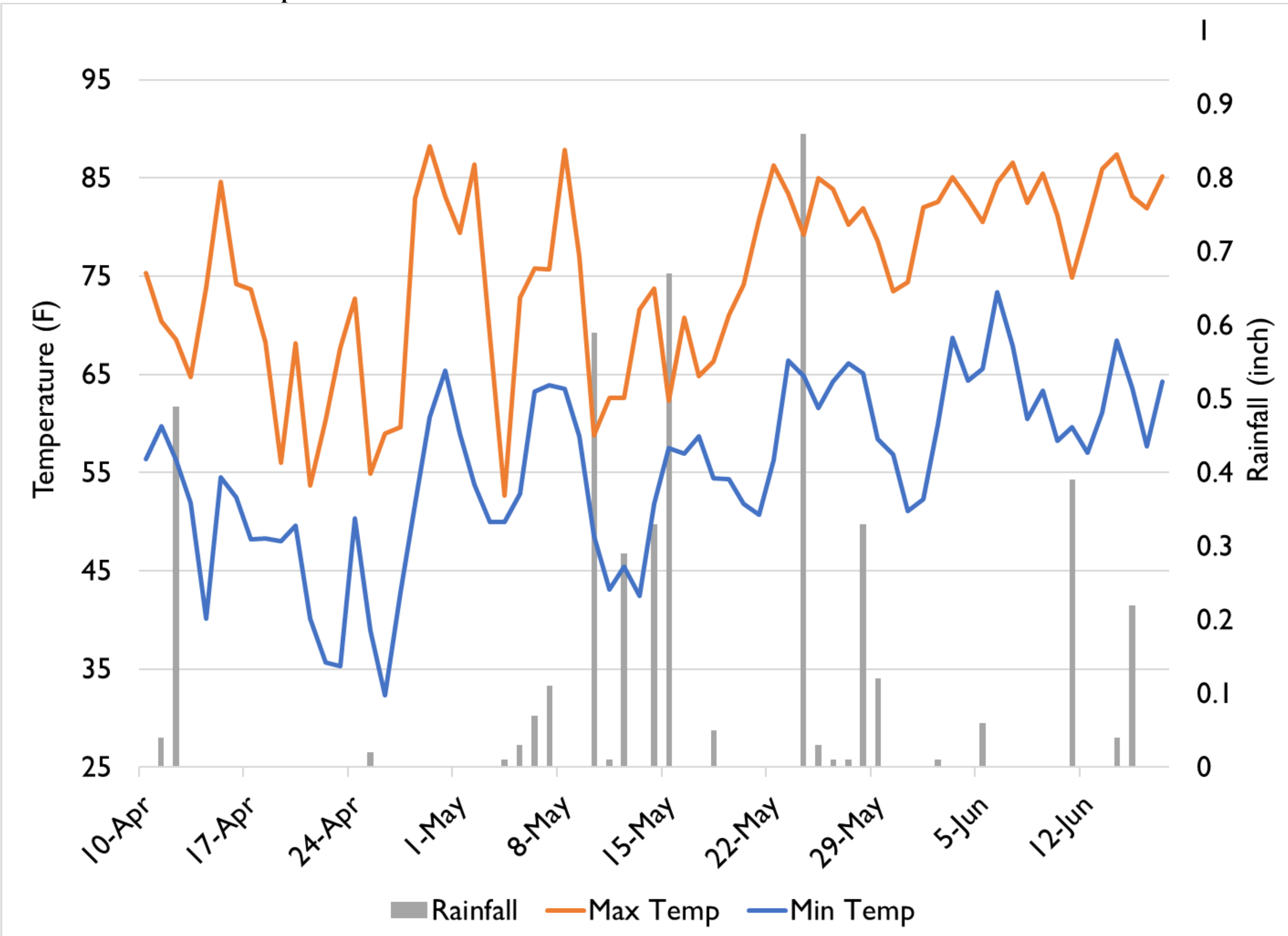


Figure 1. Delaware Pea Trial on May 17, 2024

Figure 2. Delaware Pea Trial on June 13, 2024

Appendix A: Adjusting Pea Yields to a T-reading of 100

Pumphery FV, RE Ramig, RR Allmoras. 1975 "Yield tenderness relationships in 'Dark Skinned Perfection' peas. Journal of the American Society of Horticultural Science. 100:507-509.

Yield-Tenderness Relationships in 'Dark Skinned Perfection' Peas[1]

F. V. Pumphrey, R. E. Ramig, and R. R. Allmaras[2]
Columbia Basin Research Center, Pendleton, OR

Abstract. Maturity effects on yield of fresh peas (*Pisum sativum* L.) were identified by yield-tenderometer measurements. A percent yield-tenderometer reading relationship was shown to be a useful means for yield adjustment to a common maturity—100 tenderometer reading. Analysis of random error in the predicted percent yield, as a function of tenderometer reading, indicates the need to plan harvests within the 90 to 110 tenderometer range. Alternatively, the yield-tenderometer reading relationships show the possible magnitude of errors incurred in comparing green pea yields when no adjustment is made for dissimilar tenderometer ratings.

Improved techniques are needed for determining and comparing fresh pea (*Pisum sativum* L.) yields. Expressions of fresh pea yields are generally not precise because of harvest at a growth stage when fresh pea wt is increasing rapidly while tenderness may decrease even more rapidly. Pea yields may increase as much as 900 kg/ha daily when growth conditions are favorable. Such a yield increase often causes yield differences between treatments only because the treatments affected maturity. Examples of such treatments are comparisons involving cultivars, tillage, fertilizer, irrigation, or herbicides.

The need for comparing yields of processing peas at a common tenderometer rating, such as 100, has been suggested repeatedly, but, unfortunately there is little published information. Yield and tenderness are inversely related: i.e., yield increases as tenderness decreases (tenderometer readings increase). However, changes in yield and tenderometer readings are generally not a linear function of time (2, 3, 4, 6). Yield increases per unit of increase in tenderometer readings are generally greater when tenderometer values are below 100-to 120 than at higher tenderometer values. Hagedorn et al. (1) reported an unusual linear relationship between yield and tenderometer reading up through readings of 150.

Adjustments of absolute yield to a common base of 100 tenderometer reading is complicated, because temporal changes in yield and tenderometer reading vary between years, fields, and cultivars. Some of the factors influencing increase of fresh pea wt and associated change in tenderness are temperature, wind, humidity, available soil moisture, and soil fertility. However, temperature and moisture are the dominating factors. Yield differences produced by these factors, along with seasonal and field variations preclude direct adjustments of yield based on tenderness rating, i.e., *x* pounds of peas per unit change in tenderometer reading. Norton et al. (4) presented yield-tenderness relationships indirectly in terms of percent yield at a given tenderometer reading. The method for adjusting fields was developed by H. K. Schultz and M. W. Carstens. They used the yield at 100 tenderometer reading as 100 percent yield. Kramer (2) and Sayre (7) used percent of maximum yield as their expression of the observed yields at various tenderometer readings.

Our objectives were to emphasize the need for comparing yields of fresh peas at a common tenderometer reading, and to present additional data in support of the Norton et al. (4) method for adjusting yields.

Methods and Procedures

Dark Skinned Perfection peas were grown in 17 field experiments from which fresh pea yields and tenderness evaluations were made. The experiments were conducted on or near the Columbia Basin Research Center, Pendleton, Oregon. Seeding rates varied from about 130 to 230 kg/ha, in row spacings varying from 15 to 20 cm. Plant environment varied considerably because the data were collected during 11 years from experiments testing fertilizers, herbicides, and tillage—all 3 factors alone or in various combinations. All experiments were dryland, except 2 which were irrigated. In the dryland experiments, about 61 percent of the evapotranspiration was derived from soil water stored prior to pea planting. Longterm rainfall averages during the growing season for peas are 3.9, 3.7, 3.4, and 3.5 cm, respectively, for March, April, May, and June at the Columbia Basin Research Center. Corresponding average monthly temperatures are 6.1, 10.0, 13.3, and 17.2°C.

Fresh pea harvests were made to provide tenderometer readings below 100 at the earliest harvest, near 100 at the middle harvest, and above 100 at the latest harvest. Usually 3 or more harvests were necessary and the interval between harvests was generally 1 or 2 days in each of the 17 experiments. Harvests in the dryland experiments occurred in late June and only rarely in early June, while those under irrigation occurred about 5 days later.

From the data obtained in each experiment, pea yield at 100 tenderometer reading was interpolated. Then the ratio of measured to interpolated yield at 100 tenderometer reading was used to obtain "percent yield" (when multiplied by 100). All percent yields and corresponding tenderometer readings were plotted to obtain a scattergram of percent yield versus tenderometer reading, from which a least squares fit was made using the model: $Y = a + bX + cX^{n}$, where Y is percent yield, X is tenderometer reading; a, b, and c are parameters to be estimated statistically.

Results and Discussion

Six experiments typify green pea development observed in the 17 experiments. They are presented herein (Figs. 1, 2, and 3) because their greater number of harvests more precisely defined trends. These relationships were typical, also, of those found in the literature.

Yields varied from experiment to experiment, but yields within experiments were usually nonlinear functions of time (Fig. 1). In some experiments rates of yield change (change in slope) were positive throughout all harvests, while in others they became negative soon after the harvest series was initiated.

Tenderometer readings increased as a function of time (Fig. 2), but the tenderometer readings increased more rapidly after tenderometer readings had reached 100. An exponentially increasing tenderness function of time was suggested for both dryland and irrigated peas in Fig. 2.

Pea yields are distinctly nonlinear functions of tenderometer reading (Fig. 3). Field to field variation also caused large separation of curves. These 2 features of the yield-tenderness curves emphasize a critical need for comparing experimental yields within an experiment on a common tenderometer rating basis. We have not found a feasible direct adjustment of yields.

Pea yields expressed as a percent of the yield expected at 100 tenderometer are plotted versus tenderometer reading (Fig. 4), and the estimated equations are shown separately for irrigated and

[1] Received for publication December 12, 1974. Contribution from the Oregon Agricultural Experiment Station in cooperation with the Agricultural Research Service, USDA. OR Agr. Expt. Sta. Techn. Paper No. 3891.

[2] Associate Professor of Agronomy, Columbia Basin Research Center, and Soil Scientists, Columbia Plateau Conservation Research Center, Pendleton, OR. Appreciation is given to Leslie G. Ekin, Agricultural Research Technician, for expert field assistance given in this study.

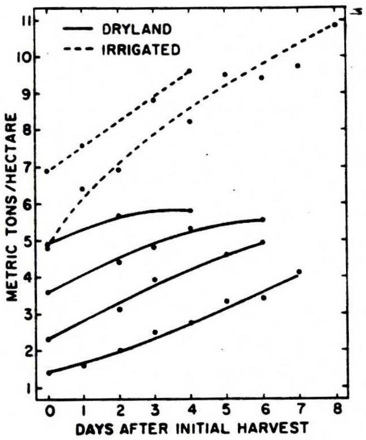


Fig. 1. Yield versus time of harvest for fresh peas in 6 typical experiments.

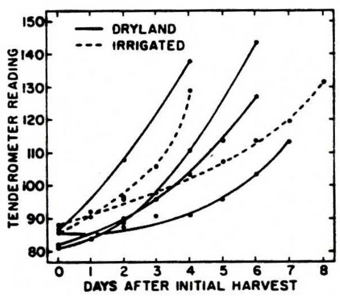


Fig. 2. Tenderometer of fresh peas as affected by time of harvest in 6 typical experiments.

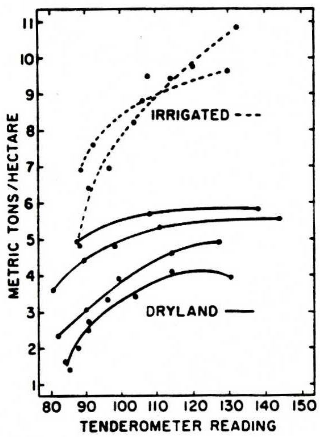


Fig. 3. Yield of fresh peas and associated tenderometer reading in 6 typical experiments.

dryland peas. These equations (Fig. 4) were slightly modified for easy use in adjusting percent yield when tenderometer readings were not 100. The modification involved estimation of Y at 100 tenderometer using equations in Fig. 4. This estimate of Y was then designated as the mean of Y when the mean of X was designated as 100. The equations are shown as follows:

Dryland peas: $(Y-97.21) = -14.134\,(X-100) + 315.14\,(X^{1/2}-10)$

Irrigated peas: $(Y-100.43) = -8.405\,(X-100) + 200.00\,(X^{1/2}-10)$

In these equations. Y is percent yield to be calculated, and X is observed tenderometer reading.

The scatter diagram of Fig. 4 (a composite over the 17 experiments) can be used to adjust yields to a common maturity (100 tenderometer). Such a calibration adjusts for maturity differences. However, the increasing scatter in Fig. 4 as the tenderometer reading deviates from 100 suggests strongly that harvests should be planned to achieve tenderometer readings within the 90 to 110 range. Ordinarily in regression, where the variance of the dependent variable is assumed independent of the independent variable, the precision of predicted dependent variable decreases as the dependent variable becomes larger or smaller than the mean (5). The scatter distribution in Fig. 4 shows a variance dependent on tenderometer reading. We have combined this variance estimate with that of regression in Table 1 to emphasize the true variability characteristics of the calibration in Fig. 4, and the need to plan harvests within the 90 to 110 tenderometer range.

The curves and data points for dryland and irrigated peas were

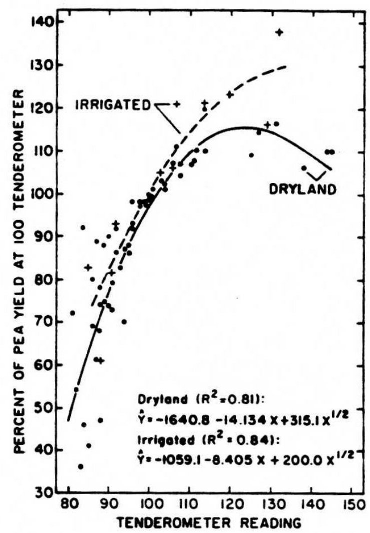


Fig. 4. Percent yield-tenderometer reading relationship for 'Dark Skinned Perfection' pea in irrigated and dryland experiments.

Table 1. Expected random error in estimating a percent-pea-yield at different ranges of tenderometer.[z]

Tenderometer range	$\sigma_{\hat{y}}$	Weighing factor	Estimated true $\sigma_{\hat{y}}$
80-85	8.8[y]	2.1[x]	18.5[w]
85-90	8.7	1.9	16.6
90-95	8.7	0.4	3.5
95-100	8.6	0.4	3.3
100-105	8.6	0.2	1.5
105-110	8.7	0.5	4.5
110-115	8.7	0.5	4.5
115-120	8.8	1.4	12.3

[z] Computations were made using regression composited over irrigated and dryland conditions.
[y] $\sigma_{\hat{y}}$ is the random error expected from multiple regression assuming a variance of y independent of x.
[x] *Weighing factor* is a ratio in which the numerator is the standard error of estimate within the indicated tenderometer range and the denominator is the standard error of estimate for the whole tenderometer range. This ratio approximates the nonuniform variance of percent pea yield at different tenderometer readings.
[w] Estimated true $\sigma_{\hat{y}}$ is the product. (weighing factor) ($\sigma_{\hat{y}}$).

maintained separate in Fig. 4. Above about 110 tenderometer reading the percent yields separate distinctly. This separation of yields indicates a major influence of available soil water on the development of fresh peas in their later stages of growth. We suggest that this factor be carefully evaluated for experiments where irrigation or stored soil water is an experimental variable.

In passing, we note the failure of an appealing normalization procedure involving both yield and tenderometer reading. For each experiment, the maximum and minimum yield or tenderometer readings were noted and the normalized observation computed as $(u-u_{min})/(u_{max}-u_{min})$. The symbol u indicates the variable to be normalized. Nearly the whole range of normalized yield was noted for normalized tenderometer readings <0.5. Furthermore, there was much scatter providing little basis for a calibration.

Norton et al. (4) and Sayre (7) point out that 1 scale is not applicable to all pea cultivars. Norton et al. (4) add that the use of a well-developed scale for 1 cultivar to adjust another cultivar may introduce less error than using a scale developed from only a few points. Information presented in Fig. 4 is consistent with earlier results (1, 2, 4, 7) showing a similar relationship between percent yield and tenderometer readings in the range of 90 to 110. Percent yields changed between 1 and 2 percentage units with each unit change in tenderometer reading.

Experience by the authors indicates that fresh pea yield comparison at a common maturity is essential to good research. Harvesting eac treatment at 2 or more times and interpolating the yield at 1C tenderometer is preferred. When only 1 harvest is possible, yields c be adjusted to 100 tenderometer by using a percent yield-tenderom eter scale (Fig. 4) which provides more reliable data than merely usin the unadjusted yields.

Literature Cited

1. Hagedorn, D. J., L. G. Holm, and J. H. Torrie. 1955. Yield-qualit relationships as influenced by maturity of canning peas. *WI Agr. Expt. Sta Res. Bul.* 187. pp. 15.
2. Kramer, Amihud. 1948. Relation of yield to quality in the production o vegetables for canning. *MD Agr. Expt. Sta. Misc. Pub.* 64.
3. Lynch, L. J., and R. S. Mitchell. 1953. The definition and prediction of th optimal harvest time of pea canning crops. *Commonwealth Scientific an Industrial Research Organization, Australia. Bul.* No. 273. pp. 43.
4. Norton, Robert, A., Walter E. Bratz, and Thomas S. Russell. 1968. An analysis of pea varieties and selections for freezing and canning in northwestern Washington—1967. *WA Agr. Expt. Sta. Cir.* 438, pp. 16.
5. Ostle, Bernard. 1963. Statistics in Research. 2nd Edition. IO State Univ Press, Ames, IO.
6. Pollard, E. H., E. B. Wilcox, and H. B. Peterson. 1947. Maturity studies with canning peas. *UT Agr. Expt. Sta. Bul.* 328, pp. 16.
7. Sayre, Charles B. 1952. Tenderometer grades, yields, and gross return of peas. *NY Agr. Expt. Sta. Farm Research* 18(3):3-4.