MALHEUR EXPERIMENT STATION
ANNUAL REPORT 2018, Ext/CrS 161

Oregon State University
Malheur Experiment Station

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On the Cover: Clint Shock and Stuart Reitz in an onion field trial at the Malheur Experiment Station.

Agricultural Experiment Station
Oregon State University
Department of Crop and Soil Science Ext/CrS 161, July 2019

Malheur Experiment Station Annual Report 2018

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Common names and manufacturers of chemical products used in the trials reported here are contained in Appendices A and B. Common and scientific names of crops are listed in Appendix C. Common and scientific names of weeds are listed in Appendix D. Common and scientific names of diseases and insects are listed in Appendix E.

We are thankful for the broad support of the work of the Oregon State University Malheur Experiment Station.

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TABLE OF CONTENTS

WEATHER

ONION

NATIVE PLANT AND WILDFLOWER SEED PRODUCTION

TABLE OF CONTENTS (continued)

POTATO

SUGAR BEETS

ALTERNATE CROPS

APPENDICES

2018 WEATHER REPORT

Erik B. G. Feibert and Clinton C. Shock, Malheur Experiment Station, Oregon State University, Ontario, OR

Introduction

Air temperature and precipitation have been recorded daily at the Malheur Experiment Station since July 20, 1942. Installation of additional equipment in 1948 allowed for evaporation and wind measurements. A soil thermometer at 4-inch depth was added in 1967. Since 1962, the Malheur Experiment Station has participated in the National Cooperative Weather Station system of the National Weather Service. The daily readings from the station are reported to the National Weather Service forecast office in Boise, Idaho.

A biophenometer to monitor degree-days and pyranometers to monitor total solar and photosynthetically active radiation were added in 1985. Starting in June 1997, the daily weather data and the monthly weather summaries have been posted on the Malheur Experiment Station web site at <www.cropinfo.net>.

On June 1, 1992, in cooperation with the U.S. Department of the Interior, Bureau of Reclamation, a fully automated weather station, linked by satellite to the Northwest Cooperative Agricultural Weather Network (AgriMet) computer in Boise, Idaho, began transmitting data from Malheur Experiment Station. The automated AgriMet station continually monitors air temperature, relative humidity, dew point temperature, precipitation, wind run, wind speed, wind direction, solar radiation, and soil temperature at 8-inch and 20-inch depths. Data are transmitted via satellite to a computer in Boise every 4 hours and are used to calculate daily Malheur County crop water-use estimates. The AgriMet database can be accessed at <www.usbr.gov/pn/agrimet> and from links on the Malheur Experiment Station web page at <www.cropinfo.net>.

Materials and Methods

The ground under and around the weather stations was bare until October 17, 1997, when it was covered with turf grass. The grass is irrigated by subsurface drip irrigation. The manually observed weather data are recorded each day at 8:00 a.m. Consequently, the data in the tables of daily observations refer to the previous 24 hours.

Evaporation is measured from April through October as inches of water evaporated from a standard class A pan (10 inches deep by 4-ft diameter) over 24 hours. Crop evapotranspiration (ET_c) for each crop is calculated by the AgriMet computer using data from the AgriMet weather station using the Kimberly-Penman equation (Wright 1982). AgriMet calculates reference evapotranspiration (ET_0) for a theoretical 12- to 20-inch-tall crop of alfalfa assuming full cover for the whole season. Evapotranspiration for each crop is calculated using (ET_0) and crop coefficients specifically developed for each crop. The crop coefficients for each crop vary throughout the growing season based on the plant growth stage (crop cover and maturity). The crop coefficients are tied to the plant growth stage by three dates: start, full cover, and termination dates. Start dates are the beginning of vegetative growth in the spring for perennial crops or the emergence date for row crops. Full cover dates are typically when plants reach full foliage. Termination dates are defined by maturity, frost, or dormancy. Alfalfa mean ET_c is calculated for alfalfa using ET_0 and assuming a 15% reduction to account for cuttings.

Wind run is measured by the AgriMet weather station as total wind movement in miles over 24 hours at 9.8 ft above the ground. Weather data averages in the tables, except evapotranspiration, refer to the years preceding and up to, but not including, the current year.

2018 Weather

The total precipitation for 2018 (7.3 inches) was considerably lower than the 10-year and 75-year averages (10.09 inches) (Table 1). Precipitation for all months, except January and October, was lower than average.

Total snowfall for 2018 (3.8 inches) was lower than the 75-year average (17.4 inches) (Table 2).

The highest air temperature for 2018 was 105°F on August 11 (Table 3). The lowest air temperature for 2018 was 9°F on February 20. The months of January and May had average maximum and minimum air temperatures substantially higher than average.

The average monthly maximum and minimum 4-inch soil temperatures were close to the 20-year average, except for May (Table 4). May had average maximum and minimum 4-inch soil temperatures substantially higher than average.

Total monthly wind runs in 2018 were close to the 25-year average (Table 5). Total pan evaporation in April, May, July, and September in 2018 was higher than the 20-year average (Table 6). Total accumulated reference evapotranspiration (ET_o) in 2018 was above the 26-year average (Table 7).

The year 2018 had 3446 growing degree-days (50 to 86°F), higher than the 25-year average of 3300 (Table 8, Fig. 1). May had substantially more growing degree-days than average. The year 2018 had a greater than average frost-free period (178 days) (Table 9). The last spring frost ($\leq$32°F) occurred on April 19, 10 days earlier than the 42-year-average date of April 29; the first fall frost occurred on October 14, 6 days later than the 42-year-average date of October 8. No weather records were broken in 2018 (Table 10).

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References

Wright, J.L. 1982. New evapotranspiration crop coefficients. Journal of Irrigation and Drainage Division, American Society of Civil Engineers 108:57-74.

Table 1. Monthly precipitation at the Malheur Experiment Station, Oregon State University, Ontario, OR, 1990-2018.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
							inches						
1990	0.44	0.35	0.72	1.52	1.7	0.36	0.04	0.61	0.00	0.49	0.69	0.29	7.2
1991	0.59	0.44	0.88	0.81	1.89	1.09	0.01	0.04	0.35	1.01	1.71	0.43	9.3
1992	0.58	1.36	0.25	0.74	0.21	1.43	0.36	0.01	0.09	0.95	1.15	1.51	8.6
1993	2.35	1.02	2.41	2.55	0.70	1.55	0.18	0.50	0.00	0.80	0.64	0.60	13.3
1994	1.20	0.57	0.05	1.02	1.62	0.07	0.19	0.00	0.15	1.23	2.46	1.49	10.1
1995	2.67	0.28	1.58	1.16	1.41	1.60	1.10	0.13	0.07	0.57	0.88	2.56	14.0
1996	0.97	0.86	1.03	1.19	2.39	0.12	0.32	0.31	0.59	0.97	1.18	2.76	12.7
1997	2.13	0.17	0.25	0.66	0.67	0.86	1.40	0.28	0.40	0.43	1.02	0.94	9.2
1998	2.26	1.45	0.95	1.43	4.55	0.36	1.06	0.00	1.00	0.04	1.07	1.11	15.3
1999	1.64	2.50	0.59	0.23	0.28	1.02	0.00	0.09	0.00	0.40	0.49	0.73	8.0
2000	2.01	2.14	0.97	0.72	0.28	0.26	0.03	0.06	0.39	1.74	0.38	0.66	9.6
2001	1.15	0.41	1.11	0.70	0.37	0.64	0.32	0.00	0.10	0.68	1.33	1.00	7.8
2002	0.77	0.27	0.49	0.77	0.09	0.60	0.14	0.10	0.36	0.29	0.44	1.86	6.2
2003	1.46	0.48	0.99	1.12	1.52	0.24	0.36	0.11	0.15	0.02	0.86	1.47	8.8
2004	1.82	1.54	0.25	0.98	1.70	0.43	0.13	0.64	0.56	2.03	0.93	0.97	12.0
2005	0.41	0.12	1.66	0.80	2.94	1.02	0.22	0.06	0.14	1.38	1.58	3.92	14.3
2006	1.91	0.67	3.33	2.00	0.62	0.45	0.00	0.08	0.55	0.28	1.14	1.76	12.8
2007	0.07	0.95	0.12	0.82	0.47	0.63	0.03	0.15	0.92	0.68	1.07	1.56	7.5
2008	0.50	0.43	0.79	0.14	0.74	0.27	0.43	0.03	1.26	0.44	1.12	1.47	7.6
2009	0.65	0.43	0.86	0.13	1.47	2.27	0.09	1.39	0.02	1.24	0.63	1.82	11.0
2010	2.13	1.19	0.59	1.21	1.18	1.95	0.02	0.86	0.19	1.16	1.09	4.19	15.8
2011	1.05	0.42	2.97	0.44	2.61	0.81	0.19	0.02	0.08	1.59	0.57	0.45	11.2
2012	1.65	0.49	1.36	1.03	0.77	0.45	0.00	0.04	0.1	0.83	1.13	1.25	9.1
2013	0.58	0.34	0.32	0.19	0.37	0.80	0.00	0.11	2.39	0.44	0.90	0.59	7.0
2014	0.69	1.58	1.22	0.92	0.45	0.24	0.02	0.28	0.62	0.52	1.46	3.04	11.0
2015	0.64	0.74	0.77	0.67	1.80	0.18	0.51	0.05	0.50	1.13	1.29	3.21	11.5
2016	0.98	0.38	0.98	0.88	0.95	0.25	0.98	0.01	0.13	0.75	0.58	2.11	9.0
2017	3.02	1.61	1.61	1.27	1.02	0.62	0.00	0.00	0.49	0.45	0.00	0.84	10.9
2018	1.41	0.26	1.12	0.62	0.56	0.47	0.00	0.00	0.01	1.23	0.51	1.13	7.3
10-yr avg	1.27	0.80	1.19	0.75	1.18	0.84	0.20	0.31	0.50	0.90	0.85	1.94	10.1
75-yr avg	1.27	0.93	0.95	0.79	1.05	0.79	0.22	0.33	0.47	0.74	1.13	1.42	10.1

Table 2. Annual total snowfall (inches) at the Malheur Experiment Station, Oregon State University, Ontario, OR, 1943-2018. Average annual snowfall (1943-2018) is 17.4 inches.

			1943	1944	1945	1946	1947	1948	1949
			24.7	10.3	19.0	8.2	9.1	14.6	9.6
1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
23.9	32.4	22.3	7.5	10.4	40.3	15.6	26.4	9.8	12.1
1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
21.2	9.7	14.8	13.3	32.6	19.6	6.3	11.9	14.9	24.8
1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
13.5	17.1	23.7	19.2	20.3	27.3	21.3	21.3	9.3	31.0
1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
11.5	14.5	32.7	35.4	21.0	33.4	13.0	15.5	34.8	25.1
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
5.7	7.5	15.5	36.0	32.0	15.0	14.5	5.8	14.6	13.2
2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
13.8	15.5	11.5	4.5	24.0	13.5	12.3	3.8	26.0	13.8
2010	2011	2012	2013	2014	2015	2016	2017	2018	
28.0	1.0	4.0	14.0	22.5	14.0	24.5	31.5	3.8	

Table 3. Maximum and minimum air temperatures by month, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Month		Highest	Lowest	2018 avg	75-yr avg
		------------------------- °F -------------------------			
Jan	Max	52	32	42	34
	Min	35	15	28	19
Feb	Max	65	32	46	43
	Min	39	9	27	25
Mar	Max	69	40	56	55
	Min	50	23	33	31
Apr	Max	88	50	65	64
	Min	49	22	38	37
May	Max	87	65	78	74
	Min	60	41	51	45
Jun	Max	93	62	82	82
	Min	60	40	53	52
Jul	Max	103	77	96	92
	Min	70	51	62	58
Aug	Max	105	74	91	90
	Min	76	45	59	56
Sep	Max	95	73	81	80
	Min	60	38	47	46
Oct	Max	73	54	64	66
	Min	48	28	37	37
Nov	Max	37	37	49	48
	Min	17	17	26	28
Dec	Max	49	28	39	37
	Min	35	16	26	22

Table 4. Monthly maximum and minimum soil temperatures at 4-inch depth, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
	------------------------- °F -------------------------																							
2018 avg	35	35	37	36	42	41	52	49	65	61	69	65	75	70	73	70	65	62	55	53	44	42	36	35
Highest	39	39	42	41	48	46	61	56	70	66	73	69	79	73	77	73	71	67	61	59	52	51	42	42
Lowest	31	31	33	32	33	33	46	42	57	53	64	61	72	67	67	65	61	58	51	49	38	37	34	33
20-yr avg	33	32	36	34	43	41	50	46	59	55	68	62	74	68	72	67	65	61	55	52	44	42	35	34

Table 5. Daily and monthly wind-run, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Daily	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	--- miles/day ---											
Mean	76	154	138	163	139	127	112	114	108	94	94	93
Max	157	427	425	339	357	237	184	194	222	247	189	290
Min	24	54	46	72	66	58	68	58	56	43	43	24
Monthly total	--- miles/month ---											
2018	2361	4307	4285	4883	4315	3806	3481	3521	3230	2917	2818	2877
25-yr average	2828	3198	4210	4618	4182	3668	3356	3273	3162	3279	3004	3248

Table 6. Daily and monthly pan-evaporation, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Totals	April	May	Jun	Jul	Aug	Sep	Oct	Total
Daily	----------------- inches/day ---------------------							
Mean	0.23	0.30	0.33	0.42	0.34	0.25	0.11	
Max	0.40	0.52	0.56	0.57	0.48	0.35	0.24	
Min	0.07	0.08	0.03	0.16	0.20	0.14	0.01	
Monthly	-------------------- inches/month -----------------------							
2018	6.8	9.2	9.9	13.1	10.4	7.4	3.4	60.2
20-yr avg	6.4	8.6	10.2	12.4	10.5	7.0	4.1	59.1

Table 7. Total accumulated reference evapotranspiration (ET_o) and estimated crop evapotranspiration (ET_c) (acre-inches/acre) for various crops over the past 27 years, Malheur Experiment Station, Oregon State University, Ontario, OR, 1992-2018.

										Poplar		
Year	ET_o	Alfalfa (mean)	Winter grain	Spring grain	Sugar beet	Onion	Potato	Dry bean	Field corn	Yr. 1	Yr. 2	Yr. 3 +
1992	53.7	44.4	26.9	27.9	36.1	30.3	28.8	21.3	29.8			
1993	51.9	36.4	21.3	22.7	29.3	24.1	22.8	17.9	23.7			
1994	57.6	40.6	21.3	22.6	34.5	29.5	28.2	21.1	27.7			
1995	49.6	37.1	18.9	22.2	29.0	26.7	23.6	16.7	23.7			
1996	52.8	39.8	22.3	24.1	32.9	27.2	26.3	19.5	25.7			
1997	55.2	41.5	23.8	25.3	33.4	28.0	26.6	19.7	25.1			
1998	55.0	40.7	21.3	23.9	32.4	28.2	26.2	21.0	27.9	23.9	37.1	44.0
1999	58.6	43.9	25.0	26.4	33.7	28.9	26.5	21.7	28.5	24.3	37.8	45.5
2000	58.7	45.5	26.0	25.7	38.3	32.0	29.5	24.1	30.6	24.9	38.9	47.1
2001	57.9	43.8	25.5	27.2	34.8	30.3	27.4	21.4	29.1	23.7	37.0	44.7
2002	58.8	41.7	25.9	28.7	35.2	30.4	27.7	21.9	27.8	23.6	36.7	44.4
2003	54.2	44.1	27.5	31.7	39.1	31.6	31.9	22.4	29.3	24.3	37.9	45.9
2004	52.8	43.5	27.8	30.6	34.3	30.2	27.9	22.1	28.4	23.3	36.3	44.1
2005	53.8	44.5	26.5	27.0	36.0	32.8	30.2	20.0	29.2	24.3	37.8	45.3
2006	57.7	47.9	24.4	31.4	38.5	33.8	29.4	23.9	29.6	26.3	41.0	49.3
2007	59.0	47.2	27.6	26.7	38.9	33.7	29.7	24.5	31.9	25.7	40.1	48.6
2008	58.0	46.4	28.1	30.4	36.4	32.7	30.0	24.0	30.4	23.3	36.5	44.5
2009	58.1	42.5	26.3	28.4	34.7	28.4	27.6	20.3	26.7	22.6	35.2	42.7
2010	51.5	41.9	21.0	26.8	33.4	28.9	27.7	21.1	26.7	22.2	34.5	41.4
2011	51.0	41.9	23.3	25.8	34.4	29.2	27.5	22.8	28.0	23.6	36.8	44.5
2012	57.3	45.3	23.6	27.6	36.4	31.5	31.6	24.0	31.2	25.3	39.4	47.4
2013	59.3	47.8	28.9	30.9	39.2	34.9	32.5	25.9	33.4	25.8	40.2	48.7
2014	59.2	49.0	29.7	32.6	37.5	35.0	34.5	26.6	35.1	26.1	40.8	49.6
2015	61.6	50.3	27.1	29.8	36.2	33.8	32.9	24.7	34.0	25.4	39.5	47.6
2016	60.0	49.7	28.0	31.3	37.0	34.0	31.5	23.4	34.6	26.3	41.1	49.9
2017	53.8	51.7	25.6	27.9	36.2	30.6	29.5	23.9	31.2	23.8	37.1	44.8
2018	59.6	48.9	27.4	29.3	38.8	36.3	31.5	24.8	32.7	25.3	39.5	47.5
Avg												
inch	56.0	44.2	25.1	27.5	35.3	30.6	28.8	22.1	29.2	24.4	38.1	46.0
mm	1423	1122	638	699	897	778	731	563	742	621	967	1168

Table 8. Monthly total growing degree-days (50-86°F), Malheur Experiment Station, Oregon State University, Ontario, OR, 1992-2018.

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
1992					480	538	647	697	456	273	12	0	
1993	0	0	58	139	451	371	473	556	459	239	17	4	2768
1994	0	5	172	242	398	507	712	695	523	195	7	0	3456
1995	2	60	77	155	330	443	646	566	469	170	16	12	2945
1996	0	19	103	188	286	490	662	614	377	216	37	11	3004
1997	3	10	122	167	447	508	632	665	489	215	35	0	3293
1998	0	4	95	175	268	436	737	690	529	220	40	5	3198
1999	0	9	81	175	320	467	629	651	458	268	69	1	3127
2000	1	13	79	277	380	541	702	684	421	202	8	0	3309
2001	0	0	122	176	433	502	680	712	507	231	62	0	3424
2002	0	4	76	202	375	564	749	620	457	230	37	11	3325
2003	1	11	134	164	370	580	782	714	479	338	27	8	3610
2004	0	0	189	264	322	535	727	657	410	238	7	1	3349
2005	0	19	126	193	342	446	692	685	435	215	6	0	3158
2006	0	18	48	204	406	597	791	647	446	219	60	4	3441
2007	0	20	183	220	441	543	796	644	442	184	50	6	3528
2008	0	2	39	144	389	512	713	665	452	228	36	6	3186
2009	1	7	66	209	415	509	702	644	523	130	34	0	3239
2010	1	5	92	159	248	467	671	605	470	271	50	0	3037
2011	0	11	46	106	272	423	676	699	531	221	11	4	2999
2012	1	8	129	253	353	484	751	694	512	222	56	12	3475
2013	0	8	130	226	407	549	745	717	491	201	18	7	3498
2014	0	22	116	227	424	544	779	685	503	293	36	17	3647
2015	7	71	190	241	427	674	716	700	461	347	33	9	3876
2016	0	42	129	305	405	576	680	683	443	227	78	0	3570
2017	0	0	114	169	380	533	766	706	461	189	19	0	3337
2018	1	28	101	225	471	516	733	683	443	210	36	0	3446
Avg 1993-2018	1	15	109	199	372	512	704	664	470	228	34	5	3300

Table 9. Last and first frost (32°F) dates and number of frost-free days, Malheur Experiment Station, Oregon State University, Ontario, OR, 1990-2018.

Year	Date of last frost Spring	Date of first frost Fall	Total frost-free days
1990	8-May	7-Oct	152
1991	30-Apr	4-Oct	157
1992	24-Apr	14-Sep	143
1993	20-Apr	11-Oct	174
1994	15-Apr	6-Oct	174
1995	16-Apr	22-Sep	159
1996	6-May	23-Sep	140
1997	3-May	8-Oct	158
1998	18-Apr	17-Oct	182
1999	11-May	28-Sep	140
2000	12-May	24-Sep	135
2001	29-Apr	10-Oct	164
2002	8-May	12-Oct	157
2003	19-May	11-Oct	145
2004	16-Apr	24-Oct	191
2005	15-Apr	6-Oct	174
2006	19-Apr	22-Oct	186
2007	4-May	11-Oct	160
2008	2-May	13-Oct	164
2009	13-May	1-Oct	141
2010	7-May	12-Oct	158
2011	4-May	25-Oct	174
2012	29-Apr	4-Oct	158
2013	23-May	5-Oct	135
2014	29-Apr	22-Oct	176
2015	15-Apr	27-Oct	195
2016	28-Mar	12-Oct	198
2017	13-May	10-Oct	150
2018	19-Apr	14-Oct	178
avg 1976-2018	29-Apr	8-Oct	162

Table 10. Record weather events at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Record event	Measurement	Date
--- Since 1943 ---		
Highest annual precipitation	16.87 inches	1983
Lowest annual precipitation	5.16 inches	1949
Highest monthly precipitation	4.55 inches	May 1998
Highest June precipitation	2.27 inches	June 2009
Highest December precipitation	4.19 inches	Dec 2010
Highest 24-hour precipitation	1.52 inches	Sep 14, 1959
Highest annual snowfall	40 inches	1955
Greatest snow depth	28 inches	Jan 17, 2017
Highest 24-hour snowfall	10 inches	Nov 30, 1975
Earliest snowfall	1 inch	Oct 25, 1970
Highest air temperature	110°F	July 22, 2003
Total days with maximum air temp. ≥100°F	18 days	2013
Lowest air temperature	-26°F	Jan 21 and 22, 1962
Total days with minimum air temp. ≤0°F	35 days	1985
Longest frost-free period	198 days	2016
--- Since 1967 ---		
Lowest soil temperature at 4-inch depth	12°F	Dec 24, 25, and 26, 1990
--- Since 1993 --		
Most yearly growing degree-days	3876	2015
Fewest yearly growing degree-days	2768	1993
Fewest growing degree-days in March	39	2008
Fewest growing degree-days in April	106	2011
Most growing degree-days in April	305	2016
--- Since 1992 --		
Highest reference evapotranspiration	61.6 inches	2015

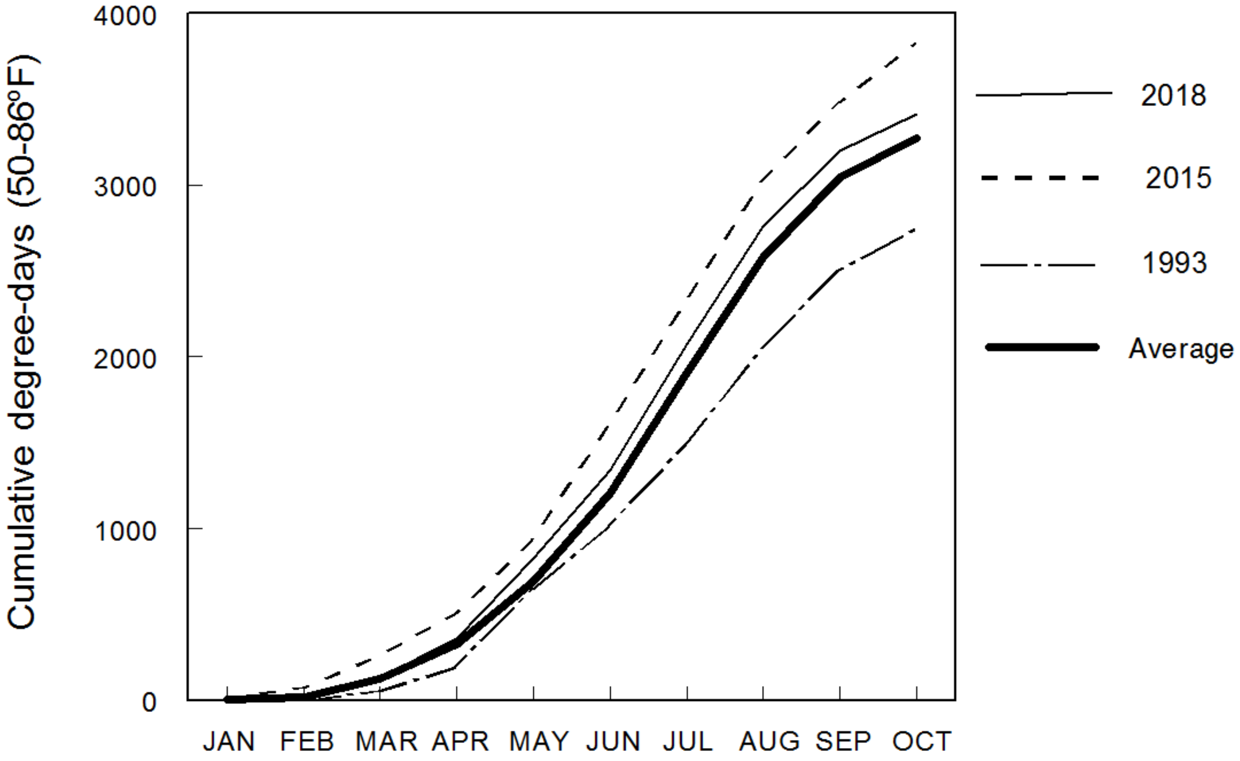

Figure 1. Cumulative growing degree-days (50-86°F) over time for 2018 compared to the years with lowest (1993) and highest (2015) totals since 1993 and to the 25-year average (1993-2018), Malheur Experiment Station, Oregon State University, Ontario, OR.

2018 ONION VARIETY TRIALS

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Introduction

Direct-seeded yellow, white, and red onion varieties were evaluated in the field in 2018 for plant disease, thrips, maturity, bolting, and bulb single centers. Out of storage, the varieties were evaluated for yield, grade, and bulb decomposition. Four early-season yellow varieties were planted in March and were harvested and graded in early August. Fifty-three full-season varieties (35 yellow, 12 red, and 6 white) were planted in March, harvested in September, and were graded out of storage in January 2019. Each year, growers and seed industry representatives have the opportunity to examine the varieties at our annual Onion Variety Field Day in late August and during bulb evaluations in January. Onion varieties were evaluated objectively for bolting, yield, grade, single centers, and storability. Varieties were evaluated subjectively for maturity, thrips leaf damage, iris yellow spot virus, bulb shape, bulb shape uniformity, flesh brightness, and skin color and retention.

Materials and Methods

Onions were grown in 2018 on a Greenleaf silt loam previously planted to wheat. A soil analysis taken in the fall of 2017 showed that the top foot of soil had a pH of 8.2, 3.4% organic matter, 7 ppm nitrate, 3 ppm ammonium, 22 ppm phosphorus (P), 386 ppm potassium (K), 20 ppm sulfur (S), 3218 ppm calcium (Ca), 533 ppm magnesium (Mg), 138 ppm sodium, 4.1 ppm zinc (Zn), 3 ppm manganese (Mn), 2.2 ppm copper (Cu), 16 ppm iron, and 0.5 ppm boron (B). In the fall of 2017, the wheat stubble was shredded and the field was irrigated. The field was then disked. Based on a soil analysis, 78 lb of P/acre, 81 lb of K/acre, 162 lb of S/acre, 9 lb of Mn/acre, and 1 lb of B/acre were broadcast before plowing. Also before plowing, 10 tons/acre of composted cattle manure were broadcast. The manure supplied 196 lb nitrogen (N)/acre, 156 lb P/acre, and 342 lb K/acre. The field was then moldboard plowed, and groundhogged. After groundhogging, the field was fumigated with K-Pam® at 15 gal/acre and bedded at 22 inches.

The experimental designs for the full-season and the early-maturing trials were randomized complete blocks with five replicates. A sixth nonrandomized replicate was planted for demonstrating onion variety performance to growers and seed company representatives at the Onion Variety Day. Both trials were planted on March 20 in plots 4 double rows wide and 27 ft long. The early-maturing trial had 4 varieties from 2 seed companies and the full-season trial had 53 varieties from 11 seed companies. An additional trial with onion transplants is not reported here.

Seed was planted in double rows spaced 3 inches apart at 9 seeds/ft of single row. Each double row was planted on beds spaced 22 inches apart. Planting was done with customized John Deere Flexi Planter units equipped with disc openers. Immediately after planting, the field received a narrow band of Lorsban 15G® at 3.7 oz/1000 ft of row (0.82 lb ai/acre) over the seed rows and the soil surface was rolled. Onion emergence started on April 9. On May 10, alleys 4 ft wide were cut between plots, leaving plots 23 ft long. On May 14-16, the seedlings were hand thinned to a target spacing of 4.75 inches between individual onion plants in each single row, or 120,000 plants/acre.

The field had drip tape laid at 4-inch depth between pairs of beds during planting. The drip tape had emitters spaced 12 inches apart and an emitter flow rate of 0.22 gal/min/100 ft (Toro Aqua-Traxx, Toro Co., El Cajon, CA). The distance between the tape and the center of each double row of onions was 11 inches.

The onions were managed to minimize yield reductions from weeds, pests, diseases, water stress, and nutrient deficiencies. For weed control, the following herbicides were broadcast: oxyfluorfen at 0.13 lb ai/acre (GoalTender® at 4 oz/acre), bromoxynil at 0.25 lb ai/acre (Brox® 2EC at 16 oz/acre), and clethodim at 0.12 lb ai/acre (Shadow® 3EC at 5.3 oz/acre) on May 7; pendimethalin at 0.95 lb ai/acre (Prowl® H_2O at 2 pt/acre) on May 17; oxyfluorfen at 0.25 lb ai/acre (GoalTender® at 8 oz/acre), bromoxynil at 0.31 lb ai/acre (Brox® 2ECat 20 oz/acre), and clethodim at 0.12 lb ai/acre (Shadow® 3EC at 5.3 oz/acre) on May 25.

For thrips control, the following insecticides were applied by ground: spirotetramat at 0.078 lb ai/acre (Movento® at 5 oz/acre) and azadirachtin at 0.0093 lb ai/acre (Aza-Direct® at 12 oz/acre) on May 21 and June 3; abamectin at 0.019 lb ai/acre (Agri-Mek® SC at 3.5 oz/acre) on June 11. The following insecticides were applied by air: Abamectin at 0.019 lb ai/acre on June 27; spinetoram at 0.078 lb ai/acre (Radiant® at 10 oz/acre) on June 30 and July 7; methomyl at 0.9 lb ai/acre (Lannate® at 3 pt/acre) on July 14 and July 21; spinetoram at 0.078 lb ai/acre on July 28 and August 5.

Starting on June 8, root tissue and soil samples were taken every week from field borders (variety 'Vaquero') and analyzed for nutrients by Western Laboratories, Inc., Parma, Idaho (Tables 1 and 2). Nutrients were applied through the drip tape based on the root tissue recommendations from Western Labs (Table 3). Urea ammonium nitrate solution (URAN) was applied through the drip tape six times from May 23 to June 25, supplying a total of 120 lb N/acre. Starting June 22, the soil solution nitrogen remained above the critical level for the rest of the season. Also starting June 22, the amount of total available soil N remained above the critical level of 60 lb N/acre for the rest of the season (Table 4, Sullivan et al. 2001). Phosphorus, K, Mg, and Cu were also applied based on the soil and tissue analyses.

Table 1. Onion root tissue nutrient content in the onion variety trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Nutrient		8-Jun	15-Jun	22-Jun	29-Jun	9-Jul	23-Jul	27-Jul	3-Aug	10-Aug
NO_3-N (ppm)	Sufficiency range	8500	7667	6833	6000	5168	4338	3508	2678	1834
NO_3-N (ppm)		4772	3668	4105	4726	3903	4644	3616	3432	2871
P (%)	0.32 - 0.7	0.52	0.44	0.34	0.40	0.44	0.37	0.28	0.41	0.35
K (%)	2.7 - 6.0	3.67	3.31	3.13	4.49	4.18	3.21	2.75	2.51	2.16
S (%)	0.24 - 0.85	1.00	0.94	0.87	1.21	0.63	0.60	0.77	0.81	0.50
Ca (%)	0.4 - 1.2	0.59	0.66	0.79	0.79	0.74	0.87	0.93	1.16	0.96
Mg (%)	0.3 - 0.6	0.33	0.42	0.47	0.36	0.32	0.35	0.43	0.43	0.36
Zn (ppm)	25 - 50	67	47	56	47	39	46	51	40	30
Mn (ppm)	35 - 100	99	93	108	82	62	73	85	92	68
Cu (ppm)	6 - 20	20	15	10	8	7	6	7	6	7
B (ppm)	19 - 60	72	80	61	52	42	33	31	25	28

Table 2. Weekly soil solution analyses in the onion variety trial. Data represent the amount of each plant nutrient per day that the soil can potentially supply to the crop. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Nutrient	Critical level, lb/ac or g/ac	8-Jun	15-Jun	22-Jun	29-Jun	9-Jul	23-Jul	27-Jul	3-Aug	10-Aug
N	Critical levels	8.6	7.8	7	6.2	5.4	4.6	3.8	2.8	2.0
N		2.0	2.3	9.7	8.6	9.7	8.6	10.0	12.6	10.0
P	0.7 lb/acre	1.2	1.1	1.5	1.6	1.5	2.0	1.8	2.2	2.3
K	5 lb/acre	8.5	9.1	9.2	7.9	6.6	7.0	8.2	6.9	7.4
S	1 lb/acre	1.5	1.0	2.3	3.1	4.3	5.5	5.5	3.8	4.7
Ca	3 lb/acre	4.9	5.0	6.1	4.7	5.5	4.5	5.5	5.1	5.0
Mg	2 lb/acre	0.2	0.2	0.5	0.6	0.7	0.9	1.0	1.0	1.1
Zn	28 g/acre	75	69	78	57	66	57	63	45	45
Mn	28 g/acre	24	30	27	21	27	33	30	27	24
Cu	12 g/acre	36	42	33	27	21	24	27	24	30
B	21 g/acre	8	9	12	11	14	12	15	12	15

Table 3. Nutrients applied through the drip irrigation system in the onion variety trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Date	N	P	K	Mg	Cu
			----------- lb/acre -----------		
23-May	20				
1-Jun	20				
11-Jun	20				
12-Jun	20				
19-Jun	20			2.5	
25-Jun	20			5	
6-Jul				5	
25-Jul					0.3
30-Jul		10			
7-Aug			10		
15-Aug			10		
total	120	10	20	12.5	0.3

Table 4. Soil available N (as $NO_3 + NH_4$) in the top foot of soil in the onion variety trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Date	Available soil N, lb/acre
8-Jun	14
15-Jun	16
22-Jun	68
29-Jun	60
9-Jul	68
23-Jul	60
27-Jul	70
3-Aug	88
10-Aug	70

Onions were irrigated automatically to maintain the soil water tension (SWT) at 8-inch depth in the onion root zone below 20 cb (Shock et al. 2000). Soil water tension was measured with eight granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co. Inc., Riverside, CA) installed at 8-inch depth in the center of the double row of onions. Sensors had been calibrated to SWT (Shock et al. 1998). The GMS were connected to the datalogger via multiplexers (AM 16/32, Campbell Scientific, Logan, UT). The datalogger (CR1000, Campbell Scientific) read the sensors and recorded the SWT every hour. The datalogger automatically made irrigation decisions every 12 hours. The field was irrigated if the average of the eight sensors was at a SWT of 20 cb or higher. The irrigations were controlled by the datalogger using a controller (SDM CD16AC, Campbell Scientific) connected to a solenoid valve. Irrigation durations were 8 hours, 19 min to apply 0.48 inch of water. The water was supplied from a well and pump that maintained a continuous and constant water pressure of 35 psi. The pressure in the drip lines was maintained at 10 psi by a pressure-regulating valve. The automated irrigation system was started on May 16 and irrigations ended on August 31.

Onions in the early-maturing trial were evaluated for maturity, severity of symptoms of iris yellow spot virus (IYSV), and bolting on August 1. Onions in the full-season trial were evaluated for maturity on August 1 and 15. On August 15, onions in the full-season trial were also evaluated for IYSV, thrips damage severity, and bolting. Onions in each plot were evaluated subjectively for maturity by visually rating the percentage of onions with the tops down and the percent dry leaves. For the IYSV evaluations, onions in each plot were given a subjective rating on a scale of 0 to 5 of increasing severity of IYSV symptoms. The rating was 0 if there were no symptoms, 1 if 1-25% of foliage was diseased, 2 if 26-50% of foliage was diseased, 3 if 51-75% of foliage was diseased, 4 if 76-99% of foliage was diseased, and 5 if 100% of foliage was diseased. For thrips leaf damage, each plot was given a subjective rating on a scale of 0 to 10 for increasing severity of leaf damage from thrips feeding. The number of bolted onion plants was counted in each plot and compared to the plant population.

Onions from the middle two double rows in each plot in the early-maturity trial were topped by hand and bagged on August 8. Onions from the early-maturity trial were graded on August 10. After grading, onions were stored in a shed at ambient air temperature for 2 weeks, after which the onions were evaluated for decomposition and sprouting.

In the full-season trial, the red and white onion varieties matured before the yellow varieties. Onions from the middle two rows in each plot of the red and white onion varieties were topped and bagged on September 5 to cure in the field until September 10 when they were put in bins and stored outdoors. The remaining yellow onions were lifted on September 10 to field cure. Onions from the middle two rows in each plot of the yellow varieties were topped by hand and bagged on September 15. The bags of red, white, and yellow varieties were moved into storage on September 21. The storage shed was ventilated and the temperature was slowly decreased to maintain air temperature as close to 34°F as possible. Onions from the full-season trial were graded out of storage on January 7-11, 2019.

After harvest, bulbs from one of the border rows in each plot of both trials were rated for single centers. Twenty-five consecutive onions ranging in diameter from 3½ to 4¼ inches were rated. The onions were cut equatorially through the bulb middle and separated into single-centered (bullet) and multiple-centered bulbs. The multiple-centered bulbs had the long axis of the inside diameter of the first single ring measured. These multiple-centered onions were ranked according to the inside diameter of the first entire single ring: small had diameters less than 1½ inches, medium had diameters from 1½ to 2¼ inches, and large had diameters greater than 2¼ inches. Onions were considered "functionally single centered" for processing if they were single centered (bullet) or had a small multiple center.

During grading, bulbs were separated according to quality: bulbs without blemishes (No. 1s), split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, bulbs infected with the fungus *Fusarium oxysporum* (plate rot), bulbs infected with the fungus *Aspergillus niger* (black mold), and bulbs infected with unidentified bacteria in the external scales. The No. 1 bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Bulb counts per 50 lb of supercolossal onions were determined for each plot of every variety by weighing and counting all supercolossal bulbs during grading. Marketable yield consisted of No.1 bulbs larger than 2¼ inches.

In late December, 2018, 50 bulbs from border rows in each plot were cut longitudinally and evaluated for the presence of incomplete scales, dry scales, internal bacterial rot, and internal rot caused by *Fusarium proliferatum* or other fungi. Incomplete scales were defined as scales that had more than 0.25 inch from the center of the neck missing or any part missing lower down on the scale. Dry scales were defined as scales that had either more than 0.25 inch from the center of the neck dry or any part dry lower down on the scale.

After grading, two replicates of each variety were evaluated for bulb shape, bulb shape uniformity, firmness, skin color, skin retention, and flesh brightness on January 15, 2019. The quality characteristics were evaluated by a group of 10 people who did not know the variety identities. Evaluators included OSU personnel, seed company employees, and others.

The varieties from each of the early-maturity and full-season trials were compared for yield, grade, internal quality, and disease expression. Varietal differences were determined using analysis of variance. Means separation was determined using a protected Fisher's least significant difference test at the 5% probability level, LSD (0.05). The least significant difference LSD (0.05) values in each table should be considered when comparisons are made between varieties for significant differences in their performance characteristics. Differences between varieties equal to or greater than the LSD value for a characteristic should exist before any variety is considered different from any other variety in that characteristic. Because variety performance varies by year, growers are encouraged to review variety performance data over a number of years before choosing a variety to plant.

Results

The rate of accumulation and total number of growing degree-days (50-86°F) in 2018 were close to the 24-year average, until May (Fig. 1), which had higher than average growing degree-days (Fig. 2). With regards to irrigation management, the SWT at 8-inch depth frequently exceeded the target of 20 cb by 5 to 10 cb during the season (Fig. 3).

Early-maturing Trial

On August 8, all varieties had at least 68% tops down (Table 5). After 2 weeks of storage, no bulb sprouting or decomposition was found. The percentage of onions that were functionally single centered averaged 65% and ranged from 44% for 'Yosemite' to 84% for 'Spanish Medallion' (Table 5). Total yield averaged 1120 cwt/acre, ranging from 995 cwt/acre for Yosemite to 1179 cwt/acre for Spanish Medallion (Table 6).

Full-season Trial

On August 1, the percentage of tops down averaged 35% and ranged from 8% for 'Joaquin' and 'Barbaro' to 89% for 'Traverse' and SV4643NT (Table 7). By August 15, the percentage of tops down averaged 83% and ranged from 27% for Joaquin to 100% for 'Ridge Line' and Traverse. The severity of thrips leaf damage, on a scale from 0 to10, averaged 2.8 and ranged from 1.2 for 'Oracle', Joaquin, SV6672, and DPLD-17-34 to 5.4 for TAS016. Bolting averaged 0.3% and ranged from 0% for many varieties to 2.6% for 'Dulce Reina'. Iris yellow spot virus severity was low in this trial, with most varieties showing low intensity of symptoms with a rating of 1 (0-25% of foliage diseased). Iris yellow spot virus severity averaged 1 and ranged from 1 for most varieties to 1.8 for 1029.

The percentage of functionally single-centered bulbs averaged 74% and ranged from 17.6% for 10284 to 99.2% for 'Cometa' (Table 8).

Marketable yield averaged 997 cwt/acre and ranged from 304 cwt/acre for variety 1029 to 1493 cwt/acre for SV6672 (Table 9). Variety SV6672 had the highest marketable yield followed by Barbaro, Vaquero, 'Ranchero', SV6646, and 'Avalon'. Storage decomposition averaged 4% and ranged from 0.3% for Traverse to 27% for 'Red Nugent'.

Subjective Quality Evaluation

Subjective bulb quality ratings can be found in Table 12 and explanation of the rating system can be found in Figure 4 and Tables 10 and 11. Significant variations were found among varieties in all the subjective characteristics except bulb shape uniformity.

Internal Defect Evaluation

The percentage of bulbs with incomplete scales, regardless of dry scale or disease, averaged 56% and ranged from 28% for Cometa to 90% for 1029 (Table 13). The percentage of bulbs with internal decomposition, regardless of incomplete or dry scales, averaged 0.4% and ranged from 0% for many varieties to 2.4% for TAS016. For most varieties, most of the internal decomposition occurred in bulbs with incomplete scales. In 2018, the percentage of bulbs with internal decomposition was low and had bacteria, *Fusarium proliferatum*, neck rot, and black mold present (Table 14).

Acknowledgements

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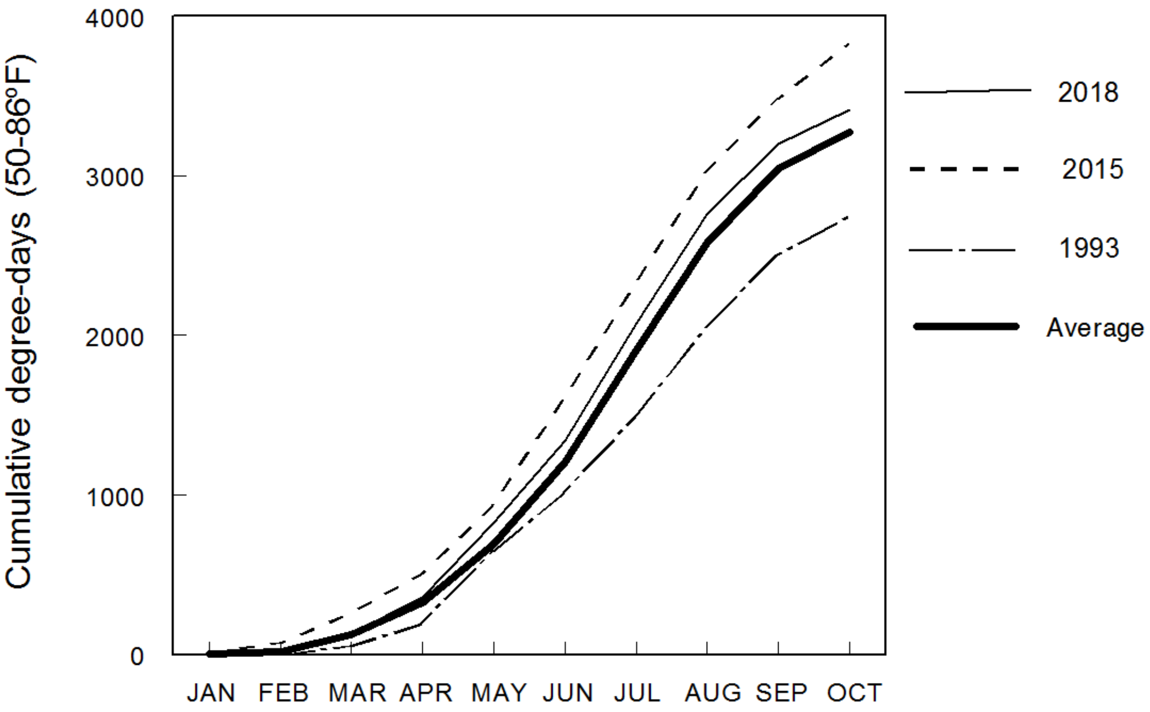

Figure 1. Cumulative growing degree-days (50-86°F) for selected years and 25-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

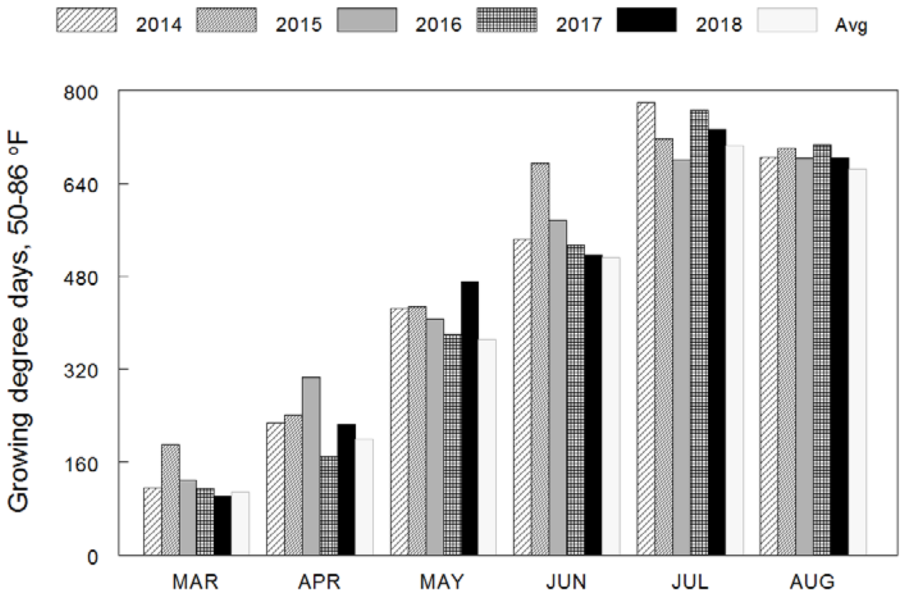

Figure 2. Monthly growing degree-days (50-86°F) for 2014-2018 and 25-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

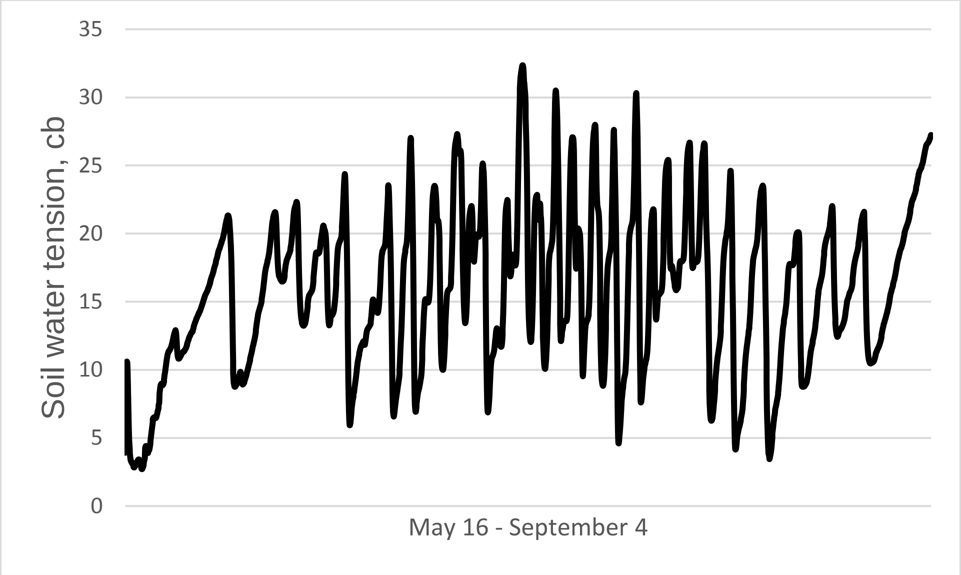

Figure 3. Soil water tension at 8-inch depth below the onion row. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Table 5. Single- and multiple-center bulb ratings for early-maturing onion varieties lifted and harvested August 8, 2018, Malheur Experiment Station, Oregon State University, Ontario, OR.

		Multiple center			Single center		Maturity Aug. 8		
Seed company	Variety	large	medium	small	functional*	bullet	tops down	leaf dryness	bolting
		----------	----------	----------	----------	%	----------	----------	----------
Enza Zaden	10106	8.0	30.4	28.0	61.6	33.6	94.0	22.0	0.0
Sakata	Ovation	12.8	18.4	18.4	68.8	50.4	68.0	19.0	0.2
	Spanish Medallion	4.0	12.0	24.0	84.0	60.0	86.0	18.0	0.2
	Yosemite	29.6	26.4	28.0	44.0	16.0	90.0	21.0	0.0
	Average	13.6	21.8	24.6	64.6	40.0	84.5	20.0	0.1
LSD (0.05)		10.2	12.4	NS	13.3	18.0	9.4	NS	NS

[a] Functional single-centered bulbs are the small multiple-centered plus the bullet-centered onion.

Table 6. Yield and grade performance of early-maturing onion varieties lifted and harvested August 8, 2018, Malheur Experiment Station, Oregon State University, Ontario, OR.

			Marketable yield by grade											
Seed company	Variety	Total yield	Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Small	No. 2s	Split root	Total rot	Black mold	Plate rot	Bulb counts >4¼ in
		----------	----------	----------	----------	cwt/acre	----------	----------	----------		---------	%	---------	#/50 lb
Enza Zaden	10106	1176.2	1149.4	308.4	463.4	361.9	15.7	11.6	6.4	1.4	0.6	0.5	0.1	30.9
Sakata	Ovation	1131.6	1115.2	153.6	510.6	438.7	12.3	5.3	0.0	11.1	0.0	0.0	0.0	31.7
	Spanish Medallion	1179.1	1166.1	240.2	490.7	424.5	10.6	12.1	0.0	0.0	0.1	0.0	0.1	31.1
	Yosemite	994.8	966.8	107.4	384.1	457.3	18.0	13.6	1.6	10.0	0.3	0.2	0.1	31.9
	Average	1120.4	1099.4	202.4	462.2	420.6	14.2	10.6	2.0	5.6	0.2	0.2	0.1	31.4
LSD (0.05)		33.9	37.2	75.8	66.3	NS	NS	4.9	NS	NS	NS	NS	NS	NS

Table 7. Maturity, bolting, thrips leaf damage, and iris yellow spot virus symptoms ratings of full-season onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Continued on next page.

			1-Aug		15-Aug			15-Aug	
Seed company	Variety	Bulb color	Tops down	Leaf dryness	Tops down	Leaf dryness	Bolting	Thrips leaf damage[a]	IYSV[b]
			--------------------	--------------------	%	--------------------		0 - 10	0 - 5
A. Takii	Grand Perfection	Y	26.0	6.0	92.0	16.0	0.1	2.2	1
	Ridge Line	Y	91.0	22.0	100.0	41.0	0.0	4.0	1
	Traverse	Y	89.0	21.0	100.0	50.0	0.0	4.4	1
Bejo	Delgado	Y	26.0	6.0	90.0	17.0	0.0	2.4	1
	Hamilton	Y	18.0	5.0	81.0	14.0	0.2	2.0	1
	Legend	Y	30.0	8.0	91.0	18.0	0.0	2.8	1
	Sedona	Y	23.0	6.0	89.0	13.0	0.7	2.0	1
Crookham	Avalon	Y	48.0	7.0	93.0	16.0	0.3	1.8	1
	Scout	Y	56.0	8.0	90.0	17.0	0.2	2.0	1
	Oracle	Y	13.0	2.0	56.0	12.0	0.5	1.2	1
	OLYX08-640	Y	82.0	12.0	94.0	27.0	0.0	3.6	1
	Red Beret	R	54.0	16.0	92.0	42.0	0.0	4.2	1
	Purple Haze	R	21.0	17.0	84.0	40.0	0.0	5.0	1.2
	White Cloud	W	44.0	8.0	90.0	16.0	0.0	1.8	1
Dorsing	1029	R	23.0	26.0	82.0	66.0	0.0	5.0	1.8
Enza Zaden	10284	Y	30.0	6.0	87.0	13.0	0.7	1.8	1
Hazera	Rhino	Y	43.0	10.0	92.0	17.0	0.0	2.8	1
New Zealand Onion	TAS016	R	35.0	26.0	92.0	52.0	0.0	5.4	1.2
	TAS040	R	62.0	20.0	91.0	43.0	0.0	4.8	1
	TAS042	R	83.0	22.0	97.0	46.0	0.0	4.6	1
	NZRW-001	R	13.3	23.3	86.7	53.3	0.0	4.7	1

[a] Thrips leaf damage: 0 = no damage, 10 = most damage.
[b] IYSV: 0 = no symptoms, 5 = 100% foliage diseased.

Table 7. (Continued.) Maturity, bolting, thrips leaf damage, and iris yellow spot virus symptoms ratings of full-season onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

			1-Aug		15-Aug			15-Aug	
Seed company	Variety	Bulb color	Tops down	Leaf dryness	Tops down	Leaf dryness	Bolting	Thrips leaf damage[a]	IYSV[b]
			--------------------	-------------------- %	--------------------	--------------------		0 - 10	0 - 5
Nunhems	Annillo	Y	17.0	7.0	74.0	15.0	0.0	2.2	1
	Arcero	Y	11.0	8.0	70.0	14.0	0.0	2.4	1
	Granero	Y	15.0	5.0	78.0	14.0	0.4	2.2	1
	Ranchero	Y	21.0	5.0	85.0	14.0	0.2	2.2	1
	Joaquin	Y	8.0	2.0	27.0	8.0	0.5	1.2	1
	Montero	Y	68.0	15.0	91.0	26.0	0.0	3.4	1.2
	Oloroso	Y	13.0	3.0	76.0	13.0	0.0	2.4	1
	Pandero	Y	12.0	1.0	67.0	12.0	1.0	1.4	1
	Vaquero	Y	18.0	5.0	80.0	14.0	0.0	2.2	1
	Cometa	W	25.0	3.0	86.0	12.0	2.3	2.2	1
	Marenge	R	39.0	24.0	97.0	54.0	0.0	5.0	1
Sakata	Aruba	Y	47.0	5.0	88.0	14.0	0.7	2.0	1
	Lasso	Y	36.0	6.0	87.0	16.0	0.5	1.8	1
	Dulce Reina	Y	20.0	5.0	70.0	12.0	2.6	2.0	1
	Yukon	Y	34.0	8.0	88.0	16.0	0.1	2.2	1
Seminis	Barbaro	Y	8.0	3.0	48.0	11.0	0.1	1.4	1
	Swale	Y	18.0	3.0	78.0	12.0	0.0	1.4	1
	Tucannon	Y	32.0	6.0	86.0	15.0	0.0	2.2	1
	16000	Y	41.0	7.0	92.0	14.0	0.2	1.6	1
	SV4058	W	17.0	7.0	74.0	15.0	0.0	2.0	1
	SV6646	Y	17.0	4.0	86.0	13.0	0.1	1.8	1
	SV6672	Y	26.0	5.0	88.0	11.0	0.7	1.2	1
	SV4643NT	R	89.0	26.0	99.0	62.0	0.0	5.2	1
	Red Nugent	R	86.0	29.0	98.0	66.0	0.0	4.4	1.2
D. Palmer	Saffron	Y	26.0	10.0	86.0	19.0	0.1	2.2	1
	Diamond Swan	W	14.0	5.0	68.0	14.0	1.2	2.0	1
	Cherry Mountain	R	19.0	15.0	82.0	28.0	0.0	4.4	1.2
	DPLD-17-34	Y	10.0	3.0	38.0	12.0	0.6	1.2	1
	DPLD-17-35	Y	31.0	7.0	91.0	18.0	0.3	2.6	1
	DPS-2056	W	18.0	6.0	78.0	14.0	0.6	2.2	1
	DPS-2075	W	72.0	14.0	92.0	30.0	0.0	3.4	1
	DPR-3088	R	17.0	14.0	80.0	28.0	0.0	4.2	1
Average			34.6	10.3	83.0	23.9	0.3	2.8	1.0
LSD (0.05)			12.7	4.1	8.8	5.8	0.4	0.8	0.2

[a] Thrips leaf damage: 0 = no damage, 10 = most damage.

[b] IYSV: 0 = no symptoms, 5 = 100% foliage diseased.

Table 8. Single- and multiple-center ratings for full-season onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Continued on next page.

			Multiple center			Single center	
Seed company	Variety	Bulb color	large	medium	small	functional[a]	bullet
			%				
A. Takii	Grand Perfection	Y	11.2	27.2	13.6	61.6	48.0
	Ridge Line	Y	28.6	26.2	17.4	45.2	27.8
	Traverse	Y	7.2	24.8	29.6	68.0	38.4
Bejo	Delgado	Y	30.2	21.9	26.9	47.9	21.0
	Hamilton	Y	9.6	11.2	8.8	79.2	70.4
	Legend	Y	30.6	26.4	25.5	43.0	17.5
	Sedona	Y	16.0	16.8	22.4	67.2	44.8
Crookham	Avalon	Y	12.0	18.4	20.0	69.6	49.6
	Scout	Y	15.5	20.1	17.1	64.4	47.3
	Oracle	Y	0.8	1.6	1.6	97.6	96.0
	OLYX08-640	Y	4.0	3.2	11.2	92.8	81.6
	Red Beret	R	8.0	11.2	13.6	80.8	67.2
	Purple Haze	R	3.2	5.6	12.8	91.2	78.4
	White Cloud	W	28.9	28.3	19.5	42.8	23.3
Dorsing	1029	R	12.0	14.4	19.2	73.6	54.4
Enza Zaden	10284	Y	48.8	33.6	5.6	17.6	12.0
Hazera	Rhino	Y	7.2	6.4	9.6	86.4	76.8
New Zealand Onion	TAS016	R	25.1	17.0	24.1	57.9	33.7
	TAS040	R	22.5	33.1	19.4	44.3	24.9
	TAS042	R	22.6	27.4	25.1	50.0	24.9
	NZRW-001	R	4.0	16.0	13.3	80.0	66.7

[a] Functional single-centered bulbs are the small multiple-centered plus the bullet-centered onion.

Table 8. (Continued.) Single- and multiple-center ratings for full-season onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

			Multiple center			Single center	
Seed company	Variety	Bulb color	large	medium	small	functional[a]	bullet
			-------------------------- % --------------------------				
Nunhems	Annillo	Y	1.6	4.0	4.0	94.4	90.4
	Arcero	Y	0.8	0.8	4.8	98.4	93.6
	Granero	Y	4.0	11.2	10.4	84.8	74.4
	Ranchero	Y	3.2	4.8	12.8	92.0	79.2
	Joaquin	Y	0.8	0.8	1.6	98.4	96.8
	Montero	Y	1.6	4.8	15.2	93.6	78.4
	Oloroso	Y	3.2	3.2	3.2	93.6	90.4
	Pandero	Y	6.4	17.6	12.8	76.0	63.2
	Vaquero	Y	1.6	8.8	11.2	89.6	78.4
	Cometa	W	0.0	0.8	1.6	99.2	97.6
	Marenge	R	4.0	7.2	18.4	88.8	70.4
Sakata	Aruba	Y	0.8	11.2	11.2	88.0	76.8
	Lasso	Y	8.8	16.0	17.6	75.2	57.6
	Dulce Reina	Y	4.8	8.8	9.6	86.4	76.8
	Yukon	Y	15.2	21.6	17.6	63.2	45.6
Seminis	Barbaro	Y	0.8	1.6	6.4	97.6	91.2
	Swale	Y	5.6	9.6	13.6	84.8	71.2
	Tucannon	Y	9.6	7.1	13.5	83.3	69.8
	16000	Y	4.8	4.0	8.0	91.2	83.2
	SV4058	W	6.4	13.6	9.6	80.0	70.4
	SV6646	Y	1.6	1.6	6.4	96.8	90.4
	SV6672	Y	8.0	11.2	5.6	80.8	75.2
	SV4643NT	R	24.5	14.4	7.9	61.2	53.3
	Red Nugent	R	20.8	14.4	6.4	64.8	58.4
D. Palmer	Saffron	Y	22.4	17.6	26.4	60.0	33.6
	Diamond Swan	W	24.0	21.6	20.8	54.4	33.6
	Cherry Mountain	R	12.0	22.4	20.0	65.6	45.6
	DPLD-17-34	Y	23.2	17.6	12.8	59.2	46.4
	DPLD-17-35	Y	22.4	20.0	16.0	57.6	41.6
	DPS-2056	W	7.2	15.2	14.4	77.6	63.2
	DPS-2075	W	49.6	15.2	10.4	35.2	24.8
	DPR-3088	R	15.2	12.0	12.0	72.8	60.8
Average			12.5	13.8	13.6	73.7	60.1
LSD (0.05)			8.6	9.5	7.8	12.3	14.6

[a]Functional single-centered bulbs are the small multiple-centered plus the bullet-centered onion.

Table 9. Yield and grade of full-season experimental and commercial onion varieties graded out of storage in January 2019, Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on next page.

				Marketable yield by grade												
Seed company	Variety	Bulb color	Total yield	Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Small	No. 2s	Bulb counts >4¼ in	Total rot	Neck rot	Plate rot	Black mold	Split basal plate
			---------------------------- cwt/acre							----------------------------	#/50 lb	------ % of total yield -----				
A. Takii	Grand Perfection	Y	1275	1239	373.1	492.1	358.9	14.7	6.3	7.8	30.5	1.0	0.9	0.1	0.0	0.8
	Ridge Line	Y	856	826	24.7	159.1	609.9	31.8	11.1	7.1	32.3	1.4	1.1	0.3	0.0	0.1
	Traverse	Y	901	887	4.6	108.5	744.3	29.4	11.3	0.0	33.8	0.3	0.1	0.2	0.0	0.0
Bejo	Delgado	Y	1123	1056	137.3	408.2	490.0	20.9	11.8	47.1	30.4	0.6	0.3	0.3	0.0	0.1
	Hamilton	Y	1214	1162	125.5	474.8	542.5	19.7	8.7	37.2	29.6	0.4	0.2	0.2	0.0	0.1
	Legend	Y	1063	1013	47.0	299.4	638.8	27.6	14.2	25.0	29.1	1.0	0.9	0.1	0.0	0.0
	Sedona	Y	1277	1204	175.5	513.7	497.4	17.8	9.9	52.6	30.7	0.8	0.7	0.0	0.0	0.0
Crookham	Avalon	Y	1506	1331	485.6	495.1	334.3	15.5	9.5	3.6	27.9	10.7	9.7	0.1	0.9	0.0
	Scout	Y	1394	1296	443.9	494.2	342.2	15.9	9.8	5.6	28.5	5.8	5.2	0.1	0.5	0.1
	Oracle	Y	1337	1277	394.2	471.7	392.4	18.9	11.2	2.2	30.8	3.4	3.3	0.1	0.0	0.0
	OLYX08-640	Y	921	883	18.1	202.6	629.7	32.7	14.3	3.7	31.4	2.2	1.8	0.3	0.1	0.0
	Red Beret	R	605	525	0.0	16.6	413.7	94.9	26.6	7.1		7.4	7.4	0.0	0.0	0.0
	Purple Haze	R	620	519	0.0	14.1	422.0	82.7	31.0	10.3		9.8	9.6	0.3	0.0	0.0
	White Cloud	W	1260	1094	208.6	422.1	447.3	15.5	8.5	27.1	29.2	9.8	8.6	0.4	0.9	0.6
Dorsing	1029	R	386	304	0.0	4.9	229.0	70.4	33.6	10.0		9.2	6.2	3.0	0.0	0.6
Enza Zaden	10284	Y	1494	1287	497.9	487.6	291.2	10.7	4.2	102.6	28.0	6.2	5.2	0.3	0.7	0.4
Hazera	Rhino	Y	1093	1043	189.4	408.3	417.4	27.9	8.9	9.8	30.9	2.8	2.6	0.2	0.0	0.0
New Zealand Onion	TAS016	R	460	358	0.0	0.0	181.9	176.3	57.3	34.8		1.8	1.4	0.4	0.0	0.3
	TAS040	R	585	477	0.0	30.8	376.1	70.4	36.1	47.0		2.8	2.7	0.1	0.0	1.4
	TAS042	R	676	598	4.9	41.7	488.0	63.8	21.5	35.9	32.7	2.8	2.4	0.4	0.0	0.1
	NZRW-001	R	479	448	0.0	13.2	349.4	85.2	19.1	4.8		1.4	0.7	0.5	0.2	0.2

Table 9. (Continued.) Yield and grade of full-season experimental and commercial onion varieties graded out of storage in January 2019, Malheur Experiment Station, Oregon State University, Ontario, OR.

Seed company	Variety	Bulb color	Total yield	Marketable yield by grade					Small	No. 2s	Bulb counts >4¼ in	Total rot	Neck rot	Plate rot	Black mold	Split basal plate
				Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in								
			------------------------------ cwt/acre ------------------------------								#/50 lb	------ % of total yield ------				
Nunhems	Annillo	Y	1254	1240	318.5	520.5	388.3	13.0	6.0	0.0	30.7	0.4	0.4	0.0	0.0	0.2
	Arcero	Y	1278	1257	263.5	548.8	432.2	12.9	10.0	1.7	31.0	0.7	0.5	0.2	0.0	0.0
	Granero	Y	1274	1247	259.8	560.6	410.5	16.2	8.6	1.1	30.8	1.2	1.0	0.1	0.1	0.1
	Ranchero	Y	1386	1347	466.2	505.3	353.0	22.5	12.1	8.7	28.9	1.3	1.3	0.0	0.0	0.0
	Joaquin	Y	1384	1300	379.6	548.9	355.2	16.7	9.2	6.6	30.0	5.0	4.9	0.1	0.0	0.2
	Montero	Y	1113	1096	174.3	404.1	503.1	14.9	9.7	1.4	31.4	0.4	0.3	0.1	0.0	0.1
	Oloroso	Y	1160	1131	104.2	487.6	519.1	19.7	8.8	6.0	32.9	1.1	1.0	0.0	0.2	0.1
	Pandero	Y	1287	1261	289.9	497.4	457.0	17.0	10.2	8.5	29.8	0.4	0.3	0.1	0.0	0.1
	Vaquero	Y	1382	1361	482.7	536.2	326.0	15.7	7.6	0.0	29.0	0.9	0.8	0.0	0.1	0.0
	Cometa	W	1207	1138	204.4	452.7	462.6	17.9	5.9	1.7	30.4	5.1	4.6	0.3	0.2	0.0
	Marenge	R	607	522	1.7	15.8	441.0	63.7	26.2	14.9	30.1	6.4	4.1	2.2	0.0	0.8
Sakata	Aruba	Y	1210	1166	297.2	437.0	411.6	19.9	8.9	6.2	30.0	2.4	2.0	0.4	0.0	0.0
	Lasso	Y	1202	1158	280.8	471.6	389.6	16.0	5.9	20.0	30.5	1.5	1.2	0.3	0.1	0.0
	Dulce Reina	Y	1329	1267	429.8	484.4	332.0	20.7	9.5	5.7	31.2	3.5	3.4	0.0	0.1	0.0
	Yukon	Y	1327	1271	354.8	502.6	392.0	21.4	10.4	24.2	29.3	1.5	0.6	0.5	0.4	0.1
Seminis	Barbaro	Y	1441	1369	599.2	469.0	287.9	13.2	11.4	4.2	28.9	3.3	3.0	0.3	0.0	0.5
	Swale	Y	1319	1273	263.4	513.3	483.0	12.9	7.3	10.9	30.7	1.0	0.9	0.1	0.0	1.1
	Tucannon	Y	1153	1119	216.8	412.8	463.0	26.8	11.7	10.7	30.3	0.9	0.8	0.1	0.0	0.0
	16000	Y	1274	1234	350.2	481.0	386.5	15.8	10.0	8.8	28.9	1.7	1.5	0.1	0.1	0.0
	SV4058	W	1213	1116	269.7	428.3	405.9	11.8	11.0	9.3	29.5	6.3	5.5	0.8	0.0	0.1
	SV6646	Y	1372	1337	427.9	544.3	352.1	12.7	7.5	7.9	29.6	1.4	1.3	0.1	0.0	0.1
	SV6672	Y	1531	1493	625.4	552.9	308.2	6.1	6.8	9.2	26.9	1.3	1.1	0.1	0.1	0.2
	SV4643NT	R	624	490	1.6	37.3	383.1	67.9	25.1	37.7	31.6	11.3	10.1	1.2	0.0	0.0
	Red Nugent	R	643	412	0.0	26.4	321.3	64.7	28.5	32.4		27.3	26.7	0.6	0.0	0.2
D. Palmer	Saffron	Y	896	803	26.0	167.7	554.4	54.5	19.3	62.8	31.4	1.1	1.1	0.0	0.0	0.0
	Diamond Swan	W	1124	953	114.2	328.3	485.0	26.0	11.3	95.5	29.8	5.1	4.3	0.5	0.3	0.5
	Cherry Mountain	R	559	432	0.0	22.5	340.6	68.9	24.6	63.1		6.6	5.5	1.1	0.0	0.4
	DPLD-17-34	Y	1311	1230	317.8	496.3	397.8	18.2	10.1	63.6	29.8	0.5	0.4	0.1	0.0	0.1
	DPLD-17-35	Y	1118	1037	140.1	389.6	485.4	22.0	7.9	55.3	30.0	1.5	0.9	0.2	0.3	0.1
	DPS-2056	W	1115	981	207.5	350.9	397.7	24.8	11.0	44.8	29.4	7.1	7.0	0.1	0.0	0.0
	DPS-2075	W	772	519	51.1	119.3	306.1	42.7	17.5	148.6	28.1	11.0	11.0	0.0	0.0	0.1
	DPR-3088	R	566	463	3.0	43.0	353.1	63.8	25.5	44.8	35.6	5.6	4.2	1.4	0.0	0.1
Average			1075	997	208.5	338.0	416.6	34.0	14.3	24.5	30.3	3.9	3.5	0.3	0.1	0.2
LSD (0.05)			69	81	71.7	64.6	79.1	13.4	7.3	18.7	1.9	4.3	4.3	1.0	0.4	0.3

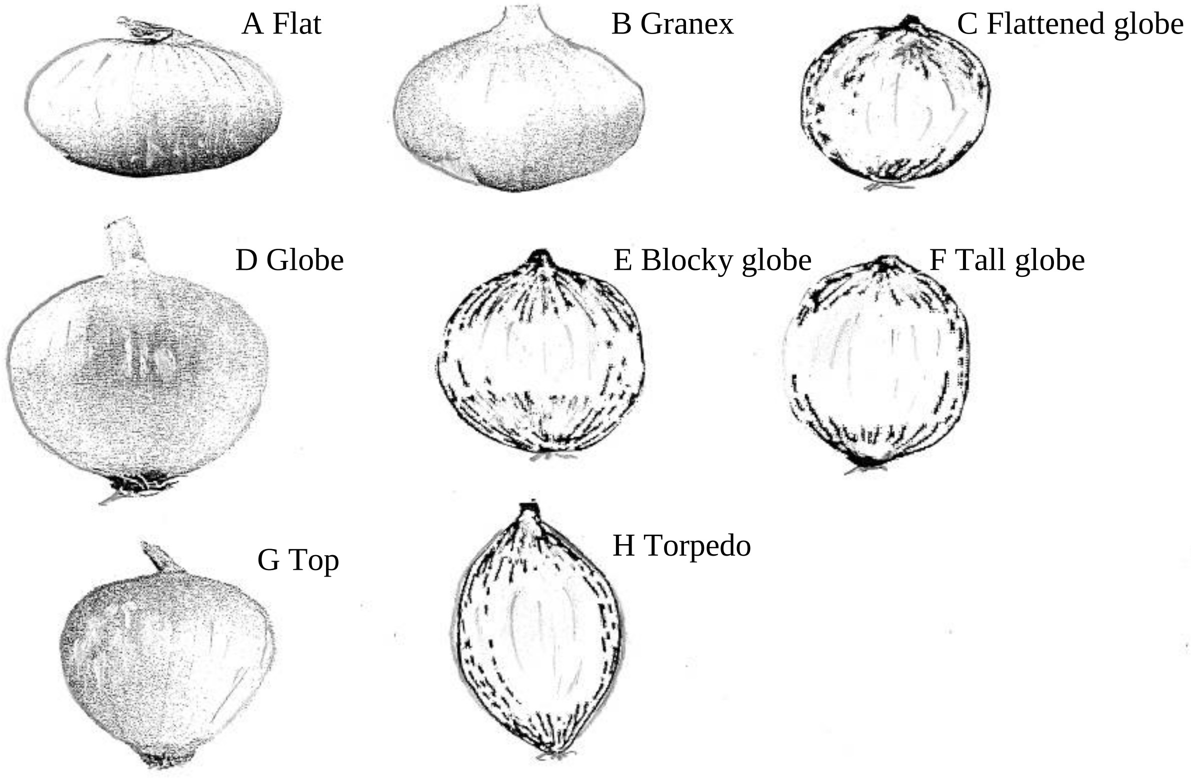

Figure 4. Onion bulb shape rating system (see Table 10). Malheur Experiment Station, Oregon State University, Ontario, OR.

Table 10. Bulb shapes. For a description of bulb shapes, see Fig. 4.

Bulb shape	
Scale	Shape
A	Flat
B	Granex
C	Flattened globe
D	Globe
E	Blocky globe
F	Tall globe
G	Top
H	Torpedo

Table 11. Onion variety subjective quality evaluation rating system.

Characteristic	Scale	Description
Bulb shape	A-H	see Fig. 4
Skin color	1-5	1 = light, 5 = dark
Bulb shape uniformity	1-5	1 = nonuniform shape, 5 = uniform shape
Firmness	1-5	1 = soft, 5 = hard
Skin retention	1-5	1 = bald, 5 = no cracks
Flesh brightness	1-5	yellow varieties: 1 = yellow, 5 = white red varieties: 1 = dark red, 5 = pale red white varieties: 1 = less white, 5 = very white

Table 12. Subjective evaluations of onion appearance and firmness by variety on January 15, 2019, Malheur Experiment Station, Oregon State University, Ontario, OR.

Company	Variety	Color	Bulb shape[a]	Skin color[b]	Bulb shape uniformity[b]	Firmness[b]	Scale retention[b]	Flesh brightness[b]
					----------------------------	1 - 5	----------------------------	
A. Takii	Grand Perfection	Y	d	3.3	3.5	3.0	3.5	4.0
	Ridge Line	Y	d	3.0	3.5	3.0	2.0	4.5
	Traverse	Y	e	3.0	4.0	3.3	3.0	4.0
Bejo	Delgado	Y	d	3.5	4.0	3.8	3.5	3.8
	Hamilton	Y	d	3.5	3.5	4.8	4.8	4.0
	Legend	Y	d	4.0	3.5	4.3	4.5	4.0
	Sedona	Y	d	3.5	3.5	3.5	4.0	3.3
Crookham	Avalon	Y	d	2.0	2.5	2.3	2.5	4.8
	Scout	Y	e	2.3	2.8	3.5	3.0	4.3
	Oracle	Y	f	2.8	3.5	3.0	3.5	4.3
	OLYX08-640	Y	d	3.8	3.0	4.0	4.0	3.0
	Red Beret	R	d	3.0	2.3	2.8	3.0	3.8
	Purple Haze	R	f	3.3	2.3	3.0	3.0	2.5
	White Cloud	W	d	2.5	3.5	3.0	3.0	4.0
Dorsing	1029	R	c	3.0	2.5	2.8	3.0	2.0
Enza Zaden	10284	Y	c	2.0	3.0	2.0	2.5	3.8
Hazera	Rhino	Y	e	3.3	4.0	3.5	3.5	3.5
New Zealand Onion	TAS016	R	c	3.0	3.0	3.0	3.0	3.3
	TAS040	R	d	3.3	3.0	3.0	2.0	3.0
	TAS042	R	c	2.5	3.0	2.8	2.0	3.5
	NZRW-001	R	g	3.0	3.0	3.5	4.0	3.8
Nunhems	Annillo	Y	e	3.5	4.0	4.0	4.0	4.0
	Arcero	Y	d	3.5	4.0	4.0	3.8	4.5
	Granero	Y	d	3.5	3.5	4.0	4.0	3.0
	Ranchero	Y	e	2.8	4.0	3.5	4.0	3.5
	Joaquin	Y	f	3.0	4.0	4.0	4.0	4.0
	Montero	Y	d	2.8	3.5	3.0	3.8	5.0
	Oloroso	Y	d	4.0	4.0	4.0	5.0	3.8
	Pandero	Y	d	3.5	2.8	3.3	4.0	3.5
	Vaquero	Y	d	3.0	3.3	3.8	4.0	3.8
	Cometa	W	d	3.5	4.0	3.0	4.0	4.5
	Marenge	R	e	4.0	3.8	3.0	3.0	3.3
Sakata	Aruba	Y	d	2.3	3.5	3.5	3.0	4.8
	Lasso	Y	e	2.3	3.3	3.0	3.0	3.8
	Dulce Reina	Y	d	2.5	3.5	3.0	3.0	5.0
	Yukon	Y	d	2.0	3.0	3.0	3.0	3.5
Seminis	Barbaro	Y	f	3.0	3.5	3.5	3.3	4.5
	Swale	Y	d	3.5	4.0	3.3	4.5	3.3
	Tucannon	Y	d	3.8	3.0	3.8	4.0	3.5
	16000	Y	d	3.0	3.0	3.0	3.5	4.3
	SV4058	W	d	3.0	3.5	3.0	3.0	4.3
	SV6646	Y	d	3.0	3.5	3.0	3.0	4.3
	SV6672	Y	d	3.0	3.0	3.3	3.0	4.0
	SV4643NT	R	g	2.8	3.5	2.3	2.8	3.0
	Red Nugent	R	g	2.8	2.8	2.5	3.3	3.5
D. Palmer	Saffron	Y	d	4.0	2.8	3.8	4.5	3.3
	Diamond Swan	W	d	3.0	3.0	3.0	3.0	3.5
	Cherry Mountain	R	d	4.3	2.5	3.0	4.0	1.5
	DPLD-17-34	Y	e	3.0	3.0	3.3	4.0	3.5
	DPLD-17-35	Y	d	3.0	2.5	3.8	2.5	3.3
	DPS-2056	W	d	2.8	2.5	3.0	3.0	4.5
	DPS-2075	W	d	2.3	2.0	2.8	2.5	3.0
	DPR-3088	R	f	4.0	3.0	3.0	4.0	3.0
Average			d	3.1	3.2	3.3	3.4	3.7
LSD (0.05)			1.5	0.7	NS	0.6	1.0	0.9

[a] Bulb shape: see Fig. 4. [b] Subjective ratings are described in Table 12.

Table 13. Internal defects of full-season experimental and commercial onion varieties evaluated out of storage in January 2019, Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on next page.

			All bulbs							Diseased bulbs						
			Complete scales			Incomplete scales			Total	Complete scales			Incomplete scales			Total
Seed company	Variety	Bulb color	no dry scale	dry scale	total	no dry scale	dry scale	total		no dry scale	dry scale	total	no dry scale	dry scale	total	
			%													
A. Takii	Grand Perfection	Y	60.0	3.3	63.3	26.9	9.8	36.7	100	0.0	0.0	0.0	0.0	0.8	0.8	0.8
	Ridge Line	Y	13.6	0.0	13.6	41.6	44.8	86.4	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Traverse	Y	15.2	0.0	15.2	38.0	46.8	84.8	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bejo	Delgado	Y	62.1	1.2	63.3	24.7	12.0	36.7	100	0.4	0.4	0.8	0.4	0.0	0.4	1.2
	Hamilton	Y	49.0	5.2	54.1	27.1	18.7	45.9	100	0.0	0.0	0.0	0.8	0.0	0.8	0.8
	Legend	Y	48.4	12.0	60.4	17.2	22.4	39.6	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sedona	Y	41.3	4.8	46.2	34.9	18.9	53.8	100	0.0	0.0	0.0	0.4	0.0	0.4	0.4
Crookham	Avalon	Y	55.3	0.5	55.8	26.3	17.9	44.2	100	0.0	0.0	0.0	0.6	0.6	1.2	1.2
	Scout	Y	38.2	0.0	38.2	34.8	27.0	61.8	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oracle	Y	61.7	1.2	62.9	21.1	16.0	37.1	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	OLYX08-640	Y	32.0	0.4	32.4	39.6	28.0	67.6	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Red Beret	R	25.2	1.6	26.8	14.4	58.8	73.2	100	0.4	0.0	0.4	0.0	0.0	0.0	0.4
	Purple Haze	R	13.1	0.0	13.1	26.7	60.1	86.9	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	White Cloud	W	59.6	0.4	60.0	25.6	14.4	40.0	100	0.0	0.0	0.0	0.4	0.0	0.4	0.4
Dorsing	1029	R	8.4	2.0	10.4	8.5	81.1	89.6	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Enza Zaden	10284	Y	44.4	0.8	45.2	33.7	21.1	54.8	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hazera	Rhino	Y	29.6	2.8	32.4	26.4	41.2	67.6	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Zealand Onion	TAS016	R	35.6	0.0	35.6	42.8	21.6	64.4	100	0.0	0.0	0.0	1.2	1.2	2.4	2.4
	TAS040	R	27.5	0.0	27.5	31.5	41.0	72.5	100	0.4	0.0	0.4	0.0	1.2	1.2	1.6
	TAS042	R	14.4	0.0	14.4	30.8	54.8	85.6	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	NZRW-001	R	11.7	7.9	19.6	12.4	67.9	80.4	100	0.0	0.0	0.0	0.0	1.3	1.3	1.3

Table 13. (Continued.) Internal defects of full-season experimental and commercial onion varieties evaluated out of storage in January 2019, Malheur Experiment Station, Oregon State University, Ontario, OR.

			All bulbs							Diseased bulbs						
			Complete scales			Incomplete scales			Total	Complete scales			Incomplete scales			Total
Seed company	Variety	Bulb color	no dry scale	dry scale	total	no dry scale	dry scale	total		no dry scale	dry scale	total	no dry scale	dry scale	total	
			%													
Nunhems	Annillo	Y	20.8	0.0	20.8	34.0	45.2	79.2	100	0.4	0.0	0.4	0.4	0.0	0.4	0.8
	Arcero	Y	51.2	6.0	57.2	20.8	22.0	42.8	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	Granero	Y	44.8	1.6	46.4	35.6	18.0	53.6	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Ranchero	Y	57.8	0.8	58.6	15.2	26.1	41.4	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Joaquin	Y	54.8	0.0	54.8	21.2	24.0	45.2	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	Montero	Y	22.4	4.8	27.2	22.8	50.0	72.8	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oloroso	Y	33.8	4.8	38.6	30.6	30.8	61.4	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pandero	Y	57.2	6.8	64.0	17.2	18.8	36.0	100	0.0	0.0	0.0	0.4	0.4	0.8	0.8
	Vaquero	Y	42.5	11.7	54.2	23.2	22.6	45.8	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cometa	W	70.8	1.6	72.4	11.6	16.0	27.6	100	0.0	0.0	0.0	0.4	0.4	0.8	0.8
	Marenge	R	17.6	0.8	18.4	33.6	48.0	81.6	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sakata	Aruba	Y	44.9	4.9	49.8	29.6	20.7	50.2	100	0.0	0.0	0.0	0.8	0.0	0.8	0.8
	Lasso	Y	65.8	4.0	69.8	22.9	7.3	30.2	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dulce Reina	Y	66.7	2.5	69.2	17.2	13.6	30.8	100	0.0	0.0	0.0	0.8	0.0	0.8	0.8
	Yukon	Y	58.2	2.9	61.1	22.1	16.8	38.9	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seminis	Barbaro	Y	61.8	2.6	64.4	22.8	12.8	35.6	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Swale	Y	61.6	1.6	63.2	22.0	14.8	36.8	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Tucannon	Y	52.0	0.8	52.8	25.6	21.6	47.2	100	0.0	0.0	0.0	0.4	0.0	0.4	0.4
	16000	Y	43.3	0.4	43.7	28.7	27.7	56.3	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SV4058	W	65.4	0.8	66.2	26.1	7.7	33.8	100	0.0	0.0	0.0	0.4	0.0	0.4	0.4
	SV6646	Y	62.3	0.0	62.3	23.2	14.4	37.7	100	0.0	0.0	0.0	0.4	0.0	0.4	0.4
	SV6672	Y	52.6	0.0	52.6	35.9	11.5	47.4	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SV4643NT	R	27.7	3.4	31.1	29.2	39.7	68.9	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	Red Nugent	R	12.8	0.4	13.2	33.6	53.2	86.8	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D. Palmer	Saffron	Y	46.4	2.8	49.2	32.0	18.8	50.8	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	Diamond Swan	W	50.9	0.8	51.7	38.0	10.3	48.3	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	Cherry Mountain	R	22.8	2.0	24.8	21.6	53.6	75.2	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	DPLD-17-34	Y	56.4	5.5	61.9	19.7	18.4	38.1	100	0.0	0.0	0.0	0.8	1.3	2.1	2.1
	DPLD-17-35	Y	40.1	2.4	42.6	27.4	30.0	57.4	100	0.0	0.0	0.0	0.4	0.4	0.8	0.8
	DPS-2056	W	66.4	0.8	67.2	17.6	15.2	32.8	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	DPS-2075	W	28.0	0.4	28.4	56.8	14.8	71.6	100	0.0	0.4	0.4	0.8	0.0	0.8	1.2
	DPR-3088	R	25.6	4.4	29.9	20.4	49.7	70.1	100	0.4	0.0	0.4	0.0	0.0	0.0	0.4
	average		42.1	2.4	44.5	26.9	28.7	55.5	100	0.0	0.0	0.1	0.2	0.2	0.4	0.4
LSD (0.05)			15.6	5.9	16.3	14.6	16.7	16.3		NS	NS	NS	NS	NS	NS	1.3

Table 14. Internal decomposition by disease type of full-season experimental and commercial onion varieties evaluated out of storage in January 2019, Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on next page.

Seed company	Variety	Bulb color	Bacterial rot	*Fusarium proliferatum*	Neck rot	Black mold
			----------------------------------	%	----------------------------------	
A. Takii	Grand Perfection	Y	0.4	0.0	0.4	0.0
	Ridge Line	Y	0.0	0.0	0.0	0.0
	Traverse	Y	0.0	0.0	0.0	0.0
Bejo	Delgado	Y	0.0	0.8	0.4	0.0
	Hamilton	Y	0.0	0.4	0.4	0.0
	Legend	Y	0.0	0.0	0.0	0.0
	Sedona	Y	0.0	0.0	0.4	0.0
Crookham	Avalon	Y	1.1	0.0	0.0	0.0
	Scout	Y	0.0	0.0	0.0	0.0
	Oracle	Y	0.0	0.0	0.0	0.0
	OLYX08-640	Y	0.0	0.0	0.0	0.0
	Red Beret	R	0.4	0.0	0.0	0.0
	Purple Haze	R	0.0	0.0	0.0	0.4
	White Cloud	W	0.0	0.0	0.0	0.4
Dorsing	1029	R	0.0	0.0	0.0	0.0
Enza Zaden	10284	Y	0.0	0.0	0.0	0.0
Hazera	Rhino	Y	0.0	0.0	0.0	0.0
New Zealand Onion	TAS016	R	0.0	0.0	0.0	2.4
	TAS040	R	0.4	0.0	0.0	1.2
	TAS042	R	0.4	0.0	0.0	0.0
	NZRW-001	R	0.0	0.0	0.0	1.3

Table 14. (Continued.) Internal decomposition by disease type of full-season experimental and commercial onion varieties evaluated out of storage in January 2019, Malheur Experiment Station, Oregon State University, Ontario, OR.

Seed company	Variety	Bulb color	Bacterial rot	*Fusarium proliferatum*	Neck rot	Black mold
			--------------------------------	%	--------------------------------	
Nunhems	Annillo	Y	0.0	0.0	0.4	0.4
	Arcero	Y	0.0	0.0	0.4	0.0
	Granero	Y	0.0	0.0	0.0	0.0
	Ranchero	Y	0.0	0.0	0.0	0.0
	Joaquin	Y	0.0	0.0	0.0	0.4
	Montero	Y	0.0	0.0	0.0	0.0
	Oloroso	Y	0.0	0.0	0.0	0.0
	Pandero	Y	0.0	0.4	0.4	0.0
	Vaquero	Y	0.0	0.0	0.0	0.0
	Cometa	W	0.4	0.0	0.4	0.0
	Marenge	R	0.0	0.0	0.0	0.0
Sakata	Aruba	Y	0.8	0.0	0.0	0.0
	Lasso	Y	0.0	0.0	0.0	0.0
	Dulce Reina	Y	0.0	0.0	0.8	0.0
	Yukon	Y	0.0	0.0	0.0	0.0
Seminis	Barbaro	Y	0.0	0.0	0.0	0.0
	Swale	Y	0.0	0.0	0.0	0.0
	Tucannon	Y	0.4	0.0	0.0	0.0
	16000	Y	0.0	0.0	0.0	0.0
	SV4058	W	0.4	0.0	0.0	0.0
	SV6646	Y	0.0	0.0	0.4	0.0
	SV6672	Y	0.0	0.0	0.0	0.0
	SV4643NT	R	0.0	0.0	0.0	0.4
	Red Nugent	R	0.0	0.0	0.0	0.0
D. Palmer	Saffron	Y	0.0	0.0	0.0	0.4
	Diamond Swan	W	0.0	0.4	0.0	0.0
	Cherry Mountain	R	0.0	0.0	0.0	0.0
	DPLD-17-34	Y	1.2	0.4	0.4	0.0
	DPLD-17-35	Y	0.8	0.0	0.0	0.0
	DPS-2056	W	0.0	0.0	0.0	0.4
	DPS-2075	W	0.0	0.4	0.4	0.4
	DPR-3088	R	0.0	0.0	0.4	0.0
	average		0.1	0.1	0.1	0.2
LSD (0.05)			NS	NS	NS	0.7

ONION PRODUCTION FROM TRANSPLANTS IN 2018

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Introduction

Interest in an earlier start for onion harvest and marketing has led to interest in transplanting onions. In the Treasure Valley, onions are available out of the field from mid-August through October and then out of storage from October through March. An earlier harvest would extend the time when local onions are available, which is important for onion processors and possibly for onion packing sheds. Onion varieties suitable for processing into onion rings must be single centered, produce large bulbs, and store well. Previous research at the OSU Malheur Experiment Station (MES) has shown that when onions are grown from transplants, they can be harvested starting in July (Shock et al. 2004, 2007-2009, and 2011-2018). The 2018 trial evaluated 10 onion varieties grown from transplants potentially suitable for processing or fresh market. Seven varieties were grown from transplants produced in a greenhouse at MES and three varieties were grown from transplants produced in Arizona.

Materials and Methods

Transplants were grown at MES in a heated greenhouse with minimum air temperatures during the day of 65°F and 45°F at night. Onion seed of varieties ‘Jasmine’, 4062, and 4500 (Crookham Co., Caldwell, ID); SPCI-1 and SPCI-5 (Seminis Vegetable Seed, Payette, ID); and 903S and TAS027 (New Zealand Onion, Pukekohe, New Zealand) was planted in the greenhouse on January 29, 2018 in flats with a vacuum seeder at 72 seeds/flat. The seed was sown on a 1-inch layer of Salamander Soil potting mix (Fox Farm Soil and Fertilizer Co., Arcata, CA). The seed was then covered with 1 inch of the potting mix. The trays were watered immediately after planting and were kept moist. Onion seedlings began emerging on February 4. Transplants were grown without supplemental light. On February 19 and 26, Ridomil Gold® SL was watered into each flat to control damping off. Bare-rooted transplants of ‘Montero’ (Nunhems, Parma, ID), ‘Avenger’ (Crookham Co.), and KW-0106 (Seminis) were grown in Arizona during the winter of 2017-2018.

Onions were grown from the transplants on an Owyhee silt loam at MES previously planted to wheat. In the fall of 2017, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. A soil analysis taken in the fall of 2017 showed a pH of 8.2, 3.4% organic matter, 7 ppm nitrogen (N) as nitrate, 3 ppm N as ammonium, 22 ppm phosphorus (P), 386 ppm potassium (K), 20 ppm sulfur (S), 3218 ppm calcium, 533 ppm magnesium, 138 ppm sodium, 4.1 ppm zinc (Zn), 3 ppm manganese (Mn), 2.2 ppm copper (Cu), 16 ppm iron, and 0.5 ppm boron (B). Based on the soil analysis, 78 lb of P/acre, 81 lb of K/acre, 162 lb of S/acre, 9 lb of Mn/acre, and 1 lb of B/acre were broadcast before plowing. In addition to the chemical fertilizer, 10 ton/acre of composted cattle feedlot manure was broadcast before plowing. Based on an analysis of the manure, 196 lb of N/acre, 156 lb of P/acre, and 342 lb of K/acre were added from the manure. After plowing, the field was fumigated with Vapam® at 15 gal/acre and bedded at 22 inches.

Drip tape was laid at 4-inch depth between pairs of onion beds before planting. The drip tape had emitters spaced 12 inches apart and an emitter flow rate of 0.22 gal/min/100 ft (Toro Aqua-Traxx, Toro Co., El Cajon, CA). The distance between the tape and the center of each double row of onions was 11 inches.

Varieties Jasmine, 4062, 4500, SPCI-1, SPCI-5, 903S, and TAS027, grown in the greenhouse, were transplanted on March 28. Varieties Avenger, KW-0106, and Montero, grown in Arizona, were transplanted on April 4. The onions were transplanted on 4 22-inch beds in double rows 3 inches apart. The spacing between plants in each row was 4.8 inches, equivalent to 120,000 plants/acre. Plots of each variety were 20 ft long by 4 double rows wide. The experimental design was a randomized complete block with five replicates.

The onion crop was managed to minimize yield reductions from weeds, pests, diseases, water stress, and nutrient deficiencies. The herbicide Prowl® H_2O at 2 pt/acre (0.95 lb ai/acre) was broadcast for weed control on April 6. The herbicides GoalTender® at 4 oz/acre (0.09 lb ai/acre), Brox® at 16 oz/acre (0.25 lb ai/acre), and Shadow® at 5.3 oz/acre (0.12 lb ai/acre) were broadcast on May 7 for weed control. Thrips were controlled by ground application using the following insecticides: Aza-Direct® at 12 oz/acre (0.00093 lb ai/acre) and Movento® at 5 oz/acre (0.008 lb ai/acre) on May 9 and 16, and Agri-Mek® SC at 3.5 oz/acre (0.02 lb ai/acre) on May 24.

A total of 60 lb N/acre was applied in 3 20-lb increments during the season as urea ammonium nitrate solution (URAN) injected through the drip tape.

Onions were irrigated automatically to maintain the soil water tension (SWT) in the onion root zone below 20 cb (Fig. 1, Shock et al. 2000). Soil water tension was measured with eight granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co. Inc., Riverside, CA) installed at 8-inch depth in the center of the double row. Sensors had been calibrated to SWT (Shock et al. 1998). The GMS were connected to the datalogger via multiplexers (AM 16/32, Campbell Scientific, Logan, UT). The datalogger (CR1000, Campbell Scientific) read the sensors and recorded the SWT every hour. The datalogger automatically made irrigation decisions every 12 hours. The field was irrigated if the average SWT of the eight sensors was 20 cb or higher. The irrigations were controlled by the datalogger using a controller (SDM CD16AC, Campbell Scientific) connected to a solenoid valve. Irrigation durations were 8 hours, 19 min to apply 0.48 inch of water. The water supply was well water maintained at a constant water pressure of 35 psi. The pressure in the drip lines was maintained at 10 psi by a pressure-regulating valve. The automated irrigation system was started on April 13 and terminated on July 23.

On July 9, 16, and 23, bulbs from 6 ft of the middle 2 double rows in each plot were topped and bagged. Variety SPCI-5 started maturing earlier than the other varieties and harvest began 1 week earlier. Variety SPCI-5 had bulbs from 5 ft of the middle 2 double rows in each plot harvested on July 2, 9, 16, and 23. Bolted onions were counted in each plot on July 23. Decomposing bulbs were not bagged. At each harvest, onions in each plot were rated visually for the percentage of tops that were down and the percent dry leaves. Following each harvest, the onions were graded. Bulbs were separated according to quality: bulbs without blemishes

(No. 1s), split bulbs (No. 2s), bulbs infected with neck rot (*Botrytis allii*) in the neck or side, plate rot (*Fusarium oxysporum*), or black mold (*Aspergillus niger*). The No. 1 bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Bulb counts per 50 lb of supercolossal onions were calculated for each plot of every variety by weighing and counting all supercolossal bulbs during grading.

After grading, bulbs from each harvest were stored in a shed at ambient temperature for 2 weeks. After 2 weeks the bulbs were evaluated for single centers and for the number of sprouted or decomposed bulbs.

Twenty-five onions ranging in diameter from 3½ to 4¼ inches from each plot from each harvest were rated for single centers. The onions were cut equatorially through the bulb middle and separated into single-centered and multiple-centered bulbs. The multiple-centered bulbs had the long axis of the inside diameter of the first single ring measured. These multiple-centered onions were ranked according to the diameter of the first single ring: small multiple-centered onions had diameters under 1½ inch, medium multiple-centered onions had diameters from 1½ to 2¼ inches, and large multiple-centered onions had diameters over 2¼ inches. Onions were considered "functionally single centered" for processing if they were single centered or had a small multiple center.

Variety differences were compared using repeated measures analysis of variance. Means separation was determined using a protected Fisher's least significant difference test at the 5% probability level, LSD (0.05).

Results and Discussion

July 2 Harvest – SPCI-5

Marketable yield for variety SPCI-5 was 912 cwt/acre on July 13 (Table 1). The percentage of functionally single-centered bulbs was 93% (Table 2). The percentage of tops down at harvest was 40% and bulb decomposition or sprouting after 2 weeks of storage was 0% (Table 3).

July 9 Harvest

Marketable yield on July 9 ranged from 442 cwt/acre for TAS027 to 1078 cwt/acre for KW-0106 (Table 1). The marketable yield of the yellow varieties averaged 989 cwt/acre and the reds averaged 460 cwt/acre. The percentage of functionally single-centered bulbs averaged 84.8% and ranged from 54.4% for KW-0106 to 98.7% for SPCI-1 (Table 2). The percentage of tops down at harvest averaged 52% and ranged from 18% for SPCI-1 to 91% for Avenger (Table 3). Bulb decomposition or sprouting after 2 weeks of storage averaged 1.3% and ranged from 0% for SPCI-5, 903S, and TAS027 to 3.2% for Montero.

July 16 Harvest

Marketable yield on July 16 ranged from 468 cwt/acre for TAS027 to 1127 cwt/acre for SPCI-1 (Table 1). The marketable yield of the yellow varieties averaged 988 cwt/acre and the reds averaged 475 cwt/acre. The percentage of functionally single-centered bulbs averaged 79% and ranged from 50% for KW-0106 to 98% for Jasmine (Table 2). The percentage of tops down at harvest averaged 70% and ranged from 54% for SPCI-1 to 91% for Jasmine and SPCI-5 (Table

3). Bulb decomposition or sprouting after 2 weeks of storage averaged 0.6% and ranged from 0% for several varieties to 1.6% for Avenger and KW-0106.

July 23 Harvest

Marketable yield on July 23 ranged from 549 cwt/acre for 903S to 1366 cwt/acre for SPCI-1 (Table 1). The marketable yield of the yellow varieties averaged 1177 cwt/acre and the reds averaged 564 cwt/acre. The percentage of functionally single-centered bulbs averaged 69% and ranged from 31% for KW-0106 to 94% for Jasmine (Table 2). The percentage of tops down at harvest averaged 88% and ranged from 78% for 4062 to 94% for Jasmine (Table 3). Bulb decomposition or sprouting after 2 weeks of storage averaged 1% and ranged from 0% for SPCI-1, SPCI-5, and TAS027 to 3% for Jasmine (Table 3).

Overall

Bulb yields were high in 2018. May of 2018 had the highest number of growing degree-days since 2014. In 2018, the accumulated number of growing degree-days from April through July was higher than the 25-year average (Table 4). For comparison, performance data for variety Montero, which was in the transplant trials in 2014-2018 is presented in Table 5. Compared with recent years, Montero matured earlier in 2018, having 36% tops down on July 9.

Acknowledgements

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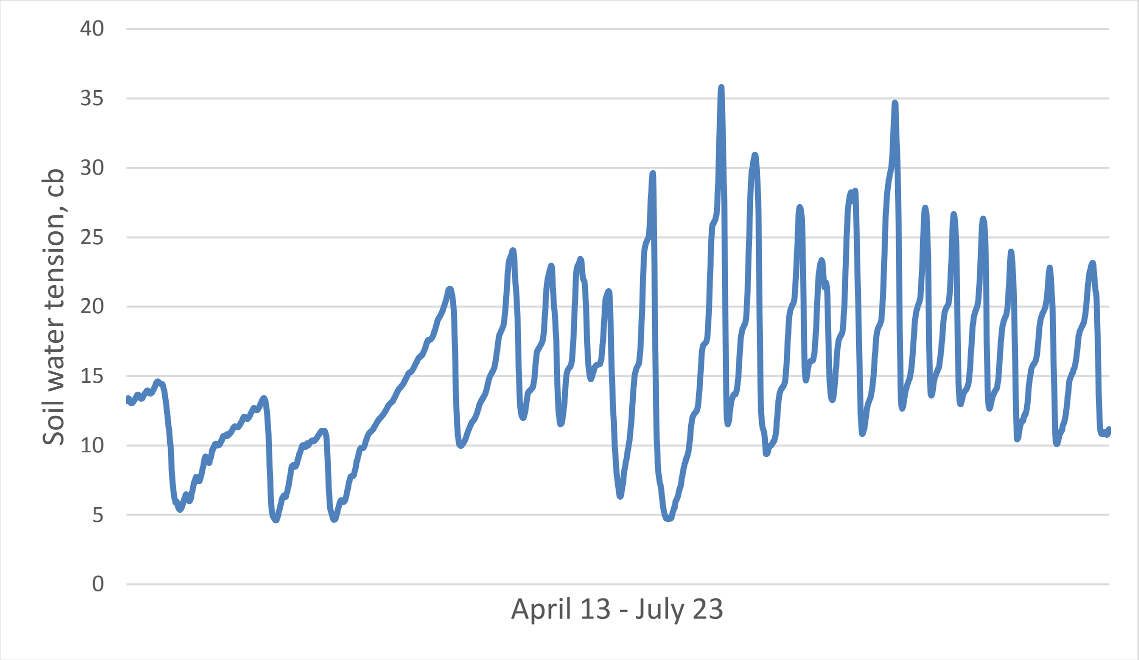

Figure 1. Soil water tension at 8-inch depth. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Table 1. Bulb yield and grade for eight yellow onion varieties and two red varieties (903S and TAS027) grown from transplants over three harvest dates, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Continued on next page.

Bulb color	Company	Variety	Total yield	Marketable yield by grade					Small	Doubles	Sunscald	Total rot	Plate rot	Slime rot	Bulb counts >4¼ in
				Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in							
			cwt/acre									%			#/50 lb
July 2 harvest															
	Seminis	SPCI-5[a]	925	912	52.9	350.5	493.9	14.6	13.7	0.0	0.0	0.0	0.0	0.0	35.7
July 9 harvest															
yellow	Nunhems	Montero	947.3	933.5	12.9	194.7	705.8	20.0	6.3	0.0	0.0	0.8	0.2	0.6	30.9
yellow	Crookham	Avenger	950.3	928.6	0.0	283.7	620.6	24.3	6.4	0.0	0.0	1.6	0.2	1.4	
yellow		Jasmine	999.6	985.6	106.5	361.4	480.0	37.7	12.4	0.0	0.0	0.2	0.0	0.2	33.6
yellow		4062	944.5	926.5	49.6	347.5	502.4	26.9	6.4	0.0	0.0	1.2	0.0	1.2	36.2
yellow		4500	990.3	984.6	75.5	327.3	555.6	26.1	5.7	0.0	0.0	0.0	0.0	0.0	36.5
yellow	Seminis	KW-0106	1090.0	1077.9	68.6	470.2	519.6	19.6	3.2	0.0	0.0	0.8	0.0	1.0	35.0
yellow		SPCI-1	1066.0	1052.3	192.6	436.9	402.9	19.9	7.8	0.0	0.0	0.5	0.0	0.5	33.8
yellow		SPCI-5	1064.3	1022.4	296.8	372.8	332.4	20.4	15.8	0.0	0.0	2.5	0.0	2.5	33.1
yellow		average	1006.6	988.9	100.3	349.3	514.9	24.4	8.0	0.0	0.0	0.9	0.0	0.9	34.2
red	N. Zealand Onion	903S	506.0	477.3	0.0	6.1	345.7	125.5	28.6	0.0	0.0	0.0	0.0	0.0	
red		TAS027	483.1	442.3	0.0	0.0	361.7	80.6	40.8	0.0	0.0	0.0	0.0	0.0	
red		average	494.5	459.8	0.0	3.0	353.7	103.1	34.7	0.0	0.0	0.0	0.0	0.0	
	Average		904.2	883.1	80.2	280.1	482.7	40.1	13.4	0.0	0.0	0.8	0.0	0.7	34.2
July 16 harvest															
yellow	Nunhems	Montero	999.9	974.7	0.0	233.5	727.7	13.5	3.7	0.0	7.6	1.4	0.0	1.4	
yellow	Crookham	Avenger	1015.0	964.8	28.8	233.9	690.0	12.0	10.8	3.4	9.2	2.7	0.0	2.7	34.4
yellow		Jasmine	1055.9	929.1	127.5	397.6	382.9	21.1	8.9	8.9	21.0	8.2	0.0	8.2	32.8
yellow		4062	972.4	928.9	106.4	384.6	426.2	11.7	8.8	0.0	30.9	0.4	0.0	0.4	34.2
yellow		4500	1005.6	968.1	52.4	435.0	464.9	15.8	6.3	0.0	24.2	0.9	0.3	0.6	34.0
yellow	Seminis	KW-0106	1056.6	979.5	135.2	365.3	466.1	12.9	7.1	8.4	26.3	3.5	0.0	3.5	32.0
yellow		SPCI-1	1194.5	1126.6	143.6	550.8	420.2	12.1	7.1	0.0	60.8	0.0	0.0	0.0	34.3
yellow		SPCI-5	1079.7	1035.8	361.5	424.8	228.3	21.2	13.0	0.0	24.7	0.6	0.0	0.6	31.6
yellow		average	1047.5	988.4	119.4	378.2	475.8	15.0	8.2	2.6	25.6	2.2	0.0	2.2	33.3
red	N. Zealand Onion	903S	525.1	478.0	0.0	32.1	363.9	82.0	36.2	7.3	0.0	0.7	0.0	0.7	
red		TAS027	500.3	467.5	0.0	18.8	372.2	76.4	28.7	4.2	0.0	0.0	0.0	0.0	
red		average	512.7	472.7	0.0	25.4	368.1	79.2	32.5	5.7	0.0	0.3	0.0	0.3	
	Average		940.5	885.3	95.5	307.7	454.2	27.9	13.1	3.2	20.5	1.8	0.0	1.8	33.3

[a] Data for the July 2 harvest for SPCI-5 were not included in the statistical analysis.

Table 1. (Continued.) Bulb yield and grade for eight yellow onion varieties and two red varieties (903S and TAS027) grown from transplants over three harvest dates, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Bulb color	Company	Variety	Total yield	Marketable yield by grade					Small	Doubles	Sunscald	Total rot	Plate rot	Slime rot	Bulb counts >4¼ in
				Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in							
			------------------------------------ cwt/acre -------------------------------------									------------- % ------------			#/50 lb
			July 23 harvest												
yellow	Nunhems	Montero	1111.1	1085.6	113.0	428.0	530.9	13.7	3.3	2.3	2.1	1.6	0.0	1.6	30.2
yellow	Crookham	Avenger	1052.2	1008.3	124.7	308.2	555.4	20.0	10.9	17.0	4.3	1.2	0.0	1.2	29.1
yellow		Jasmine	1335.9	1187.1	443.8	460.0	269.1	14.2	4.9	7.7	42.5	7.1	0.4	6.7	29.8
yellow		4062	1083.9	1070.7	286.2	437.8	338.4	8.2	7.0	0.0	3.5	0.2	0.0	0.2	28.3
yellow		4500	1248.8	1229.9	307.3	550.0	365.0	7.6	4.2	0.0	8.3	0.6	0.0	0.6	29.7
yellow	Seminis	KW-0106	1249.6	1196.5	265.0	542.0	377.8	11.6	8.2	7.1	3.0	2.9	0.0	2.9	30.4
yellow		SPCI-1	1455.7	1366.4	623.8	489.7	239.4	13.5	1.0	0.0	28.4	4.2	0.0	4.2	30.1
yellow		SPCI-5	1426.8	1275.5	587.7	374.4	267.2	46.1	18.5	12.6	30.6	6.4	0.0	6.4	26.6
yellow		average	1245.5	1177.5	343.9	448.8	367.9	16.9	7.2	5.8	15.3	3.0	0.1	3.0	29.3
red	N. Zealand Onion	903S	581.3	549.4	0.0	0.0	428.4	121.0	32.0	0.0	0.0	0.0	0.0	0.0	
red		TAS027	620.5	578.2	0.0	26.8	500.1	51.3	29.3	0.0	0.0	2.2	1.9	0.4	
red		average	600.9	563.8	0.0	13.4	464.2	86.2	30.6	0.0	0.0	1.1	0.9	0.2	
	Average		1116.6	1054.7	275.2	361.7	387.2	30.7	11.9	4.7	12.3	2.6	0.2	2.4	29.3
			Average over harvest dates												
yellow	Nunhems	Montero	1019.4	997.9	42.0	285.4	654.8	15.8	4.4	0.8	4.9	1.2	0.1	1.2	30.4
yellow	Crookham	Avenger	1005.8	967.2	51.2	275.3	622.0	18.7	9.4	6.8	6.7	1.8	0.1	1.8	30.8
yellow		Jasmine	1115.8	1023.0	210.4	402.5	385.0	25.0	9.0	5.4	30.5	5.0	0.1	4.9	32.2
yellow		4062	1000.3	975.3	147.4	390.0	422.3	15.6	7.4	0.0	17.2	0.6	0.0	0.6	32.4
yellow		4500	1081.6	1060.9	145.1	437.4	461.8	16.5	5.4	0.0	16.2	0.5	0.1	0.4	33.4
yellow	Seminis	KW-0106	1123.7	1076.7	148.5	453.3	460.0	14.9	6.0	5.0	15.9	2.4	0.0	2.6	32.6
yellow		SPCI-1	1214.1	1163.3	301.8	484.5	361.1	15.9	5.7	0.0	44.6	1.4	0.0	1.4	32.9
yellow		SPCI-5	1105.6	1047.9	303.3	377.9	342.2	24.4	15.2	3.4	27.7	2.2	0.0	2.2	31.9
yellow		average	1083.3	1039.0	168.7	388.3	463.7	18.4	7.8	2.7	20.5	1.9	0.0	1.9	32.1
red	N. Zealand Onion	903S	533.0	498.1	0.0	11.8	374.5	111.8	31.8	2.1	0.0	0.2	0.0	0.2	
red		TAS027	534.6	496.0	0.0	15.2	411.4	69.4	32.9	1.0	0.0	0.7	0.6	0.1	
red		average	533.8	497.0	0.0	13.5	392.9	90.6	32.4	1.6	0.0	0.5	0.3	0.2	
LSD (0.05) Variety			81.7	88.8	47.1	68.6	64.6	10.2	5.5	NS	10.2	1.9	NS	1.9	NS
LSD (0.05) Date			39.6	41.9	31.8	NS	69.8	6.0	NS	NS	NS	NS	NS	NS	1.2
LSD (0.05) Variety x date			NS	NS	100.4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Single- and multiple-centered bulbs, and bolting for eight yellow onion varieties and two red varieties (903S and TAS027) grown from transplants over three harvest dates, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Continued on next page.

		Multiple center			Single center		
Company	Variety	Large	Medium	Small	Functional[a]	Bullet[b]	Bolters[c]
				%			
			July 2 harvest				
Seminis	SPCI-5	0.0	6.8	37.8	93.2	55.4	
			July 9 harvest				
Nunhems	Montero	2.4	4.8	14.4	92.8	78.4	
Crookham	Avenger	0.0	2.0	31.0	98.0	67.0	
	Jasmine	0.0	2.4	21.6	97.6	76.0	
	4062	2.4	2.4	19.2	95.2	76.0	
	4500	0.0	14.0	32.0	86.0	54.0	
Seminis	KW-0106	6.4	39.2	36.0	54.4	18.4	
	SPCI-1	0.0	1.3	38.7	98.7	60.0	
	SPCI-5	1.0	17.3	45.5	81.8	36.3	
N. Zealand Onion	903S	2.0	26.0	38.0	72.0	34.0	
	TAS027	12.0	16.0	68.0	72.0	4.0	
	Average	2.6	12.5	34.4	84.8	50.4	
			July 16 harvest				
Nunhems	Montero	3.0	9.0	18.0	88.0	70.0	
Crookham	Avenger	4.0	9.6	35.2	86.4	51.2	
	Jasmine	0.0	2.4	35.7	97.6	62.0	
	4062	2.4	13.5	32.2	84.1	51.9	
	4500	1.0	29.0	37.0	70.0	33.0	
Seminis	KW-0106	22.5	27.2	33.3	50.3	17.0	
	SPCI-1	0.0	4.0	34.0	96.0	62.0	
	SPCI-5	2.6	35.6	36.7	61.8	25.1	
N. Zealand Onion	903S	6.0	20.0	52.0	74.0	22.0	
	TAS027	6.0	12.0	70.0	82.0	12.0	
	Average	4.7	16.2	38.4	79.0	40.6	
			July 23 harvest				
Nunhems	Montero	2.4	8.0	11.2	89.6	78.4	0.7
Crookham	Avenger	3.0	10.0	34.0	87.0	53.0	0.3
	Jasmine	1.0	5.0	18.0	94.0	76.0	1.0
	4062	8.8	19.2	17.6	72.0	54.4	3.1
	4500	8.0	27.0	30.0	65.0	35.0	0.0
Seminis	KW-0106	25.2	44.3	20.3	30.5	10.2	0.1
	SPCI-1	2.2	10.9	42.1	87.0	44.9	0.3
	SPCI-5	10.7	22.7	32.0	66.7	34.7	0.0
N. Zealand Onion	903S	14.0	34.0	30.0	52.0	22.0	0.0
	TAS027	17.0	38.7	28.8	44.4	15.6	0.0
	Average	9.2	22.0	26.4	68.8	42.4	0.5

[a] Functional single centers are the small multiple centers plus the bullet single centers.
[b] bullet: single center. [c] Bolted onions were counted in each plot on July 23.

Table 2. (Continued.) Single- and multiple-centered bulbs, and bolting for eight yellow onion varieties and two red varieties (903S and TAS027) grown from transplants averaged over three harvest dates, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

		Multiple center			Single center	
Company	Variety	Large	Medium	Small	Functional[a]	Bullet[b]
		%				
	Average over harvest dates					
Nunhems	Montero	2.6	7.1	14.3	90.3	76.0
Crookham	Avenger	2.5	7.4	33.5	90.2	56.6
	Jasmine	0.3	3.1	25.6	96.6	71.0
	4062	4.5	11.7	23.0	83.8	60.8
	4500	3.0	23.3	33.0	73.7	40.7
Seminis	KW-0106	17.5	36.4	30.5	46.1	15.5
	SPCI-1	0.6	4.8	38.3	94.6	56.2
	SPCI-5	3.4	20.3	38.6	76.3	37.7
N. Zealand Onion	903S	7.3	26.7	40.0	66.0	26.0
	TAS027	11.6	23.5	53.1	64.9	11.8
LSD (0.05) Variety		2.9	4.6	NS	4.7	8.1
LSD (0.05) Date		3.0	5.2	6.2	5.5	5.9
LSD (0.05) Variety x date		NS	NS	NS	NS	NS

[a] Functional single centers are the small multiple centers plus the bullet single centers.
[b] bullet: single center.

Table 3. Maturity at harvest and bulb quality 2 weeks after harvest for eight yellow onion varieties and two red varieties (903S and TAS027) grown from transplants over three harvest dates, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Continued on next page.

		Maturity at harvest		Bulb quality 2 weeks after harvest			
Company	Variety	Tops down	Leaf dryness	Sprouted	Decomposed	Sprouted and decomposed	Total sprouted or decomposed
		----------------------	----------------------	---------------------- %	----------------------	----------------------	----------------------
			July 2 harvest				
Seminis	SPCI-5	40.0	7.5	0.0	0.0	0.0	0.0
			July 9 harvest				
Nunhems	Montero	36.0	6.0	2.4	0.8	0.0	3.2
Crookham	Avenger	91.3	13.8	0.8	0.8	0.0	1.6
	Jasmine	88.0	15.0	0.8	0.0	0.0	0.8
	4062	20.0	4.0	2.4	0.0	0.0	2.4
	4500	26.3	5.0	1.6	0.0	0.0	1.6
Seminis	KW-0106	78.0	15.0	0.8	0.0	0.0	0.8
	SPCI-1	18.3	1.7	2.4	0.0	0.0	2.4
	SPCI-5	90.0	22.5	0.0	0.0	0.0	0.0
N. Zealand Onion	903S	30.0	20.0	0.0	0.0	0.0	0.0
	TAS027	40.0	17.5	0.0	0.0	0.0	0.0
	Average	51.8	12.0	1.1	0.2	0.0	1.3
			July 16 harvest				
Nunhems	Montero	58.0	20.0	0.0	0.0	0.0	0.0
Crookham	Avenger	90.0	25.6	0.8	0.8	0.0	1.6
	Jasmine	88.8	25.5	0.0	0.8	0.0	0.8
	4062	50.0	11.0	0.8	0.0	0.0	0.8
	4500	55.0	12.5	0.0	0.8	0.0	0.8
Seminis	KW-0106	79.0	25.5	1.6	0.0	0.0	1.6
	SPCI-1	56.7	7.5	0.0	0.0	0.0	0.0
	SPCI-5	91.3	28.8	0.0	0.0	0.0	0.0
N. Zealand Onion	903S	56.7	30.0	0.0	0.0	0.0	0.0
	TAS027	60.0	28.8	0.0	0.0	0.0	0.0
	Average	68.5	21.5		0.2	0.0	0.6
			July 23 harvest				
Nunhems	Montero	88.0	34.0	0.8	0.0	0.0	0.8
Crookham	Avenger	90.0	37.5	2.4	0.0	0.0	2.4
	Jasmine	94.0	36.0	0.0	3.2	0.0	3.2
	4062	78.0	18.0	0.8	0.0	0.0	0.8
	4500	87.5	20.0	0.8	0.8	0.0	1.6
Seminis	KW-0106	84.0	36.0	0.8	0.0	0.0	0.8
	SPCI-1	90.0	13.3	0.0	0.0	0.0	0.0
	SPCI-5	92.5	35.0	0.0	0.0	0.0	0.0
N. Zealand Onion	903S	90.0	46.7	0.0	0.8	0.0	0.8
	TAS027	90.0	40.0	0.0	0.0	0.0	0.0
	Average	88.4	31.7	0.6	0.5	0.0	1.0

Table 3. (Continued). Maturity at harvest and bulb quality 2 weeks after harvest for eight yellow onion varieties and two red varieties (903S and TAS027) grown from transplants averaged over three harvest dates, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

		Maturity at harvest		Bulb quality 2 weeks after harvest			
Company	Variety	Tops down	Leaf dryness	Sprouted	Decomposed	Sprouted and decomposed	Total sprouted or decomposed
		%					
Average over harvest dates							
Nunhems	Montero	60.7	20.0	1.1	0.3	0.0	1.3
Crookham	Avenger	90.4	25.6	1.3	0.5	0.0	1.9
	Jasmine	90.4	25.5	0.3	1.3	0.0	1.6
	4062	49.3	11.0	1.3	0.0	0.0	1.3
	4500	56.3	12.5	0.8	0.5	0.0	1.3
Seminis	KW-0106	80.3	25.5	1.1	0.0	0.0	1.1
	SPCI-1	55.0	7.5	0.8	0.0	0.0	0.8
	SPCI-5	78.4	23.4	0.0	0.0	0.0	0.0
N. Zealand Onion	903S	62.5	33.8	0.0	0.3	0.0	0.3
	TAS027	63.3	28.8	0.0	0.0	0.0	0.0
LSD (0.05) Variety		7.6	3.2	NS	NS	NS	NS
LSD (0.05) Date		3.4	1.6	NS	NS	NS	NS
LSD (0.05) Variety x date		10.8	NS	NS	NS	NS	NS

Table 4. Monthly growing degree-days (50-86°F) in 2014-2018 and the 25-year average, Malheur Experiment Station, Oregon State University, Ontario, OR.

Year	April	May	June	July	Total April-July
2014	227	424	544	779	1974
2015	241	427	674	716	2059
2016	305	405	576	680	1967
2017	169	380	533	766	1848
2018	225	471	516	733	1945
Avg. 1993-2017	199	372	512	704	1787

Table 5. The average percentage of tops down, leaf dryness, and marketable yield at three harvest dates for onion variety ‘Montero’ grown from transplants in 2014, 2015, 2016, 2017, and 2018. Malheur Experiment Station, Oregon State University, Ontario, OR.

	Year	9-Jul	14-Jul	16-Jul	21-Jul	23-Jul	28-Jul	4-Aug
% tops down	2014				12		40	76
	2015		18		54		80	
	2016		0		16		58	
	2017				22		70	80
	2018	36		62		88		
% dry leaves	2014				16		28	32
	2015		0		20		32	
	2016		0		12		20	
	2017				12		24	30
	2018	6		20		34		
Marketable yield	2014				826		911	1024
cwt/acre	2015		730		847		898	
	2016		731		931		1154	
	2017				768		841	947
	2018	934		975		1086		

ONION INTERNAL QUALITY IN RESPONSE TO ARTIFICIAL HEAT AND HEAT MITIGATION DURING BULB DEVELOPMENT IN 2018

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Introduction

In 2014 and 2015 there was an increase in internal onion bulb decomposition of one or more scales in onion bulbs grown in the Treasure Valley. Unlike neck rot or plate rot, this internal decomposition is difficult to detect externally, and can result in quality issues in marketing. We have thought that the internal decomposition is associated with one or more scales that do not finish forming completely into the neck, resulting in small gaps close to the neck. The 2014 and 2015 growing seasons were unusually warm, suggesting that excessive heat could be associated with the problems of internal decomposition. This trial sought to determine whether heat is a factor in bulb decomposition and whether or not treatments that increase or reduce the heat load in the soil and onion bulbs would affect the expression of internal bulb decomposition.

Materials and Methods

Onions were grown in 2018 on an Owyhee silt loam previously planted to wheat. A soil analysis taken in the fall of 2017 showed that the top foot of soil had a pH of 7.8, 2.5% organic matter, 18 ppm nitrate-N, 6 ppm ammonium-N, 24 ppm phosphorus (P), 287 ppm potassium (K), 21 ppm sulfur (S), 2171 ppm calcium (Ca), 444 ppm magnesium (Mg), 111 ppm sodium, 3.6 ppm zinc (Zn), 5 ppm manganese (Mn), 1 ppm copper (Cu), 5 ppm iron, and 0.3 ppm boron (B). In the fall of 2017, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. Based on a soil analysis, 72 lb P/acre, 163 lb K/acre, 57 lb S/acre, 1 lb Zn/acre, 5 lb Mn/acre, 1 lb Cu/acre, and 2 lb B/acre were broadcast before plowing. After plowing, the field was fumigated with K-Pam® at 15 gal/acre and bedded at 22 inches.

Onion seed was planted on March 19 in double rows spaced 3 inches apart at 9 seeds/ft of single row. Each double row was planted on beds spaced 22 inches apart. Planting was done in rows running east to west with customized John Deere Flexi Planter units equipped with disc openers. Immediately after planting, the field received a narrow band of Lorsban® 15G at 3.7 oz/1000 ft of row (0.82 lb ai/acre) over the seed rows and the soil surface was rolled.

The field had drip tape laid at 4-inch depth between pairs of beds during planting. The drip tape had emitters spaced 12 inches apart and an emitter flow rate of 0.22 gal/min/100 ft (Toro Aqua-Traxx, Toro Co., El Cajon, CA). The distance between the tape and the center of each double row of onions was 11 inches.

Onion emergence started on April 8. On May 9, alleys 4 ft wide were cut between split plots, leaving split plots 23 ft long. On May 16, the seedlings were hand thinned to a spacing of 4.75 inches between individual onion plants in each single row, or 120,000 plants/acre.

The experimental design was a split-plot randomized complete block with six replicates. There were four treatments to affect temperature as the main plots and two varieties as split plots within each main plot. Each split plot was planted with 4 double rows wide and 27 ft long. The two varieties were 'Joaquin' and 'Granero' (Nunhems, Parma, ID). The four treatments were: 1) untreated check, 2) artificial heat, 3) kaolinite, and 4) straw mulch. Kaolinite and straw mulch were treatments intended to reduce the heat load on the onions. The artificial heat was applied using one heat cable (self-regulating heat cable, maximum temperature 185°F, Chromalox, Pittsburgh, PA) laid next to each of the middle 2 double rows in the center of each heated plot. The heat cables were turned on and run continuously starting on June 1 and ending August 31. Kaolinite clay (Surround WP, Novasource, Phoenix, AZ) was applied at 45 lb/acre in a solution of 0.45 lb kaolinite/gal of water. The kaolinite was applied with a backpack sprayer by aiming the nozzle at the base of the onion plants on the south side of each double row. The kaolinite was applied on June 5, June 20, and July 2. The straw was applied between the onion double rows at 243 ft^3/acre (32 7.5-ft^3 bales/acre) on June 1.

The onions were managed to minimize yield reductions from weeds, pests, diseases, water stress, and nutrient deficiencies. For weed control, the following herbicides were broadcast: oxyfluorfen at 0.13 lb ai/acre (GoalTender® at 4 oz/acre), bromoxynil at 0.25 lb ai/acre (Brox® 2EC at 16 oz/acre), and clethodim at 0.12 lb ai/acre (Shadow® 3EC at 5.3 oz/acre) on May 7; pendimethalin at 0.95 lb ai/acre (Prowl® H_2O at 2 pt/acre) on May 17; oxyfluorfen at 0.25 lb ai/acre (GoalTender at 8 oz/acre), bromoxynil at 0.31 lb ai/acre (Brox 2EC at 20 oz/acre), and clethodim at 0.12 lb ai/acre (Shadow 3EC at 5.3 oz/acre) on May 25.

For thrips control, the following insecticides were applied by ground: spirotetramat at 0.078 lb ai/acre (Movento® at 5 oz/acre) and azadirachtin at 0.0093 lb ai/acre (Aza-Direct® at 12 oz/acre) on May 21 and June 3; abamectin at 0.019 lb ai/acre (Agri-Mek® SC at 3.5 oz/acre) on June 11. The following insecticides were applied by air: abamectin at 0.019 lb ai/acre on June 27; spinetoram at 0.078 lb ai/acre (Radiant® at 10 oz/acre) on June 30 and July 7; methomyl at 0.9 lb ai/acre (Lannate® at 3 pt/acre) on July 14 and 21; spinetoram at 0.078 lb ai/acre on July 28 and August 5.

Starting on June 8, root tissue and soil samples were taken every week from borders of check treatment plots and analyzed for nutrients by Western Laboratories, Inc., Parma Idaho (Tables 1 and 2). Nutrients were applied through the drip tape based on recommendations from Western Labs (Table 3). Urea ammonium nitrate solution (URAN) was applied through the drip tape six times from June 3 to July 25, supplying a total of 140 lb N/acre. A total of 100 lb K/acre was applied in 10- to 20-lb increments during the growing season based on the soil and tissue analyses.

Table 1. Onion root tissue sufficiency levels and nutrient content, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Nutrient		8-Jun	15-Jun	22-Jun	29-Jun	9-Jul	23-Jul	27-Jul	3-Aug	10-Aug
NO_3-N (ppm)	Sufficiency range	8500	7667	6833	6000	5168	4338	3508	2678	1834
NO_3-N (ppm)		3943	4301	3356	4057	3728	3422	3051	2725	2604
P (%)	0.32 - 0.7	0.54	0.45	0.42	0.58	0.43	0.36	0.30	0.43	0.31
K (%)	2.7 - 6.0	2.74	2.60	2.15	3.02	1.97	1.72	1.50	1.27	0.97
S (%)	0.24 - 0.85	0.91	0.82	0.60	0.74	0.85	0.71	0.85	0.85	0.80
Ca (%)	0.4 - 1.2	0.61	0.57	0.56	0.61	0.59	0.70	0.74	0.87	0.84
Mg (%)	0.3 - 0.6	0.37	0.39	0.44	0.35	0.36	0.30	0.34	0.36	0.27
Zn (ppm)	25 - 50	57	67	71	50	40	41	43	44	40
Mn (ppm)	35 - 100	85	98	109	92	85	98	114	130	92
Cu (ppm)	6 - 20	16	13	12	10	8	7	8	8	7
B (ppm)	19 - 60	67	76	62	56	46	44	36	28	35

Table 2. Weekly soil solution analyses. Data represent the amount of each plant nutrient per day that the soil can potentially supply to the crop. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Nutrient	Critical level, lb/ac or g/ac	8-Jun	15-Jun	22-Jun	29-Jun	9-Jul	23-Jul	27-Jul	3-Aug	10-Aug
N	Critical levels	8.6	7.8	7	6.2	5.4	4.6	3.8	2.8	2.0
N		2.9	2.9	8.6	10.0	7.7	7.7	10.6	12.9	10.3
P	0.7 lb/acre	1.9	2.1	1.6	1.0	1.5	1.2	1.7	2.1	2.4
K	5 lb/acre	4.1	5.0	6.1	5.2	5.7	5.0	6.2	5.1	5.4
S	1 lb/acre	1.3	1.1	2.7	3.3	4.9	4.0	5.1	3.7	3.8
Ca	3 lb/acre	4.8	5.2	6.0	6.2	5.1	4.5	5.0	5.3	5.3
Mg	2 lb/acre	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1
Zn	28 g/acre	87	69	90	78	72	57	66	57	60
Mn	28 g/acre	27	27	24	21	30	36	27	30	30
Cu	12 g/acre	36	33	36	48	39	48	42	30	36
B	21 g/acre	14	11	15	12	17	14	17	15	12

Table 3. Nutrients applied through the drip irrigation system, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Date	N	P	K	Mg
	----------- lb/acre -----------			
3-Jun	40			
11-Jun	40			
19-Jun	20		20	5
26-Jun	20		20	4
5-Jul				10
10-Jul	10		10	
14-Jul			10	
25-Jul	10			2
31-Jul		10	10	
6-Aug			10	
7-Aug			10	
13-Aug			10	
Total	140	10	100	21

Onions were irrigated automatically to maintain the soil water tension (SWT) in the onion root zone below 20 cb (Shock et al. 2000). Soil water tension in each treatment plot was measured with two granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Inc., Riverside, CA) installed at 8-inch depth in the center of the double row. Sensors had been calibrated to SWT (Shock et al. 1998). The GMS were connected to the datalogger via multiplexers (AM 16/32, Campbell Scientific, Logan, UT). The datalogger (CR10X, Campbell Scientific) read the sensors and recorded the SWT every hour. The datalogger automatically made irrigation decisions every 12 hours. The field was irrigated if the average of the 24 sensors in the check and kaolinite treatments was a SWT of 20 cb or higher. The irrigations were controlled by the datalogger using a controller (SDM CD16AC, Campbell Scientific) connected to a solenoid valve. Irrigation durations were 8 hours, 19 min to apply 0.48 inch of water. The water was supplied from a well and pump that maintained a continuous and constant water pressure of 35 psi. The pressure in the drip lines was maintained at 10 psi by a pressure regulating valve. The automated irrigation system was started on June 4 and irrigations ended August 31.

Onion bulb temperatures and soil surface temperatures were measured weekly in the mid-afternoon using an infrared thermometer (Close Focus IR, ThermoWorks, Salt Lake City, UT) starting on June 13 and ending July 25. After July 25 the leaves shaded the soil and bulbs and walking among the onions to obtain temperature data would have substantially injured the plants. Bulb and soil temperature measurements were made as close as practical to 2 p.m. (12:30 p.m. to 3:30 p.m.) on clear days. The bulb temperatures were measured on the south side of the bulbs farthest from the drip tape and approximately 0.5 inches above the soil surface. The soil surface temperature was measured approximately 0.5 inches to the south from the same bulbs. Four temperature measurements for the bulbs and the soil were taken weekly in each plot. Soil temperature at 4-inch depth was measured approximately 0.5 inches to the south of onion bulbs in each plot using digital thermometers (Hanna Instruments, Limena, Italy).

Onions were evaluated for maturity, severity of symptoms of iris yellow spot virus (IYSV), and bolting on August 14. Onions in each plot were evaluated subjectively for maturity by visually rating the percentage of onions with the tops down and the percent dry leaves. For IYSV, onions in each plot were given a subjective rating on a scale of 0 to 5 of increasing severity of IYSV symptoms. The rating was 0 if there were no symptoms, 1 if 1-25% of foliage was diseased, 2 if 26-50% of foliage was diseased, 3 if 51-75% of foliage was diseased, 4 if 76-99% of foliage was diseased, and 5 if 100% of foliage was diseased. The number of bolted onion plants was counted in each plot.

The onions were lifted on September 11 to cure in the field. Onions from the middle two double rows in each split plot were topped by hand and bagged on September 15. The bags were put into storage on September 22. The storage shed was ventilated and the temperature was slowly decreased to maintain air temperature as close to 34°F as possible. Onions were graded out of storage on November 27.

During grading, bulbs were separated according to quality: bulbs without blemishes (No. 1s), split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, bulbs infected with the fungus *Fusarium oxysporum* (plate rot), bulbs infected with the fungus *Aspergillus niger* (black mold), and bulbs infected with unidentified bacteria in the external scales. The No. 1 bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Bulb counts per 50 lb of supercolossal onions were determined for each split plot by weighing and counting all supercolossal bulbs during grading. Marketable yield consisted of No.1 bulbs larger than 2¼ inches.

During grading, two bags of No. 1 bulbs (with no observable external decomposition) from each plot were saved for evaluations of internal bulb quality. On November 29, 2018, 25 bulbs from each plot were cut longitudinally and evaluated for the presence of incomplete scales, dry scales, internal bacterial rot, and internal rot caused by *Fusarium proliferatum* or other fungi. Incomplete scales were defined as scales that had either more than 0.25 inch from the center of the neck missing or any part missing lower down in the bulb. Dry scales were defined as scales that had dry parts at the top of the bulb or any place lower down on one or more scale.

Treatment differences were determined using analysis of variance. Means separation was determined using a protected Fisher’s least significant difference test at the 5% probability level, LSD (0.05). The least significant difference LSD (0.05) values in each table should be considered when comparisons are made among treatments. A statistically significant difference in a characteristic between two treatments exists if the difference between the two treatments for that characteristic is equal to or greater than the LSD value for that characteristic. The effects of mid-day bulb temperature or soil temperature on bulb yield, yield components, or internal decomposition were determined by regression.

Results and Discussion

The rate of accumulation and total number of growing degree-days (50-86°F) in 2018 were higher than the 24-year average in April, May, July, and August (Figs. 1 and 2).

Surface soil and bulb temperatures for the check treatment onions were on average 20°F and 8°F higher, respectively, than ambient air temperature for the corresponding measurements (Table 4).

On average, the artificial heat treatment resulted in the highest and straw mulch resulted in the lowest bulb, surface soil, and soil at 4-inch-depth temperatures. Bulb, surface soil, and soil at 4-inch-depth temperatures for the check and the kaolinite treatments were on average higher than the straw mulch treatment, but lower than the artificial heat treatment.

Averaged over the two varieties, artificial heat resulted in the lowest total yield (Table 5). Averaged over the two varieties, artificial heat was among the treatments with the lowest supercolossal bulb yield and yield of bulbs larger than 4 inches. Averaged over the two varieties, straw mulch was among the treatments with the highest supercolossal bulb yield and straw mulch and kaolinite were among the treatments with the highest yield of bulbs larger than 4 inches. Averaged over heat treatments, Joaquin had higher yields than Granero.

For both varieties, total yield, marketable yield, and yield of bulbs larger than 4 inches decreased with increasing bulb and soil surface temperature (Figs 4-7).

Artificial heat resulted in the highest percentage of tops down on August 14 (Table 5). Straw mulch was among the treatments with the lowest percentage of tops down on August 14. Straw mulch resulted in the highest amount of bolting.

Improved yields with the use of straw mulch with drip irrigation can be a result of more optimum temperatures and also of modification of the soil moisture by a reduction of evaporation from the soil surface. The average SWT in June and July in the check and kaolinite treatments were similar (16.6 cb and 14.0 cb, respectively) since they were irrigated based on the average of all their sensors (Fig. 3). The average SWT in June and July in the straw mulch treatment (14.9 cb) was similar to the check and kaolinite treatments. The average SWT in June and July in the heat treatment (21 cb) was slightly higher than the other treatments. These small differences in SWT were unlikely to have a significant effect on onion yield based on previously published work (Shock et al. 2000).

The total amount of internal decomposition in this trial in November was low and ranged from 0% to 2% (Table 6). The internal decomposition was due to bacterial rot, neck rot, and black mold, averaging 0.3, 0.2, and 0.1%, respectively (Table 7). No internal decomposition due to *Fusarium proliferatum* was found in this trial. There was no statistically significant difference between treatments in internal decomposition, incomplete scales, or dry scales.

The results of this trial in 2018 are similar to the results of the 2016 and 2017 trials (Shock et al. 2017, 2018), when straw mulch was among the treatments with the highest bulb yields and artificial heat was among the treatments with the lowest bulb yields. In the 2016 and 2018 trials, internal decomposition was not affected by treatment. In 2017, straw mulch was among the treatments with the highest internal decomposition and artificial heat was among the treatments with the lowest internal decomposition, but the differences were very small.

Acknowledgements

This project was funded by the Idaho-Eastern Oregon Onion Committee, cooperating onion seed companies, Oregon State University, the Malheur County Education Service District, and was supported by Formula Grant nos. 2018-31100-06041 and 2018-31200-06041 from the USDA National Institute of Food and Agriculture.

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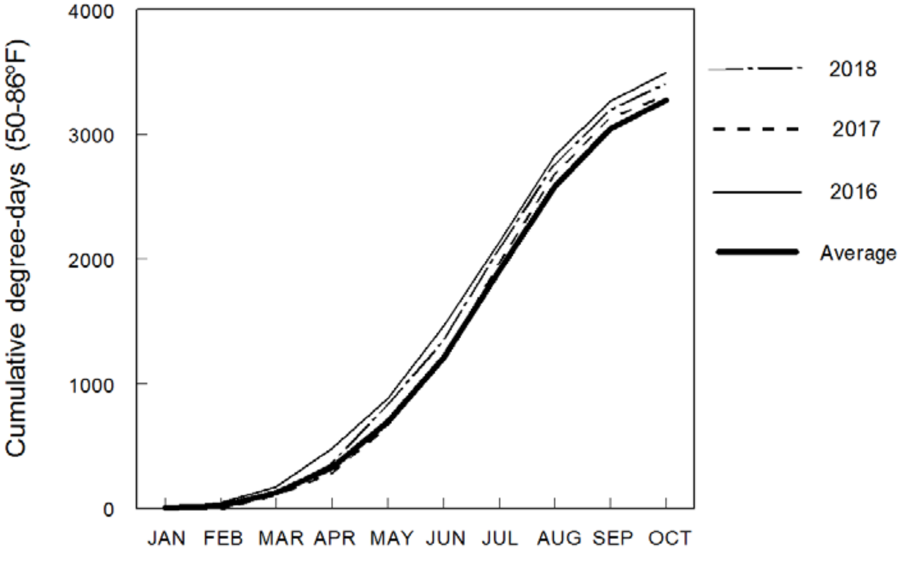

Figure 1. Cumulative growing degree-days (50-86°F) for 2016, 2017, 2018 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

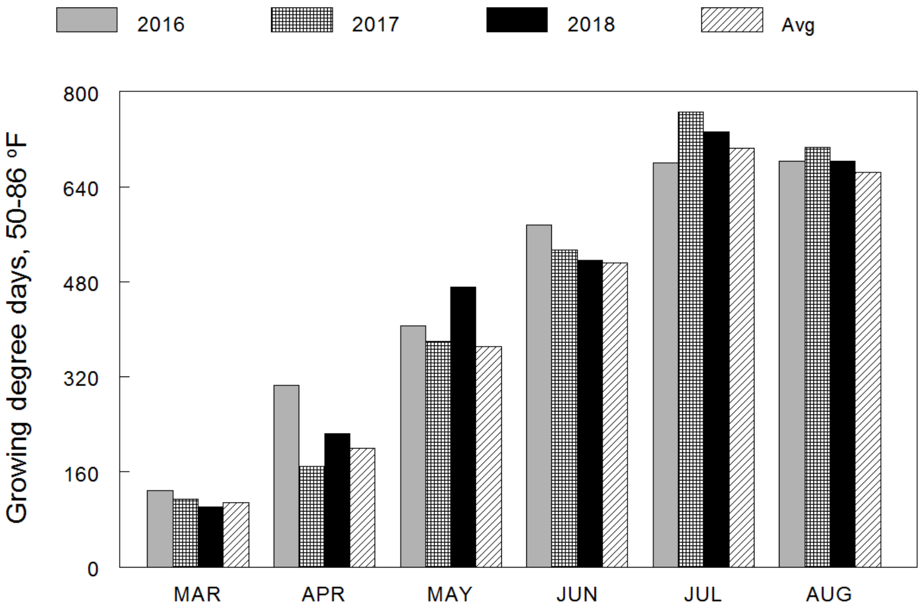

Figure 2. Monthly growing degree-days (50-86°F) for 2016-2018 and 25-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

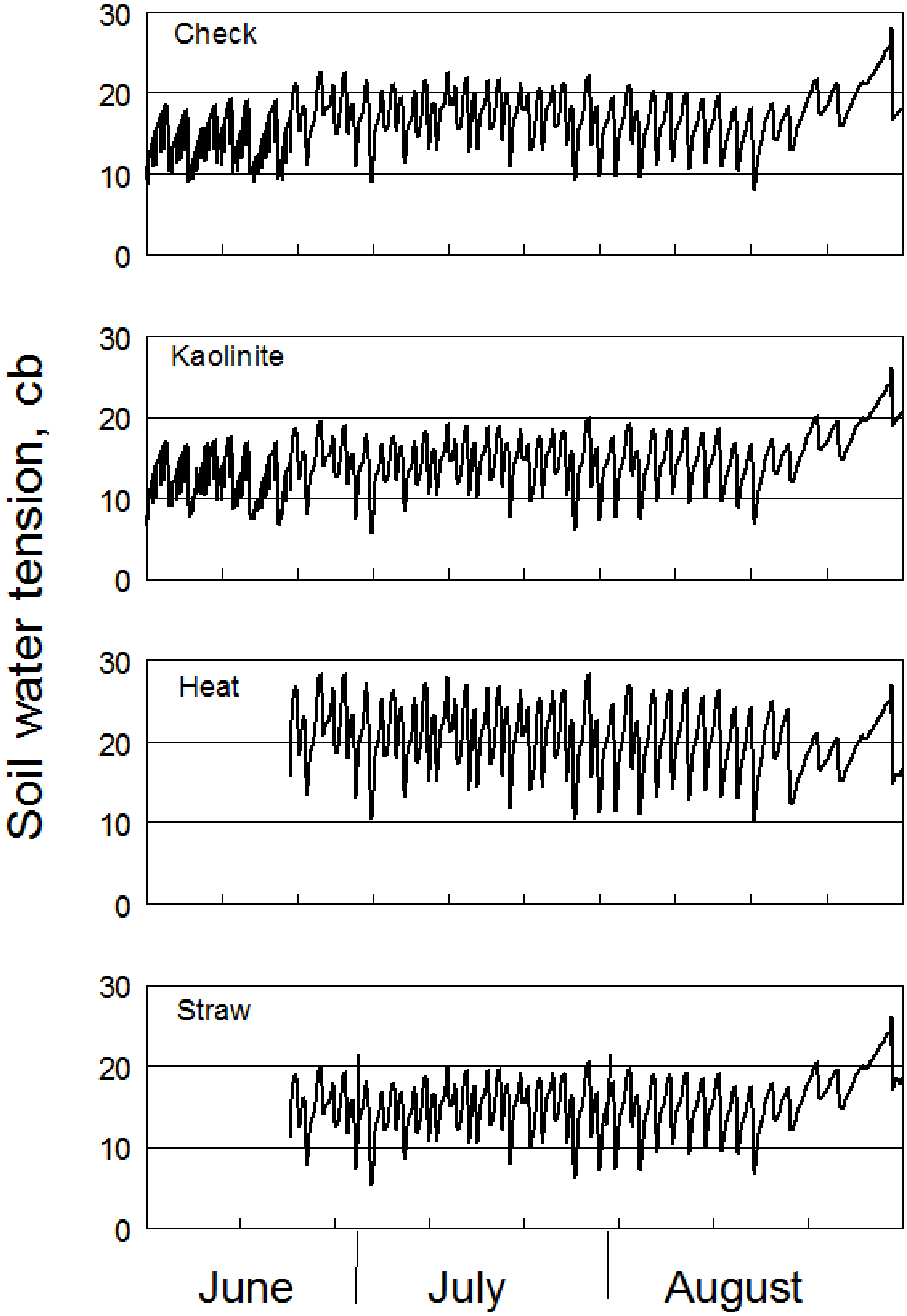

Figure 3. Soil water tension over time for four treatments of two onion varieties. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Table 4. Soil and onion bulb temperature (°F) measurements for four management treatments to affect bulb and soil surface temperatures. Measurements were made between 12:30 and 3:30 p.m. on the south side of the onion bulbs one-half inch above the soil surface and one-half inch south of the same onion bulbs. Ambient air temperature was recorded at 2 p.m. Solar noon was close to 2 p.m. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Treatment	13-Jun	22-Jun	25-Jun	5-Jul	17-Jul	25-Jul	Average
				Ambient air			
	82	85	86	92	91	96	89
				Surface soil			
Check	139.2	112.0	92.8	107.9	98.3	103.8	109.0
Heat	141.0	113.9	97.8	109.1	116.1	112.7	115.1
Kaolinite	141.2	107.3	90.2	101.9	102.6	101.4	107.4
Straw	126.7	88.9	80.3	88.3	95.8	91.7	95.3
LSD (0.05)	7.1	6.8	6.3	4.2	5.9	3.2	2.7
				Soil 4-inch depth			
Check	70.8	72.6	70.3	69.8	70.8	71.2	70.9
Heat	72.2	75.3	73.8	73.5	74.7	77.0	74.4
Kaolinite	70.4	72.4	70.3	69.7	70.7	72.0	71.0
Straw	68.3	70.8	69.1	68.2	70.2	71.7	69.8
LSD (0.05)	1.4	1.4	1.3	1.3	1.3	1.6	1.1
				Bulb			
Check	124.4	93.7	87.5	91.2	88.9	97.5	97.2
Heat	127.4	94.3	90.3	94.7	97.0	104.3	101.3
Kaolinite	123.2	91.0	85.1	89.1	90.1	96.1	95.8
Straw	120.4	88.1	81.9	86.3	89.7	93.6	93.3
LSD (0.05)	3.8	3.4	5.0	2.0	3.3	3.6	2.2

Table 5. Yield and grade of two varieties of onions submitted to four temperature treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

			Marketable yield by grade															
Variety	Treatment	Total yield	Total	>4¼ in	4-4¼ in	>4 in	3-4 in	2¼-3 in	Small	No. 2s	Bulb counts >4¼ in	Total rot	Neck rot	Plate rot	Split root	Tops down	Leaf dryness	Bolting
		cwt/acre									#/50 lb		%					
Joaquin	Check	1231.8	1194.9	391.7	467.2	858.8	322.2	13.9	11.0	1.8	30.6	1.8	1.0	0.8	0.0	16.7	4.2	1.2
	Heat	1175.7	1142.6	293.6	481.9	775.5	353.9	13.2	8.3	2.2	30.8	1.6	0.6	1.0	0.1	21.7	7.5	0.5
	Kaolinite	1229.6	1208.0	334.3	519.1	853.4	340.2	14.4	8.6	1.1	30.1	0.8	0.2	0.5	0.0	19.2	7.5	0.7
	Straw	1253.0	1209.7	411.2	481.5	892.6	296.0	21.1	6.8	0.3	30.1	2.5	1.2	1.3	0.1	17.5	4.2	4.1
	Average	1222.5	1188.8	357.7	487.4	845.1	328.1	15.6	8.7	1.3	30.4	1.7	0.7	0.9	0.1	18.8	5.8	1.6
Granero	Check	1197.9	1168.9	228.8	487.5	716.3	439.7	12.9	10.2	6.5	30.5	0.9	0.1	0.8	0.0	50.0	9.2	0.7
	Heat	1112.9	1085.0	176.3	492.4	668.8	400.1	16.0	6.4	5.4	30.8	1.2	0.1	1.1	0.0	63.3	13.3	0.2
	Kaolinite	1240.6	1199.6	247.1	512.6	759.7	421.5	18.4	8.6	3.3	30.0	2.2	0.5	1.6	0.0	55.0	10.0	0.5
	Straw	1210.9	1177.5	271.7	582.9	854.6	306.7	16.3	6.8	1.3	31.1	1.9	0.9	1.1	0.0	34.2	7.5	3.5
	Average	1190.6	1157.7	231.0	518.8	749.8	392.0	15.9	8.0	4.1	30.6	1.5	0.4	1.1	0.0	50.6	10.0	1.2
Average	Check	1214.8	1181.9	310.2	477.3	787.5	380.9	13.4	10.6	4.1	30.6	1.3	0.5	0.8	0.0	33.3	6.7	0.9
	Heat	1144.3	1113.8	235.0	487.1	722.1	377.0	14.6	7.4	3.8	30.8	1.4	0.3	1.0	0.1	42.5	10.4	0.4
	Kaolinite	1235.1	1203.8	290.7	515.8	806.5	380.9	16.4	8.6	2.2	30.1	1.5	0.4	1.1	0.0	37.1	8.8	0.6
	Straw	1232.0	1193.6	341.4	532.2	873.6	301.4	18.7	6.8	0.8	30.6	2.2	1.0	1.2	0.1	25.8	5.8	3.8
	Average	1206.5	1173.3	294.3	503.1	797.4	360.0	15.8	8.3	2.7	30.5	1.6	0.6	1.0	0.0	34.7	7.9	1.4
LSD (0.05)																		
Treatment		67.8	NS[a]	64.8	NS	92.6	62.2	NS	NS	NS	NS	NS	NS	NS	NS	9.2	2.2	0.9
Variety		33.6	NS	53.9	NS	62.4	51.6	NS	NS	NS	NS	NS	NS	NS	NS	6.9	1.4	NS
Treatment X variety		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[a] Not significant.

Table 6. Internal bulb defects on November 29, 2018 for two varieties of onions submitted to four treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

		All bulbs							Diseased bulbs						
		Complete scales			Incomplete scales			Total	Complete scales			Incomplete scales			Total
Variety	Treatment	no dry scale	dry scale	total	no dry scale	dry scale	total		no dry scale	dry scale	total	no dry scale	dry scale	total	
		%													
Joaquin	Check	30.0	2.0	32.0	27.3	40.7	68.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Heat	40.7	2.7	43.3	24.7	32.0	56.7	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kaolinite	32.0	1.3	33.3	29.2	37.7	66.8	100.0	0.7	0.0	0.7	0.6	0.7	1.3	2.0
	Straw	24.0	0.7	24.7	26.7	48.7	75.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	average	31.7	1.7	33.3	27.0	39.8	66.7	100.0	0.2	0.0	0.2	0.2	0.2	0.3	0.5
Granero	Check	13.3	0.0	13.3	28.0	58.7	86.7	100.0	0.0	0.0	0.0	0.7	0.7	1.3	1.3
	Heat	15.3	0.7	16.0	26.8	57.8	84.6	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kaolinite	13.3	0.7	14.0	16.7	69.3	86.0	100.0	0.7	0.0	0.7	0.0	0.7	0.7	1.3
	Straw	18.7	0.7	19.3	32.0	48.7	80.7	100.0	0.0	0.0	0.0	0.7	0.0	0.7	0.7
	average	15.2	0.5	15.7	25.9	58.6	84.5	100.0	0.2	0.0	0.2	0.3	0.3	0.7	0.8
Average	Check	21.7	1.0	22.7	27.7	49.7	77.3	100.0	0.0	0.0	0.0	0.3	0.3	0.7	0.7
	Heat	28.0	1.7	29.7	25.7	44.9	70.6	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Kaolinite	22.7	1.0	23.7	22.9	53.5	76.4	100.0	0.7	0.0	0.7	0.3	0.7	1.0	1.7
	Straw	21.3	0.7	22.0	29.3	48.7	78.0	100.0	0.0	0.0	0.0	0.3	0.0	0.3	0.3
	average	23.4	1.1	24.5	26.4	49.2	75.6	100.0	0.2	0.0	0.2	0.2	0.3	0.5	0.7
LSD (0.05)															
Treatment		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Variety		6.6	NS	6.4	NS	6.5	6.4	NS	NS	NS	NS	NS	NS	NS	NS
Treatment X variety		NS	NS	NS	NS	8.5	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 7. Internal decomposition by disease type on November 29, 2018 for two varieties of onions submitted to four treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety	Treatment	Bacterial rot	*Fusarium proliferatum*	Neck rot	Black mold
		------------------------------	%	------------------------------	
Joaquin	Check	0.0	0.0	0.0	0.0
	Heat	0.0	0.0	0.0	0.0
	Kaolinite	1.3	0.0	0.6	0.0
	Straw	0.0	0.0	0.0	0.0
	average	0.3	0.0	0.2	0.0
Granero	Check	0.7	0.0	0.7	0.0
	Heat	0.0	0.0	0.0	0.0
	Kaolinite	0.7	0.0	0.0	0.7
	Straw	0.0	0.0	0.7	0.0
	average	0.3	0.0	0.3	0.2
Average	Check	0.3	0.0	0.3	0.0
	Heat	0.0	0.0	0.0	0.0
	Kaolinite	1.0	0.0	0.3	0.3
	Straw	0.0	0.0	0.3	0.0
	average	0.3	0.0	0.2	0.1
LSD(0.05)					
Treatment		NS	NS	NS	NS
Variety		NS	NS	NS	NS
Treatment X variety		NS	NS	NS	NS

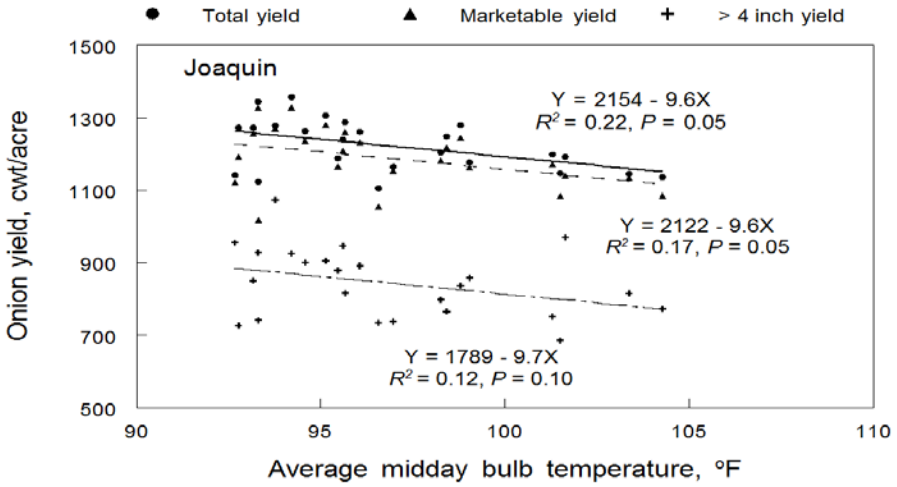

Figure 4. Onion yield response to average midday bulb temperature for 'Joaquin', Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. The bulb temperatures were measured on the south side of the bulbs farthest from the drip tape and approximately 0.5 inch above the soil surface.

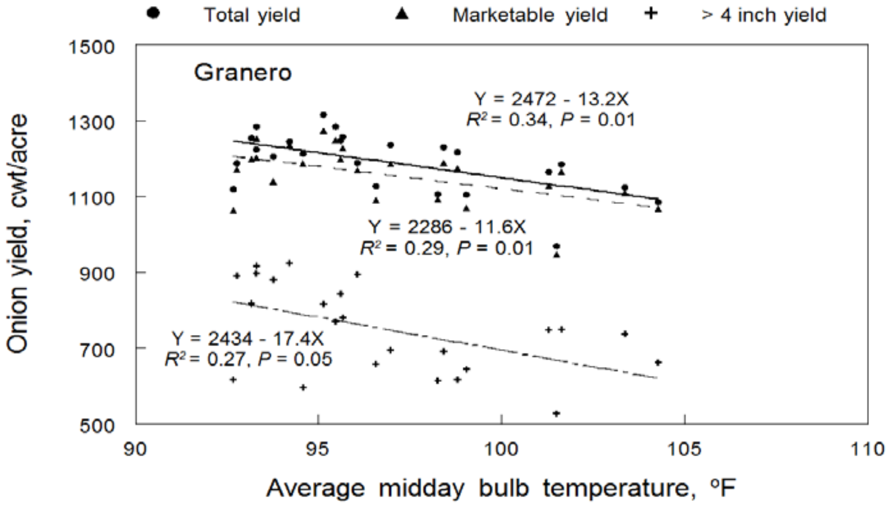

Figure 5. Onion yield response to average midday bulb temperature for 'Granero', Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. The bulb temperatures were measured on the south side of the bulbs farthest from the drip tape and approximately 0.5 inch above the soil surface.

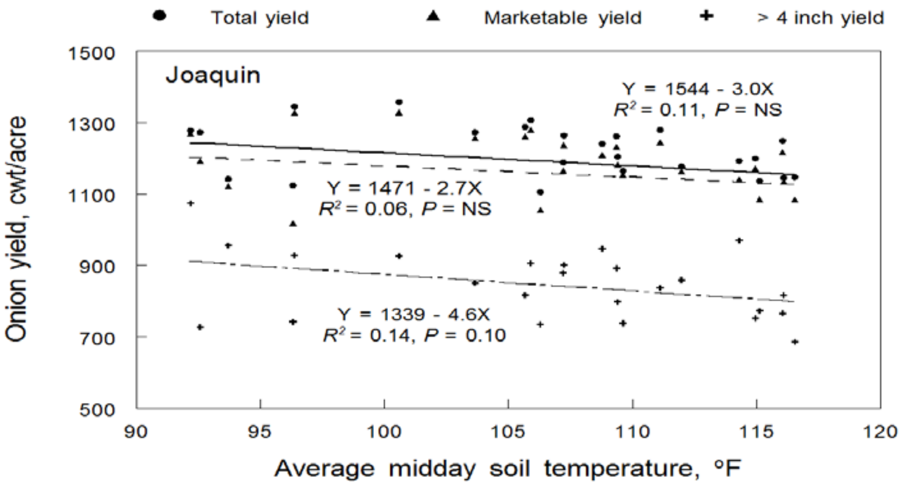

Figure 6. Onion yield response to average midday soil surface temperature for 'Joaquin', Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. The soil surface temperature was measured approximately 0.5 inch to the south from the bulbs farthest from the drip tape.

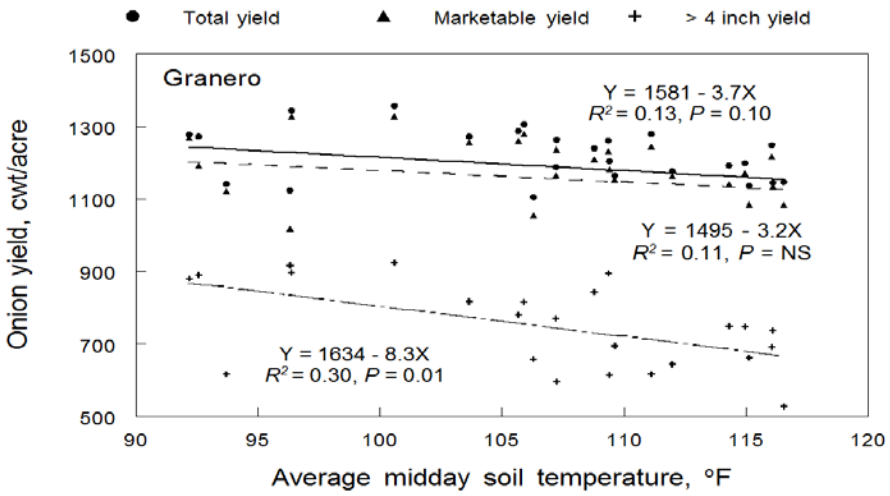

Figure 7. Onion yield response to average midday soil surface temperature for 'Granero', Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. The soil surface temperature was measured approximately 0.5 inch to the south from the bulbs farthest from the drip tape.

TIMING OF THE OCCURRENCE OF INTERNAL QUALITY PROBLEMS IN ONION BULBS IN 2018

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Introduction

In the past few years in the Pacific Northwest, there has been an increase in internal onion bulb decomposition of one or more scales. Unlike neck rot or plate rot, this internal decomposition is difficult to detect externally, resulting in quality control issues in marketing. We have suggested that the internal decomposition is often associated with one or more scales that do not finish forming completely in the neck or become dehydrated, resulting in gaps close to the neck, which we have called “incomplete scale”. Another suggestion is that internal decomposition is favored by the occurrence of dry scales in the neck or in the neck extending down into the bulb, providing a path for pathogen entry. To learn more about bulb internal quality problems, this trial sought to determine when incomplete scale, dry scale, and internal decomposition can be observed and how quickly they increase.

Materials and Methods

Onions were grown in 2018 on an Owyhee silt loam previously planted to wheat. A soil analysis taken in the fall of 2017 showed that the top foot of soil had a pH of 7.8, 2.5% organic matter, 18 ppm nitrate-N, 6 ppm ammonium-N, 24 ppm phosphorus (P), 287 ppm potassium (K), 21 ppm sulfur (S), 2171 ppm calcium (Ca), 444 ppm magnesium (Mg), 111 ppm sodium, 3.6 ppm zinc (Zn), 5 ppm manganese (Mn), 1 ppm copper (Cu), 5 ppm iron, and 0.3 ppm boron (B). In the fall of 2017, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. Based on a soil analysis, 72 lb P/acre, 163 lb K/acre, 57 lb S/acre, 1 lb Zn/acre, 5 lb Mn/acre, 1 lb Cu/acre, and 2 lb B/acre were broadcast before plowing. After plowing, the field was fumigated with K-Pam® at 15 gal/acre and bedded at 22 inches.

The experimental design was a randomized complete block with five replicates. Seed of two varieties (‘Joaquin’ and ‘Granero’, Nunhems, Parma, ID) was planted on March 19 in double rows spaced 3 inches apart at 9 seeds/ft of single row. Each double row was planted on beds spaced 22 inches apart. Planting was done with customized John Deere Flexi Planter units equipped with disc openers. Immediately after planting, the field received a narrow band of Lorsban® 15G at 3.7 oz/1000 ft of row (0.82 lb ai/acre) over the seed rows and the soil surface was rolled. Onion emergence started on April 8. On May 9, alleys 4 ft wide were cut between plots, leaving plots 23 ft long. On May 16, the seedlings were hand thinned to a spacing of 4.75 inches between individual onion plants in each single row, or 120,000 plants/acre.

The field had drip tape laid at 4-inch depth between pairs of beds during planting. The drip tape had emitters spaced 12 inches apart and an emitter flow rate of 0.22 gal/min/100 ft (Toro Aqua-

Traxx, Toro Co., El Cajon, CA). The distance between the tape and the center of each double row of onions was 11 inches.

The onions were managed to minimize yield reductions from weeds, pests, diseases, water stress, and nutrient deficiencies. For weed control, the following herbicides were broadcast: oxyfluorfen at 0.13 lb ai/acre (GoalTender® at 4 oz/acre), bromoxynil at 0.25 lb ai/acre (Brox® 2EC at 16 oz/acre), and clethodim at 0.12 lb ai/acre (Shadow® 3EC at 5.3 oz/acre) on May 7; pendimethalin at 0.95 lb ai/acre (Prowl® H_2O at 2 pt/acre) on May 17; oxyfluorfen at 0.25 lb ai/acre (GoalTender at 8 oz/acre), bromoxynil at 0.31 lb ai/acre (Brox 2EC at 20 oz/acre), and clethodim at 0.12 lb ai/acre (Shadow 3EC at 5.3 oz/acre) on May 25.

For thrips control, the following insecticides were applied by ground: spirotetramat at 0.078 lb ai/acre (Movento® at 5 oz/acre) and azadirachtin at 0.0093 lb ai/acre (Aza-Direct® at 12 oz/acre) on May 21 and June 3; abamectin at 0.019 lb ai/acre (Agri-Mek® SC at 3.5 oz/acre) on June 11. The following insecticides were applied by air: abamectin at 0.019 lb ai/acre on June 27; spinetoram at 0.078 lb ai/acre (Radiant® at 10 oz/acre) on June 30 and July 7; methomyl at 0.9 lb ai/acre (Lannate® at 3 pt/acre) on July 14 and July 21; spinetoram at 0.078 lb ai/acre on July 28 and August 5.

Starting on June 8, root tissue and soil samples were taken every week from borders of check treatment plots and analyzed for nutrients by Western Laboratories, Inc., Parma Idaho (Tables 1 and 2). Nutrients were applied through the drip tape based on recommendations from Western Labs (Table 3). Urea ammonium nitrate solution (URAN) was applied through the drip tape six times from June 3 to July 25, supplying a total of 140 lb N/acre. A total of 100 lb K/acre was applied in 10- to 20-lb increments during the growing season based on the soil and tissue analyses.

Onions were irrigated automatically to maintain the soil water tension (SWT) in the onion root zone below 20 cb (Shock et al. 2000). Soil water tension was measured in the check and kaolinite plots in the adjacent heat treatment trial. Each plot had two granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Inc., Riverside, CA) installed at 8-inch depth in the center of the double row. Sensors had been calibrated to SWT (Shock et al. 1998). The GMS were connected to the datalogger via multiplexers (AM 16/32, Campbell Scientific, Logan, UT). The datalogger (CR10X, Campbell Scientific) read the sensors and recorded the SWT every hour. The datalogger automatically made irrigation decisions every 12 hours. The field was irrigated if the average of the 24 sensors in the adjoining trial planted at the same time (check and kaolinite) treatments was a SWT of 20 cb or higher. The irrigations were controlled by the datalogger using a controller (SDM CD16AC, Campbell Scientific) connected to a solenoid valve. Irrigation durations were 8 hours, 19 min to apply 0.48 inch of water. The water was supplied from a well and pump that maintained a continuous and constant water pressure of 35 psi. The pressure in the drip lines was maintained at 10 psi by a pressure regulating valve. The automated irrigation system was started on June 4 and irrigations ended August 31.

Onions in each plot were evaluated weekly in the field starting July 5 and ending September 21. Five consecutive bulbs from each single row in a four-double-row plot (a total of 40 bulbs per plot) were cut longitudinally and rated for the presence of incomplete scales, dry scales, and internal decay caused by bacteria, neck rot, black mold, or *Fusarium proliferatum*. Incomplete scales were defined as scales that had more than 0.25 inch from the center of the neck missing or any part missing lower down on the scale. Dry scales were defined as scales with a small dry section inside the bulb either near the top of the neck or lower down on the scale. Bulbs from the first two single rows in each plot had the number of leaves counted and the diameter measured. After harvest, the onions from each plot were evaluated out of storage monthly starting in mid-November.

Table 1. Onion root tissue sufficiency levels and nutrient content, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Nutrient		8-Jun	15-Jun	22-Jun	29-Jun	9-Jul	23-Jul	27-Jul	3-Aug	10-Aug
NO_3-N (ppm)	Sufficiency range	8500	7667	6833	6000	5168	4338	3508	2678	1834
NO_3-N (ppm)		3943	4301	3356	4057	3728	3422	3051	2725	2604
P (%)	0.32 - 0.7	0.54	0.45	0.42	0.58	0.43	0.36	0.30	0.43	0.31
K (%)	2.7 - 6.0	2.74	2.60	2.15	3.02	1.97	1.72	1.50	1.27	0.97
S (%)	0.24 - 0.85	0.91	0.82	0.60	0.74	0.85	0.71	0.85	0.85	0.80
Ca (%)	0.4 - 1.2	0.61	0.57	0.56	0.61	0.59	0.70	0.74	0.87	0.84
Mg (%)	0.3 - 0.6	0.37	0.39	0.44	0.35	0.36	0.30	0.34	0.36	0.27
Zn (ppm)	25 - 50	57	67	71	50	40	41	43	44	40
Mn (ppm)	35 - 100	85	98	109	92	85	98	114	130	92
Cu (ppm)	6 - 20	16	13	12	10	8	7	8	8	7
B (ppm)	19 - 60	67	76	62	56	46	44	36	28	35

Table 2. Weekly soil solution analyses. Data represent the amount of each plant nutrient per day that the soil can potentially supply to the crop. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Nutrient	Critical level, lb/ac or g/ac	8-Jun	15-Jun	22-Jun	29-Jun	9-Jul	23-Jul	27-Jul	3-Aug	10-Aug
N	Critical levels	8.6	7.8	7	6.2	5.4	4.6	3.8	2.8	2.0
N		2.9	2.9	8.6	10.0	7.7	7.7	10.6	12.9	10.3
P	0.7 lb/acre	1.9	2.1	1.6	1.0	1.5	1.2	1.7	2.1	2.4
K	5 lb/acre	4.1	5.0	6.1	5.2	5.7	5.0	6.2	5.1	5.4
S	1 lb/acre	1.3	1.1	2.7	3.3	4.9	4.0	5.1	3.7	3.8
Ca	3 lb/acre	4.8	5.2	6.0	6.2	5.1	4.5	5.0	5.3	5.3
Mg	2 lb/acre	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1
Zn	28 g/acre	87	69	90	78	72	57	66	57	60
Mn	28 g/acre	27	27	24	21	30	36	27	30	30
Cu	12 g/acre	36	33	36	48	39	48	42	30	36
B	21 g/acre	14	11	15	12	17	14	17	15	12

Table 3. Nutrients applied through the drip irrigation system, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Date	N	P	K	Mg
	----------- lb/acre -----------			
3-Jun	40			
11-Jun	40			
19-Jun	20		20	5
26-Jun	20		20	4
5-Jul				10
10-Jul	10		10	
14-Jul			10	
25-Jul	10			2
31-Jul		10	10	
6-Aug			10	
7-Aug			10	
13-Aug			10	
Total	140	10	100	21

The onions were lifted on September 11 to cure in the field. Onions from each single row in each plot were topped by hand and bagged on September 15. The bags were moved into storage on September 22. The storage shed was ventilated and the temperature was slowly decreased to maintain air temperature as close to 34°F as possible.

The effects of variety and evaluation date were determined using repeated measures analysis of variance. Means separation was determined using a protected Fisher's least significant difference test at the 5% probability level, LSD (0.05). The least significant difference LSD (0.05) values in each table should be considered when comparisons are made between treatments. A statistically significant difference in a characteristic between two treatments exists if the difference between the two treatments for that characteristic is equal to or greater than the LSD value for that characteristic.

Results and Discussion

The rate of accumulation and total number of growing degree-days (50-86°F) in 2018 were higher than the 24-year average in April and May and slightly higher than average in July (Fig. 1 and 2).

On July 5, 2018 the bulbs had an average of 13 leaves, were 1.6 inches in diameter (Table 4), and had no symptoms of incomplete scale or decomposition (Tables 5 and 6). The average number of leaves peaked at 17.5 and the average diameter peaked at close to 4 inches.

Both dry scales and incomplete scales were detected starting in early August (Table 5). The percentage of bulbs with incomplete scales with or without dry scales increased over time through the November evaluation for both varieties. Incomplete and dry scales became prominent by 21 September in 2018 (Table 5). The percentage of bulbs with internal decomposition in 2018 was very low (Table 6). For Joaquin, bulbs with bacterial decomposition were found only on November 20 at 1% and bulbs with *Fusarium proliferatum* were found only on September 21 at 0.5%. For Granero, bulbs with bacterial decomposition were found only on July 12 at 1%. No other type of internal decomposition was found.

In 2016, incomplete scales were first detected in early September and internal decomposition was first detected in early November (Shock et al. 2017). In 2017, incomplete scales were first detected in late July and internal decomposition was first detected in late August (Shock et al. 2018). In 2016, most of the internal decomposition was due to bacterial rot and *Botrytis* neck rot, with very little *Fusarium proliferatum*. No internal decomposition due to black mold was detected in 2016. In 2017, most of the internal decomposition was caused by black mold. There was very little internal decomposition caused by bacteria, *Fusarium proliferatum*, or *Botrytis* neck rot in 2017. Over the 3 years of this trial, internal decomposition has been low, 0.3% in November of 2016, 3.3% in November of 2017, and 0.5% in November of 2018, averaged over the two varieties.

Acknowledgements

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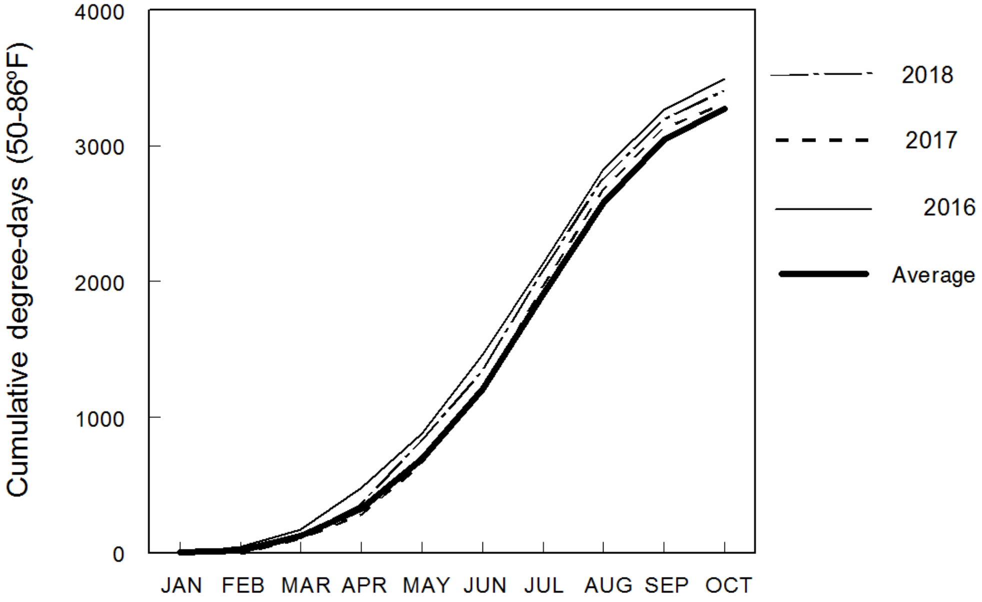

Figure 1. Cumulative growing degree-days (50-86°F) for 2016-2018 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

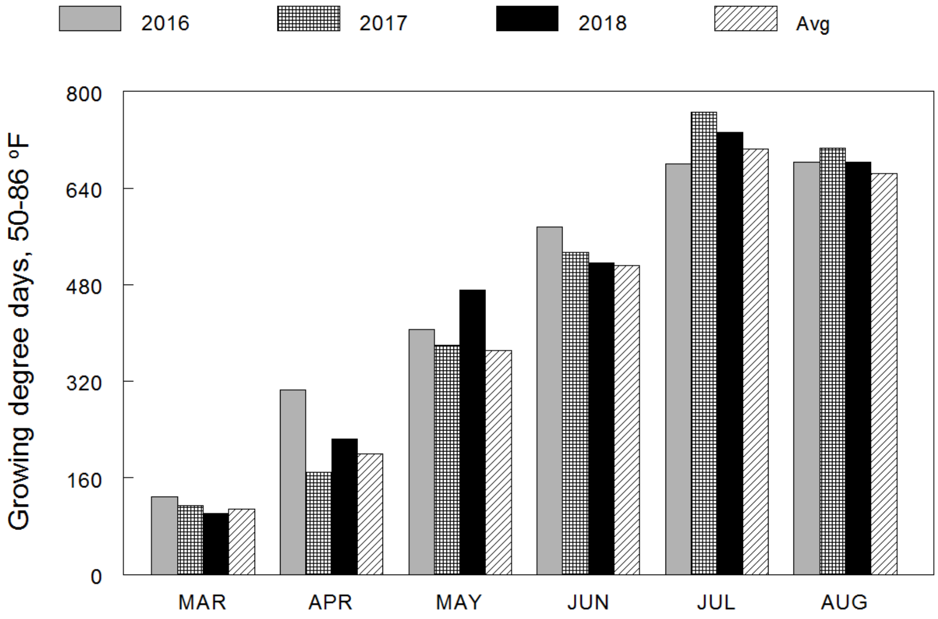

Figure 2. Monthly growing degree-days (50-86°F) for 2016-2018 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Table 4. Number of leaves and bulb diameter over time for onion bulbs evaluated for internal defects, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety	Date	No. of leaves	Bulb diameter, inch
Joaquin	5-Jul	12.9	1.5
	12-Jul	15.1	1.8
	18-Jul	16.0	2.2
	24-Jul	16.2	2.8
	1-Aug	17.4	3.2
	7-Aug	17.5	3.4
	13-Aug	18.2	3.7
	21-Aug		3.7
	29-Aug		3.9
	3-Sep		3.9
	21-Sep		4.2
Granero	5-Jul	13.3	1.7
	12-Jul	15.9	2.3
	18-Jul	16.8	2.5
	24-Jul	16.6	3.1
	1-Aug	17.7	3.5
	7-Aug	17.4	3.6
	13-Aug	16.8	3.6
	21-Aug		3.9
	29-Aug		3.9
	3-Sep		4.2
	21-Sep		4.1
Average	5-Jul	13.1	1.6
	12-Jul	15.5	2.0
	18-Jul	16.4	2.3
	24-Jul	16.4	2.9
	1-Aug	17.6	3.3
	7-Aug	17.5	3.5
	13-Aug	17.5	3.6
	21-Aug		3.8
	29-Aug		3.9
	3-Sep		4.1
	21-Sep		4.1
LSD (0.05)	Variety	NS	NS
	Date	1.1	0.2
	Variety X date	NS	0.3

Table 5. Internal defects over time for two onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Continued on next page.

		All bulbs							Diseased bulbs						
		Complete scales			Incomplete scales			Total	Complete scales			Incomplete scales			Total
Variety	Date	no dry scale	dry scale	total	no dry scale	dry scale	total		no dry scale	dry scale	total	no dry scale	dry scale	total	
		%													
Joaquin	5-Jul	100.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12-Jul	99.5	0.0	99.5	0.5	0.0	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	18-Jul	100.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	24-Jul	100.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1-Aug	99.0	0.0	99.0	1.0	0.0	1.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7-Aug	96.5	0.0	96.5	3.5	0.0	3.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	13-Aug	99.5	0.0	99.5	0.0	0.5	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	21-Aug	100.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	29-Aug	100.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3-Sep	97.5	1.5	99.0	0.0	1.0	1.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	20-Sep	68.0	0.5	68.5	23.5	8.0	31.5	100.0	0.5	0.0	0.5	0.0	0.0	0.0	0.5
	20-Nov	46.5	5.0	51.5	26.5	22.0	48.5	100.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0
	Average	92.2	0.6	92.8	4.6	2.6	7.2	100.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1
Granero	5-Jul	100.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12-Jul	99.0	0.0	99.0	1.0	0.0	1.0	100.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0
	18-Jul	99.5	0.0	99.5	0.5	0.0	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	24-Jul	98.0	0.0	98.0	2.0	0.0	2.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1-Aug	98.0	0.0	98.0	2.0	0.0	2.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7-Aug	81.3	0.0	81.3	18.2	0.5	18.7	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	13-Aug	99.5	0.0	99.5	0.0	0.5	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	21-Aug	99.5	0.0	99.5	0.5	0.0	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	29-Aug	97.5	2.0	99.5	0.0	0.5	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3-Sep	84.5	3.5	88.0	10.5	1.5	12.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	21-Sep	32.5	0.0	32.5	40.5	27.0	67.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	20-Nov	20.0	2.5	22.5	28.5	49.0	77.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Average	84.1	0.7	84.8	8.6	6.6	15.2	100.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1

Table 5. (Continued.) Internal defects over time averaged over two onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

		All bulbs							Diseased bulbs						
		Complete scales			Incomplete scales			Total	Complete scales			Incomplete scales			Total
Variety	Date	no dry scale	dry scale	total	no dry scale	dry scale	total		no dry scale	dry scale	total	no dry scale	dry scale	total	
		%													
Average	5-Jul	100.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12-Jul	99.3	0.0	99.3	0.8	0.0	0.8	100.0	0.0	0.0	0.0	0.5	0.0	0.5	0.5
	18-Jul	99.8	0.0	99.8	0.3	0.0	0.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	24-Jul	99.0	0.0	99.0	1.0	0.0	1.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1-Aug	98.5	0.0	98.5	1.5	0.0	1.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7-Aug	88.9	0.0	88.9	10.9	0.3	11.1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	13-Aug	99.5	0.0	99.5	0.0	0.5	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	21-Aug	99.8	0.0	99.8	0.3	0.0	0.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	29-Aug	98.8	1.0	99.8	0.0	0.3	0.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3-Sep	91.0	2.5	93.5	5.3	1.3	6.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	21-Sep	50.3	0.3	50.5	32.0	17.5	49.5	100.0	0.3	0.0	0.3	0.0	0.0	0.0	0.3
	20-Nov	33.3	3.8	37.0	27.5	35.5	63.0	100.0	0.5	0.0	0.5	0.0	0.0	0.0	0.5
LSD (0.05)															
Variety		2.0	NS	2.1	1.5	1.0	2.1		NS	NS	NS	NS	NS	NS	NS
Date		3.4	1.4	3.2	3.3	1.5	3.2		NS	NS	NS	0.3	NS	0.3	NS
Var. X date		4.9	NS	4.5	4.7	2.1	4.5		NS	NS	NS	0.4	NS	0.4	NS

Table 6. Internal decomposition over time by disease for two onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety	Date	Bacterial rot	*Fusarium proliferatum*	Neck rot	Black mold
		--------------- % ---------------			
Joaquin	5-Jul	0.0	0.0	0.0	0.0
	12-Jul	0.0	0.0	0.0	0.0
	18-Jul	0.0	0.0	0.0	0.0
	24-Jul	0.0	0.0	0.0	0.0
	1-Aug	0.0	0.0	0.0	0.0
	7-Aug	0.0	0.0	0.0	0.0
	13-Aug	0.0	0.0	0.0	0.0
	21-Aug	0.0	0.0	0.0	0.0
	29-Aug	0.0	0.0	0.0	0.0
	3-Sep	0.0	0.0	0.0	0.0
	21-Sep	0.0	0.5	0.0	0.0
	20-Nov	1.0	0.0	0.0	0.0
	Average	0.1	0.0	0.0	0.0
Granero	5-Jul	0.0	0.0	0.0	0.0
	12-Jul	1.0	0.0	0.0	0.0
	18-Jul	0.0	0.0	0.0	0.0
	24-Jul	0.0	0.0	0.0	0.0
	1-Aug	0.0	0.0	0.0	0.0
	7-Aug	0.0	0.0	0.0	0.0
	13-Aug	0.0	0.0	0.0	0.0
	21-Aug	0.0	0.0	0.0	0.0
	29-Aug	0.0	0.0	0.0	0.0
	3-Sep	0.0	0.0	0.0	0.0
	21-Sep	0.0	0.0	0.0	0.0
	20-Nov	0.0	0.0	0.0	0.0
	Average	0.1	0.0	0.0	0.0
Average	5-Jul	0.0	0.0	0.0	0.0
	12-Jul	0.5	0.0	0.0	0.0
	18-Jul	0.0	0.0	0.0	0.0
	24-Jul	0.0	0.0	0.0	0.0
	1-Aug	0.0	0.0	0.0	0.0
	7-Aug	0.0	0.0	0.0	0.0
	13-Aug	0.0	0.0	0.0	0.0
	21-Aug	0.0	0.0	0.0	0.0
	29-Aug	0.0	0.0	0.0	0.0
	3-Sep	0.0	0.0	0.0	0.0
	21-Sep	0.0	0.3	0.0	0.0
	20-Nov	0.5	0.0	0.0	0.0
LSD (0.05)					
Variety		NS	NS	NS	NS
Date		NS	NS	NS	NS
Var. X date		NS	NS	NS	NS

EVALUATION OF ZEBA® FOR ONION PRODUCTION

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Introduction

Zeba® marketed by United Phosphorus Inc. (King of Prussia, PA) is a cornstarch-based soil enhancement product. Zeba reportedly increases the soil water holding capacity. This trial compared plant stands and bulb yields for an untreated check treatment with three rates of soil-applied Zeba.

Materials and Methods

Onions were grown in 2018 on a Greenleaf silt loam previously planted to wheat. A soil analysis taken in the fall of 2017 showed that the top foot of soil had a pH of 8.2, 3.4% organic matter, 7 ppm nitrate-N, 3 ppm ammonium-N, 22 ppm phosphorus (P), 386 ppm potassium (K), 20 ppm sulfur (S), 3218 ppm calcium, 533 ppm magnesium (Mg), 138 ppm sodium, 4.1 ppm zinc (Zn), 3 ppm manganese (Mn), 2.2 ppm copper (Cu), 16 ppm iron, and 0.5 ppm boron (B). In the fall of 2017, the wheat stubble was shredded and the field was irrigated. The field was then disked. Based on a soil analysis, 78 lb of P/acre, 81 lb K/acre, 162 lb of S/acre, 9 lb of Mn/acre, and 1 lb of B/acre were broadcast before plowing. Also before plowing, 10 tons/acre of composted cattle manure were broadcast. The manure was estimated to supply 196 lb nitrogen (N)/acre, 156 lb P/acre, and 342 lb K/acre. The field was then moldboard plowed, and groundhogged. After ground hogging, the field was fumigated with K-Pam® at 15 gal/acre and bedded at 22 inches.

Seed of variety ‘Vaquero’ (Nunhems, Parma, ID) was planted on March 26 in double rows spaced 3 inches apart. Each double row was planted on beds spaced 22 inches apart. The vacuum seeder was set to drop seed every 3 inches/ft of single row.

The experimental design was a randomized complete block with four treatments and nine replicates. The field was divided into plots 4 double rows wide and 27 ft long. The treatments were an untreated check and 3 rates of Zeba SP (4, 8, and 12 lb/acre). Zeba was applied at planting to each of the four single onion rows on the middle two beds in each plot. Zeba was applied to the seed furrow after seed drop using a Gandy box applicator. The seed and then the Zeba fell into the seed furrow before the soil covered the seed.

Immediately after planting, the field received a narrow band of Lorsban® 15G at 3.7 oz/1000 ft of row (0.82 lb ai/acre) over the seed rows and the soil surface was rolled. Onion emergence started on April 12. On May 10, alleys 4 ft wide were cut between plots, leaving plots 23 ft long.

The field had drip tape laid at 4-inch depth between pairs of beds during planting. The drip tape had emitters spaced 12 inches apart and an emitter flow rate of 0.22 gal/min/100 ft (Toro Aqua-Traxx, Toro Co., El Cajon, CA). The distance between the tape and the center of each double row of onions was 11 inches.

Onions were irrigated automatically to maintain the soil water tension (SWT) in the onion root zone below 20 cb (Shock et al. 2000). Soil water tension was measured with eight granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co. Inc., Riverside, CA) installed at 8-inch depth in the center of the double row. Sensors had been calibrated to SWT (Shock et al. 1998). The GMS were connected to the datalogger via multiplexers (AM 16/32, Campbell Scientific, Logan, UT). The datalogger (CR1000, Campbell Scientific) read the sensors and recorded the SWT every hour. The datalogger automatically made irrigation decisions every 12 hours. The field was irrigated if the average of the eight sensors was a SWT of 20 cb or higher. The irrigations were controlled by the datalogger using a controller (SDM CD16AC, Campbell Scientific) connected to a solenoid valve. Irrigation durations were 8 hours, 19 min to apply 0.48 inch of water. The water was supplied from a well and pump that maintained a continuous and constant water pressure of 35 psi. The pressure in the drip lines was maintained at 10 psi by a pressure-regulating valve. The automated irrigation system was started on May 16 and irrigations ended on August 31.

Starting on June 8, root tissue and soil samples were taken every week from field borders (variety 'Vaquero') and analyzed for nutrients by Western Laboratories, Inc., Parma, Idaho (Tables 1 and 2). Nutrients were applied through the drip tape based on recommendations from Western Labs (Table 3). Urea ammonium nitrate solution (URAN) was applied through the drip tape six times from May 23 to June 25, supplying a total of 120 lb N/acre. Starting June 22, the soil solution N remained above the critical level for the rest of the season. Also starting June 22, the amount of total available soil N remained above the critical level of 60 lb N/acre for the rest of the season (Table 4, Sullivan et al. 2001). Phosphorus, K, Mg, and Cu were also applied based on the soil and tissue analyses.

Table 1. Onion root tissue nutrient content in the onion variety trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Nutrient		8-Jun	15-Jun	22-Jun	29-Jun	9-Jul	23-Jul	27-Jul	3-Aug	10-Aug
NO_3-N (ppm)	Sufficiency range	8500	7667	6833	6000	5168	4338	3508	2678	1834
NO_3-N (ppm)		4772	3668	4105	4726	3903	4644	3616	3432	2871
P (%)	0.32 - 0.7	0.52	0.44	0.34	0.40	0.44	0.37	0.28	0.41	0.35
K (%)	2.7 - 6.0	3.67	3.31	3.13	4.49	4.18	3.21	2.75	2.51	2.16
S (%)	0.24 - 0.85	1.00	0.94	0.87	1.21	0.63	0.60	0.77	0.81	0.50
Ca (%)	0.4 - 1.2	0.59	0.66	0.79	0.79	0.74	0.87	0.93	1.16	0.96
Mg (%)	0.3 - 0.6	0.33	0.42	0.47	0.36	0.32	0.35	0.43	0.43	0.36
Zn (ppm)	25 - 50	67	47	56	47	39	46	51	40	30
Mn (ppm)	35 - 100	99	93	108	82	62	73	85	92	68
Cu (ppm)	6 - 20	20	15	10	8	7	6	7	6	7
B (ppm)	19 - 60	72	80	61	52	42	33	31	25	28

Table 2. Weekly soil solution analyses in the onion variety trial. Data represent the amount of each plant nutrient per day that the soil can potentially supply to the crop. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Nutrient	Critical level, lb/ac or g/ac	8-Jun	15-Jun	22-Jun	29-Jun	9-Jul	23-Jul	27-Jul	3-Aug	10-Aug
N	Critical levels	8.6	7.8	7	6.2	5.4	4.6	3.8	2.8	2
N		2	2.3	9.7	8.6	9.7	8.6	10	12.6	10
P	0.7 lb/acre	1.2	1.1	1.5	1.6	1.5	2	1.8	2.2	2.3
K	5 lb/acre	8.5	9.1	9.2	7.9	6.6	7	8.2	6.9	7.4
S	1 lb/acre	1.5	1	2.3	3.1	4.3	5.5	5.5	3.8	4.7
Ca	3 lb/acre	4.9	5	6.1	4.7	5.5	4.5	5.5	5.1	5
Mg	2 lb/acre	0.2	0.2	0.5	0.6	0.7	0.9	1	1	1.1
Zn	28 g/acre	75	69	78	57	66	57	63	45	45
Mn	28 g/acre	24	30	27	21	27	33	30	27	24
Cu	12 g/acre	36	42	33	27	21	24	27	24	30
B	21 g/acre	8	9	12	11	14	12	15	12	15

Table 3. Nutrients applied through the drip irrigation system in the onion variety trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Date	N	P	K	Mg	Cu
		----------- lb/acre -----------			
23-May	20				
1-Jun	20				
11-Jun	20				
12-Jun	20				
19-Jun	20			2.5	
25-Jun	20			5	
6-Jul				5	
25-Jul					0.3
30-Jul		10			
7-Aug			10		
15-Aug			10		
Total	120	10	20	12.5	0.3

Table 4. Soil available N ($NO_3 + NH_4$) in the top foot of soil in the onion variety trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Date	Available soil N, lb/acre
8-Jun	14
15-Jun	16
22-Jun	68
29-Jun	60
9-Jul	68
23-Jul	60
27-Jul	70
3-Aug	88
10-Aug	70

Plant stand counts were taken in the middle two double rows in each plot on April 16, April 23, and April 30.

The onions were managed to minimize yield reductions from weeds, pests, diseases, water stress, and nutrient deficiencies. For weed control, the following herbicides were broadcast: oxyfluorfen at 0.13 lb ai/acre (GoalTender® at 4 oz/acre), bromoxynil at 0.25 lb ai/acre (Brox® 2EC at 16 oz/acre), and clethodim at 0.12 lb ai/acre (Shadow® 3EC at 5.3 oz/acre) on May 7; pendimethalin at 0.95 lb ai/acre (Prowl® H_2O at 2 pt/acre) on May 17; oxyfluorfen at 0.25 lb ai/acre, bromoxynil at 0.31 lb ai/acre, and clethodim at 0.12 lb ai/acre on May 25.

For thrips control, the following insecticides were applied by ground: spirotetramat at 0.078 lb ai/acre (Movento® at 5 oz/acre) and azadirachtin at 0.0093 lb ai/acre (Aza-Direct® at 12 oz/acre) on May 21 and June 3; abamectin at 0.019 lb ai/acre (Agri-Mek® SC at 3.5 oz/acre) on June 11. The following insecticides were applied by air: abamectin at 0.019 lb ai/acre on June 27; spinetoram at 0.078 lb ai/acre (Radiant® at 10 oz/acre) on June 30 and July 7; methomyl at 0.9 lb ai/acre (Lannate® at 3 pt/acre) on July 14 and 21; spinetoram at 0.078 lb ai/acre on July 28 and August 5.

The onions were lifted on September 10 to field cure. Onions from the middle two rows in each plot were topped by hand and bagged on September 15. The bags were put in storage on September 21. The storage shed was ventilated, and the temperature was slowly decreased to maintain cool air temperature. Onions were graded out of storage on October 12.

During grading, all bulbs from each plot were counted. The bulbs were then separated according to quality: bulbs without blemishes (No. 1s), split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, bulbs infected with the fungus *Fusarium oxysporum* (plate rot), bulbs infected with the fungus *Aspergillus niger* (black mold), and bulbs infected with unidentified bacteria in the external scales. The No. 1 bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Bulb counts per 50 lb of supercolossal onions were determined for each plot of every variety by weighing and counting all supercolossal bulbs during grading. Marketable yield consisted of No.1 bulbs larger than 2¼ inches.

Treatment differences were determined using analysis of variance. Means separation was determined using a protected Fisher's least significant difference test at the 5% probability level, LSD (0.05). The least significant difference LSD (0.05) values in each table should be considered when comparisons are made between treatments for significant differences in their performance characteristics. Differences between treatments equal to or greater than the LSD value for a characteristic should exist before any treatment is considered different from any other treatment in that characteristic.

Results

The plant populations were not as high as desired because the vacuum seeder apparently failed to drop the correct amount of seed. Seed emergence was somewhat slow. There were no statistically significant differences in plant population between treatments (Table 5).

The soil water tension remained close to the target during the season (Fig. 1). Onions grew well and bulb yields were high in all treatments (Table 6). Bulb decomposition was uniformly low.

There were no statistically significant differences in onion yield or grade between treatments (Table 6).

Acknowledgements

This project was funded by United Phosphorus Inc., Oregon State University, the Malheur County Education Service District, and was supported by Formula Grant nos. 2018-31100-06041 and 2018-31200-06041 from the USDA National Institute of Food and Agriculture.

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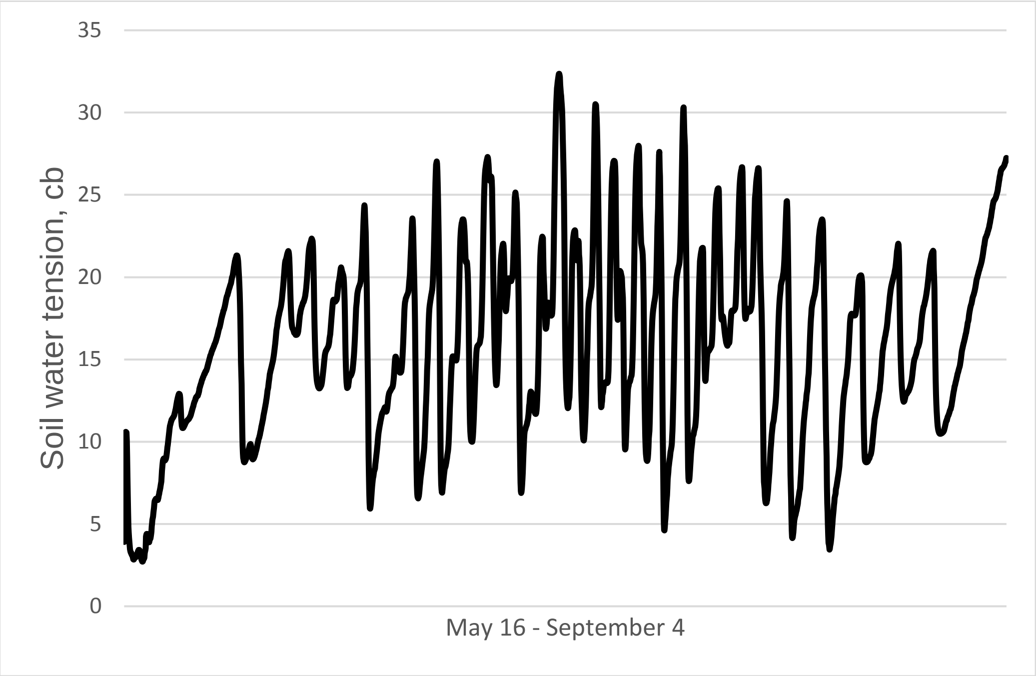

Figure 1. Soil water tension at 8-inch depth below the onion row in a corresponding check treatment. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Table 5. Plant population in response to three Zeba® treatments on three dates and at harvest. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Treatment	Zeba rate	Plant population			
		16-Apr	23-Apr	30-Apr	at harvest
	lb/acre	----- plants/acre ------			
1	none (check)	34,320	57,200	59,351	66,976
2	4	36,862	54,951	64,240	66,517
3	8	36,129	56,369	60,769	66,861
4	12	32,413	54,071	59,938	63,360
LSD (0.05)		NS	NS	NS	NS

Table 6. Onion yield and grade in response to three Zeba® treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Zeba rate	Total yield	Marketable yield by grade							Neck rot	Plate rot	Bulb counts >4¼ in
		Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Small	No. 2s			
lb/acre	------------------------------ cwt/acre --------------------------------								---- % ----		#/50 lb
none (check)	1097.1	1085.8	741.6	252.1	90.2	2.0	1.8	6.2	0.0	0.3	26.9
4	1075.6	1067.9	732.5	238.5	92.8	4.1	0.7	3.4	0.2	0.1	26.5
8	1081.7	1070.9	723.4	254.0	89.6	3.8	0.3	4.2	0.5	0.1	26.4
12	1052.4	1042.4	737.7	228.9	72.7	3.1	0.6	4.4	0.3	0.1	26.3
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

EFFECT OF ETHOTRON™ APPLICATION RATE AND TIMING ON WEEDS AND ONION BULB SINGLE CENTERS

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018

Introduction

Ethotron™ herbicide provides selective control of weeds in onions and other crops. It is a group 16 herbicide and belongs to the benzofuran family of herbicides. The current label recommends pre-emergence and/or post-emergence applications to onions at the 2- to 8-leaf stage. The use rate varies depending on the application timing, soil texture, and organic matter. The label carries a caution that the herbicide may cause temporary leaf fusion, distortion, and stunting when used according to label directions and under normal growing conditions. Growers use this product to control kochia in onions.

Reports indicate that over 20% of the onions produced in the Treasure Valley of eastern Oregon and southwestern Idaho are processed for onion rings. In order to meet the needs of this market, onion packers and shippers in southwestern Idaho and eastern Oregon adopted a new bulb size class called “supercolossal” (>4¼ inches diameter) (Shock et al. 2005). It is reported that onion ring manufacturing efficiency is reduced when bulbs have multiple centers. Bulbs with single centers (called “bullets”) or bulbs with a small multiple center (called a “small double” with multiple center diameters <1½ inches) are preferred. Together the “bullets” and “small doubles” are called “functionally single-centered” onion bulbs (Shock et al. 2005). Incentives are paid for delivering onions that are more than 75% “functionally single-centered.” Onions with progressively larger multiple centers have fewer useable rings for processing. As a result, supercolossal bulbs have become important for the processing industry.

This study was conducted to evaluate onion response to Ethotron application rate and timing as well as weed control and onion bulb single centers.

Materials and Methods

A field study was conducted at the Malheur Experiment Station, Ontario, Oregon in 2018 to evaluate the response of onion variety ‘Vaquero’ to Ethotron herbicide application rate and timing as well as bulb centers. Onion seed was planted on March 26, 2018 in double rows on beds spaced 22 inches apart. The twin rows were spaced 3 inches apart with 4.75-inch seed spacing within each row. Immediately after planting, each onion row received a 7-inch band of Lorsban® 15G at 3.7 oz/1000 ft of row (0.125 lb ai/acre) and the soil surface was rolled. The soil was an Owyhee silt loam with a pH 7.2 and 1.25% organic matter. Drip irrigation was used to supply water and fertilizer.

The study had a factorial design and treatments were arranged in randomized complete blocks with three replicates. Herbicide application timing formed the main plot onto which herbicide application rates were randomly assigned. Individual plots were 7.33 ft wide (4 beds) by 27 ft long. The study area (except the hand-weeded check plots) was treated with pendimethalin (Prowl® H_2O) at 2.0 pt/acre (0.95 lb ai/acre) late pre-emergence on April 17, 2018.

Ethotron Application Timing

The herbicide was applied 1) prior to bed harrowing followed by harrowing the beds twice; 2) harrowing down the beds, spraying, and harrowing the second time; or 3) pre-emergence (after harrowing the beds twice and planting). Timing 3 would be the standard practice for the application of Ethotron in the fields planted to onion. Ethotron was applied at 12 fl oz/acre (0.375, lb ai/acre), 16 fl oz/acre (0.5 lb ai/acre), or 32 fl oz/acre (1 lb ai/acre) on each timing (Tables 1-4). Follow up post-emergence applications were when onions were at the 2 and 4 leaf stage (Tables 1-4).

Postemergence applications of Buctril® at 12 fl oz/acre (bromoxynil at 0.188lb ai/acre) plus GoalTender® at 4 fl oz/acre (oxyfluorfen at 0.125 lb/ai acre) were made when onion seedlings were at the 2- and 4-leaf stages. All herbicide treatments were applied using a CO_2-pressurized backpack sprayer fitted with a boom equipped with four EVS8002 flat-fan nozzles at a spray volume of 20 gal/acre. Visual evaluations for onion injury and weed control were conducted on June 14 and June 22. Estimates were based on a 0-100% visual scale; where 0% = no injury or no weed control and 100% = total crop damage or complete weed control.

Fertilizer was applied through irrigation drip on May 29, June 13 and 29, and July 6 to supply 50 lb nitrogen (N)/acre at each application. All other operations including insect control followed recommended local production practices.

Single Center Assessment

After harvest, 25 bulbs from the center two rows in each plot were rated for single centers following the methods described by Shock et al. 2005. Twenty-five consecutive onions ranging in diameter from 3½ to 4¼ inches were rated. The onions were cut equatorially through the bulb middle and separated into single-centered (bullet) and multiple-centered bulbs. The multiple-centered bulbs had the long axis of the inside diameter of the first single ring measured. These multiple-centered onions were ranked according to the inside diameter of the first entire single ring: small had diameters less than 1½ inches, medium had diameters from 1½ to 2¼ inches, and large had diameters greater than 2¼ inches. Onion bulbs were considered "functionally single centered" for processing if they were single centered (bullet) or had a small multiple center (<1½ inches).

Plant tops were flailed on September 11, 2018 and bulbs were hand-harvested from the two center beds on September 12.

Bulbs were graded on September 12, 2018 for yield and quality based on USDA standards as follows: bulbs without blemishes (U.S. No. 1), split bulbs (No. 2), bulbs infected with the fungus *Botrytis allii* in the neck or side, bulbs infected with the fungus *Fusarium oxysporum* (plate rot), bulbs infected with the fungus *Aspergillus niger* (black mold), and bulbs infected with unidentified bacteria in the external scales. The U.S. No. 1 bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield consisted of U.S. No.1 bulbs greater than 2¼ inches.

Data were subjected to analysis of variance and the treatment means were compared using protected LSD at the 0.05% level of confidence.

Results

Onion emergence was observed on April 18, 2018. Evaluations on June 14 (57 days after onion emergence) indicated 0-11% onion injury (Table 1). The greatest injury was observed in plants growing in plots that received pre-emergence applications of Ethotron at 32 fl oz/acre. The injury was characterized by leaf fusion and overly green above-ground onion parts. The predominant weeds were common lambsquarters, redroot pigweed, and hairy nightshade. Weed control improved when Ethotron was applied pre-emergence at 12 to 32 fl oz/acre (Tables 1 and 2). Applications of Ethotron before bed harrowing or between the two harrowings resulted in reduced weed control regardless of the application rate.

Plant stand on May 29, 2018 ranged from 101,658 to 109,351 plants/acre across herbicide treatments and 99,460 plants/acre in the untreated control (Table 3). The number of harvested bulbs varied greatly across herbicide treatments, but tended to be higher in plots where Ethotron herbicide was applied pre-emergence.

The total marketable yield, which is comprised of medium (2¼-3 inches) to supercolossal (>4¼ inches) bulb categories, was greater when Ethotron was applied pre-emergence (1,031.9-1,123.2 cwt/acre) compared to before bed harrowing (806.5-859.4 cwt/acre) or in between two harrowings prior to planting (816.6-925.5 cwt/acre) (Table 4). The yield for small bulbs ranged from 4.2 to 14.3 cwt/acre across Ethotron rate and application timings.

Onion single-center results are presented in Table 5. The percentage of functionally single-centered onion bulbs was greater when Ethotron was applied pre-emergence (84-88%) compared to applications before planting (77-83%). Functionally single center for the hand weeded treatment was 82%.

The results suggested better weed control when Ethotron was applied pre-emergence compared to applications before bed harrowing or between the two harrowings. Similarly, onion single center was higher when Ethotron was applied pre-emergence. The study will be repeated in 2019 to confirm these results.

Acknowledgements

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Table 1. Onion response and weed control (6/14/2018) with Ethotron™ applied at different timings in direct-seeded onion variety ‘Vaquero’ at the Malheur Experiment Station, Ontario, OR 2018.

			Weed control*			
Treatment	Rate	Application timing	Injury	Common lambsquarters	Redroot pigweed	Hairy nightshade
	fl oz/acre		%			
Timing 1			1 bc	83 bc	84 cd	86 c
Ethotron 4 SC	12	Before bed harrowing				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 1			3 bc	83 bc	86 cd	94 abc
Ethotron 4 SC	16	Before bed harrowing				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 1			3 bc	83 bc	89 bcd	91 abc
Ethotron 4 SC	32	Before bed harrowing				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 2			0 c	88 abc	89 bcd	89 bc
Ethotron 4 SC	12	Harrow-spray-harrow				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 2			0 c	84 bc	93 abc	91 abc
Ethotron 4 SC	16	Harrow-spray-harrow				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 2			5 b	75 c	82 d	88 c
Ethotron 4 SC	32	Harrow-spray-harrow				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 3			1 bc	92 ab	96 ab	98 ab
Ethotron 4 SC	12	PRE-emergence				
Ethotron 4 SC	8	2-Leaf				
Brox 2 EC	12	2-Leaf				
GoalTender	4	2-Leaf				
Ethotron 4 SC	12	4-Leaf				
Brox 2 EC	12	4-Leaf				
GoalTender	4	4-Leaf				
Timing 3			0 c	97 a	100 a	100 a
Ethotron 4 SC	16	PRE-emergence				
Ethotron 4 SC	16	2-Leaf				
Brox 2 EC	12	2-Leaf				
GoalTender	4	2-Leaf				
Ethotron 4 SC	12	4-Leaf				
Brox 2 EC	12	4-Leaf				
GoalTender	4	4-Leaf				
Timing 3			11 a	97 a	99 a	99 a
Ethotron 4 SC	32	PRE-emergence				
Ethotron 4 SC	16	2-Leaf				
Brox 2 EC	12	2-Leaf				
GoalTender	4	2-Leaf				
Ethotron 4 SC	12	4-Leaf				
Brox 2 EC	12	4-Leaf				
GoalTender	4	4-Leaf				
Untreated	--		0 c	0 d	0 e	0 d
Handweeded	--		0 c	100 a	100 a	100 a
LSD (*P* = 0.05)			4.0	13	9	9
Standard deviation			2.8	8.8	6.1	6.4

*Means followed by same letter do not significantly differ (*P* = 0.05, LSD).

Table 2. Onion response and weed control (6/22/2018) with Ethotron™ applied at different timings in direct-seeded onions variety ‘Vaquero’ at the Malheur Experiment Station, Ontario, OR 2018.

				Weed control*		
Treatment	Rate	Application timing	Injury	Common lambsquarters	Redroot pigweed	Hairy nightshade
	fl oz/acre		%			
Timing 1			0 b	70 cd	75 de	74 b
Ethotron 4 SC	12	Before bed harrowing				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 1			4 b	80 bc	81 b-e	85 ab
Ethotron 4 SC	16	Before bed harrowing				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 1			9 a	73 cd	79 cde	77 ab
Ethotron 4 SC	32	Before bed harrowing				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 2			1 b	78 bc	72 de	81 ab
Ethotron 4 SC	12	Harrow-spray-harrow				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 2			0 b	76 bc	88 a-d	83 ab
Ethotron 4 SC	16	Harrow-spray-harrow				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 2			11 a	56 d	67 e	80 ab
Ethotron 4SC	32	Harrow-spray-harrow				
Brox 2 EC	12	2 & 4-Leaf				
GoalTender	4	2 & 4-Leaf				
Timing 3			3 b	86 abc	95 abc	95 ab
Ethotron 4 SC	12	PRE-emergence				
Ethotron 4 SC	8	2-Leaf				
Brox 2 EC	12	2-Leaf				
GoalTender	4	2-Leaf				
Ethotron 4 SC	12	4-Leaf				
Brox 2 EC	12	4-Leaf				
GoalTender	4	4-Leaf				
Timing 3			0 b	95 ab	97 ab	99 a
Ethotron 4 SC	16	PRE-emergence				
Ethotron 4 SC	16	2-Leaf				
Brox 2 EC	12	2-Leaf				
GoalTender	4	2-Leaf				
Ethotron 4 SC	12	4-Leaf				
Brox 2 EC	12	4-Leaf				
GoalTender	4	4-Leaf				
Timing 3			11 a	95 ab	99 ab	99 a
Ethotron 4 SC	32	PRE-emergence				
Ethotron 4 SC	16	2-Leaf				
Brox 2 EC	12	2-Leaf				
GoalTender	4	2-Leaf				
Ethotron 4 SC	12	4-Leaf				
Brox 2 EC	12	4-Leaf				
GoalTender	4	4-Leaf				
Untreated			0 b	0 e	0 f	0 c
Handweeded			3 b	100 a	100 a	100 a
LSD (*P* = 0.05)			5	19	18	24
Standard deviation			3.4	13.2	12.2	16.7

*Means followed by same letter do not significantly differ (*P* = 0.05, LSD).

Table 3. Onion plant stand (5/29/2018) and number of harvested bulbs in response to Ethotron™ rate and application timing at the Malheur Experiment Station, Ontario, OR 2018.

				Marketable bulb number by grade*							
Treatment	Rate	Application timing	Plant stand	Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Small	No.2s	Neck rot
	fl oz/acre		No./acre								
Timing 1			101,658 ab	71,280 ab	2,970 abc	14,190 abc	45,430 a	8,690 abc	3,300 abc	110 b	110 a
Ethotron 4 SC	12	Before harrowing									
Brox 2EC	12	2 & 4-Leaf									
GoalTender	4	2 & 4-Leaf									
Timing 1			101,877 ab	68,640 b	2,970 abc	12,210 bc	43,780 a	9,680 ab	4,180 ab	220 ab	0 a
Ethotron 4 SC	16	Before harrowing									
Brox 2EC	12	2 & 4-Leaf									
GoalTender	4	2 & 4-Leaf									
Timing 1			103,196 ab	71,170 ab	1,870 bc	15,730 abc	43,010 a	10,560 a	5,390 a	220 ab	0 a
Ethotron 4 SC	32	Before harrowing									
Brox 2EC	12	2 & 4-Leaf									
GoalTender	4	2 & 4-Leaf									
Timing 2			105,394 ab	72,930 ab	1,210 bc	11,000 bcd	50,820 a	9,900 ab	4,840 ab	0 b	220 a
Ethotron 4 SC	12	Harrow-spray-harrow									
Brox 2EC	12	2 & 4-Leaf									
GoalTender	4	2 & 4-Leaf									
Timing 2			105,614 ab	73,700 ab	3,080 abc	16,610 abc	45,100 a	8,910 abc	4,290 ab	220 ab	0 a
Ethotron 4 SC	16	Harrow-spray-harrow									
Brox 2EC	12	2 & 4-Leaf									
GoalTender	4	2 & 4-Leaf									
Timing 2			105,284 ab	68,530 b	2,640 bc	8,360 cd	47,300 a	10,230 a	4,840 ab	110 b	0 a
Ethotron 4SC	32	Harrow-spray-harrow									
Brox 2EC	12	2 & 4-Leaf									
GoalTender	4	2 & 4-Leaf									
Timing 3			104,515 ab	76,010 ab	4,180 ab	22,770 ab	45,100 a	3,960 bcd	1,540 bc	330 ab	0 a
Ethotron 4 SC	12	PRE-emergence									
Ethotron 4 SC	8	2-Leaf									
2EC	12	2-Leaf									
GoalTender	4	2-Leaf									
Ethotron 4 SC	12	4-Leaf									
Brox 2EC	12	4-Leaf									
GoalTender	4	4-Leaf									
Timing 3			103,306 ab	73,920 ab	6,380 a	20,790 ab	42,680 a	4,070 bcd	1,650 bc	220 ab	220 a
Ethotron 4 SC	16	PRE-emergence									
Ethotron 4 SC	16	2-Leaf									
Brox 2EC	12	2-Leaf									
GoalTender	4	2-Leaf									
Ethotron 4 SC	12	4-Leaf									
Brox 2EC	12	4-Leaf									
GoalTender	4	4-Leaf									
Timing 3			109,351 a	78,540 a	4,620 ab	24,970 a	45,650 a	3,300 cd	1,870 abc	660 a	0 a
Ethotron 4 SC	32	PRE-emergence									
Ethotron 4 SC	16	2-Leaf									
Brox 2EC	12	2-Leaf									
GoalTender	4	2-Leaf									
Ethotron 4 SC	12	4-Leaf									
Brox 2EC	12	4-Leaf									
GoalTender	4	4-Leaf									
Untreated			99,460 b	0 c	0 c	0 d	0 b	0 d	0 c	0 b	0 a
Handweeded			108,471 ab	76,670 ab	3,740 ab	21,890 ab	48,950 a	2,090 d	2,310 abc	220 ab	0 a
LSD (P = 0.05)			9,053	8,798	3,561	11,771	10,024	5,946	3,689	467	236
Standard deviation			6269.6	6,093.2	2,466.0	8,151.9	6,942.4	4,117.6	2,554.8	323.2	163.4

*Means followed by same letter do not significantly differ (*P* = 0.05, LSD).

Table 4. Onion yield (9/29/2018) by grade in response to Ethotron™ rate and application timing at the Malheur Experiment Station, Ontario, OR 2018.

			Marketable yield by grade*							
Treatment	Rate	Application timing	Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Small	No.2s	Neck rot
	fl oz/acre		---------- cwt/acre ----------							
Timing 1			838.6 bc	42.0 bc	249.5 a-d	501.0 a	46.1 ab	9.3 ab	1.4 b	1.5 ab
Ethotron 4 SC	12	Before bed harrowing								
Brox 2 EC	12	2 & 4-Leaf								
GoalTender	4	2 & 4-Leaf								
Timing 1			806.5 c	68.8 abc	210.5 bcd	479.3 a	47.9 ab	12.6 a	3.5 ab	0.0 b
Ethotron 4 SC	16	Before bed harrowing								
Brox 2 EC	12	2 & 4-Leaf								
GoalTender	4	2 & 4-Leaf								
Timing 1			859.4 abc	45.0 bc	270.7 a-d	491.7 a	52.0 a	13.4 a	2.4 b	0.0 b
Ethotron 4 SC	32	Before bed harrowing								
Brox 2 EC	12	2 & 4-Leaf								
GoalTender	4	2 & 4-Leaf								
Timing 2			816.6 bc	28.1 bc	185.8 cde	551.4 a	51.4 a	14.4 a	0.0 b	1.8 ab
Ethotron 4 SC	12	Harrow-spray-harrow								
Brox 2 EC	12	2 & 4-Leaf								
GoalTender	4	2 & 4-Leaf								
Timing 2			925.5 abc	70.9 abc	298.3 a-d	510.3 a	46.0 ab	11.4 a	2.4 b	0.0 b
Ethotron 4 SC	16	Harrow-spray-harrow								
Brox 2 EC	12	2 & 4-Leaf								
GoalTender	4	2 & 4-Leaf								
Timing 2			783.7 c	65.4 bc	145.1 de	519.0 a	54.3 a	14.3 a	1.5 b	0.0 b
Ethotron 4SC	32	Harrow-spray-harrow								
Brox 2 EC	12	2 & 4-Leaf								
GoalTender	4	2 & 4-Leaf								
Timing 3			1,077.3 ab	95.5 ab	408.9 ab	552.2 a	20.7 bc	4.2 ab	4.0 ab	0.0 b
Ethotron 4 SC	12	PRE-emergence								
Ethotron 4 SC	8	2-Leaf								
Brox 2 EC	12	2-Leaf								
GoalTender	4	2-Leaf								
Ethotron 4 SC	12	4-Leaf								
Brox 2 EC	12	4-Leaf								
GoalTender	4	4-Leaf								
Timing 3			1,031.9 abc	147.2 a	362.5 abc	501.8 a	20.4 bc	5.1 ab	2.9 ab	2.7 a
Ethotron 4 SC	16	PRE-emergence								
Ethotron 4 SC	16	2-Leaf								
Brox 2 EC	12	2-Leaf								
GoalTender	4	2-Leaf								
Ethotron 4 SC	12	4-Leaf								
Brox 2 EC	12	4-Leaf								
GoalTender	4	4-Leaf								
Timing 3			1,123.2 a	106.8 ab	438.7 a	561.1 a	16.6 c	5.5 ab	9.0 a	0.0 b
Ethotron 4 SC	32	PRE-emergence								
Ethotron 4 SC	16	2-Leaf								
Brox 2 EC	12	2-Leaf								
GoalTender	4	2-Leaf								
Ethotron 4 SC	12	4-Leaf								
Brox 2 EC	12	4-Leaf								
GoalTender	4	4-Leaf								
Untreated			0.0 d	0.0 c	0.0 e	0.0 b	0.0 c	0.0 b	0.0 b	0.0 b
Handweeded			1,080.0 ab	84.7 ab	385.3 abc	598.9 a	11.0 c	7.2 ab	1.8 b	0.0 b
LSD (*P* = 0.05)			265.16	81.75	206.92	125.65	29.38	10.37	6.16	2.44
Standard deviation			183.64	56.62	143.30	87.02	20.35	7.18	4.27	1.69

*Means followed by same letter do not significantly differ (*P* = 0.05, LSD).

Table 5. Single- and multiple-center onion bulb ratings in response to Ethotron™ rate and application timing at the Malheur Experiment Station, Oregon State University, Ontario, OR 2018.

			Multiple center*			Single center	
Treatment	Rate	Application timing	large >2.25 in	medium 1.5 - 2.25 in	small <1.5 in	bullet	functional[a] single
	fl oz/acre		%				
Timing 1			9 ab	14 abc	19 a	58 a	77 ab
Ethotron 4 SC	12	Before bed harrowing					
Brox 2 EC	12	2 & 4-Leaf					
GoalTender	4	2 & 4-Leaf					
Timing 1			7 ab	20 ab	13 a	60 a	73 ab
Ethotron 4 SC	16	Before harrowing					
Brox 2 EC	12	2 & 4-Leaf					
GoalTender	4	2 & 4-Leaf					
Timing 1			5 ab	23 ab	19 a	53 a	72 b
Ethotron 4 SC	32	Before harrowing					
Brox 2 EC	12	2 & 4-Leaf					
GoalTender	4	2 & 4-Leaf					
Timing 2			3 ab	25 a	16 a	56 a	72 b
Ethotron 4 SC	12	Harrow-spray-harrow					
Brox 2 EC	12	2 & 4-Leaf					
GoalTender	4	2 & 4-Leaf					
Timing 2			7 ab	10 bc	16 a	67 a	83 ab
Ethotron 4 SC	16	Harrow-spray-harrow					
Brox 2 EC	12	2 & 4-Leaf					
GoalTender	4	2 & 4-Leaf					
Timing 2			11 a	18 abc	15 a	56 a	71 b
Ethotron 4SC	32	Harrow-spray-harrow					
Brox 2 EC	12	2 & 4-Leaf					
GoalTender	4	2 & 4-Leaf					
Timing 3			3 ab	13 abc	19 a	65 a	84 ab
Ethotron 4 SC	12	PRE-emergence					
Ethotron 4 SC	8	2-Leaf					
Brox 2 EC	12	2-Leaf					
GoalTender	4	2-Leaf					
Ethotron 4 SC	12	4-Leaf					
Brox 2 EC	12	4-Leaf					
GoalTender	4	4-Leaf					
Timing 3			9 ab	6 c	16 a	69 a	85 ab
Ethotron 4 SC	16	PRE-emergence					
Ethotron 4 SC	16	2-Leaf					
Brox 2 EC	12	2-Leaf					
GoalTender	4	2-Leaf					
Ethotron 4 SC	12	4-Leaf					
Brox 2 EC	12	4-Leaf					
GoalTender	4	4-Leaf					
Timing 3			2 b	10 bc	18 a	70 a	88 a
Ethotron 4 SC	32	PRE-emergence					
Ethotron 4 SC	16	2-Leaf					
Brox 2 EC	12	2-Leaf					
GoalTender	4	2-Leaf					
Ethotron 4 SC	12	4-Leaf					
Brox 2 EC	12	4-Leaf					
GoalTender	4	4-Leaf					
Untreated			--	--	--	--	--
Handweeded			5 ab	13 abc	16 a	66 a	82 ab
LSD (P = 0.05)			8	14	12	17	15
Standard Deviation			6	9.6	8.3	12	10.6

*Means followed by same letter do not significantly differ (P = 0.05, LSD).

[a] Functional single-centered bulbs are the small multiple-centered plus the bullet-centered onions.

RED AND WHITE ONION CULTIVAR RESPONSE TO OUTLOOK® APPLIED THROUGH DRIP IRRIGATION

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018

Introduction

In 2016, Oregon and Idaho departments of agriculture approved the application of dimethenamid-p (Outlook®) herbicide through drip irrigation systems to control yellow nutsedge in onion. The current Section 24C Special Local Need (SLN) label allows this use on yellow onions grown in the Treasure Valley of eastern Oregon and southwestern Idaho. In Oregon, the application of Outlook through drip irrigation is allowed only in Malheur County. The Idaho label allows application through drip irrigation in Ada, Canyon, Gem, Owyhee, Payette, and Washington counties. Both labels reference the chemigation section of the federal label regarding restrictions and directions on how to properly chemigate Outlook in onion production. The user is required to have both the entire Outlook container label and the SLN label in their possession at the time of application.

The research conducted at the Oregon State University's Malheur Experiment Station near Ontario, Oregon indicated improved yellow nutsedge control with Outlook applied through drip irrigation compared to Outlook applied by broadcast spraying. The label still limits the maximum use rate to 21 fl oz/acre/season (0.98 lb ai/acre/season). Sequential applications are allowed as long as the total amount does not exceed 21 fl oz/acre/season. Applications through drip irrigation are allowed starting when onions are at the 2-leaf stage but not after the 6-leaf stage.

This study was conducted to generate data needed in order to allow the use of Outlook through drip irrigation in red and white onions. The study included three red and three white varieties.

Materials and Methods

A field study was conducted at the Malheur Experiment Station, Ontario, Oregon in 2018 to evaluate the response of red and white onion cultivars to various Outlook herbicide rates applied through drip irrigation. The study included three red cultivars ('Red Beret', SV4643NT, and 'Red Wing') and three white cultivars ('Antarctica', 'White Cloud', and SV4058NU). Onion seed was planted on March 28, 2018 in double rows spaced 3 inches apart with 4-inch seed spacing within each row. Each pair of rows was planted on beds spaced 22 inches apart. Immediately after planting, each onion bed received a 7-inch band of Lorsban® 15G at 3.7 oz/1000 ft of row (0.125 lb ai/acre) and the soil surface was rolled. The soil was an Owyhee silt loam with a pH 7.2 and 1.8% organic matter.

The study had a split-block design and treatments were arranged in randomized complete blocks with three replicates. Onion cultivars formed the main plot onto which herbicide treatments were randomly assigned. Individual plots were 7.33 ft wide (4 beds) by 27 ft long. The study area (except the hand-weeded check plots) was treated with pendimethalin (Prowl® H_2O) at 2.0 pt/acre (0.95 lb ai/acre) late pre-emergence on April 17, 2018. Postemergence applications of Buctril® at 12 fl oz/acre (bromoxynil at 0.188lb ai/acre) plus GoalTender® at 4 fl oz/acre (oxyfluorfen at 0.125 lb/ai acre) were made when onion seedlings were at the 2- and 4-leaf stages.

In order to achieve uniform herbicide distribution in the top soil layer, each Outlook herbicide rate was mixed into 35 gal of water and metered into the drip irrigation system at a continuous uniform rate of 5 gal/hour during the middle irrigation period. Applications were initiated when onion plants were at the 2-leaf stage and were made on May 15, 22, 29, and June 5, 2018. Fertilizer was applied through drip irrigation on May 31, June 14 and 29, and July 5 to supply 50 lb nitrogen (N)/acre per application. All other operations followed recommended local production practices.

Plant tops were flailed and onion bulbs lifted on September 11, 2018. Bulbs were hand-harvested from the two center beds on September 12, 2018. Bulbs were graded for yield and quality based on USDA standards as follows: bulbs without blemishes (U.S. No. 1), split bulbs (No. 2), bulbs infected with the fungus *Botrytis allii* in the neck or side, bulbs infected with the fungus *Fusarium oxysporum* (plate rot), bulbs infected with the fungus *Aspergillus niger* (black mold), and bulbs infected with unidentified bacteria in the external scales. The U.S. No. 1 bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield consisted of U.S. No.1 bulbs greater than 2¼ inches in diameter.

Data were subjected to analysis of variance and the treatment means were compared using protected LSD at the 0.05% level of confidence.

Results

Onion emergence was observed on April 18, 2018. Data analysis indicated variability attributed to varietal differences or herbicide treatments without any interactions between variety and herbicide rates. Therefore, the data presented here illustrate variety and herbicide effects on plant stand and the number of harvested bulbs in each category (Table 1) and bulb yield (Table 2).

Evaluations on June 7 (49 days after onion emergence) indicated no variations in plant stand attributed to variety or herbicide treatments (Table 1). Plant stand ranged from 87,413 to 120,707 plants/acre across onion varieties. The number of harvested bulbs for different categories is presented in Table 1. Variations in the number of small bulbs were attributed to varieties and herbicide rates and the interaction of herbicide by varieties. Variations in the number of harvested medium (2¼-3 in) and colossal (4-4¼ in) bulbs were individually affected by varieties and herbicide rates without any interaction of the two. Varieties and herbicide rates interacted to affect the number of harvested supercolossal (>4¼ in) bulbs. However, there were no differences attributed to varieties or herbicide rates when bulbs were grouped into marketable category (2¼ - >4¼ in).

Onion yield for various bulb categories is presented in Table 2. The yield for bulbs with neck rot was related to varieties and herbicide rates. Yield for No. 2s, small, medium, and jumbo was similar across varieties and herbicide rates (Table 2). Yield variations in the colossal bulb category was attributed to varieties only. Varieties and herbicide rates interacted to affect the supercolossal yield. Overall, variations in marketable bulb yield (2¼ - >4¼ in) were primarily attributed to varietal differences.

The results demonstrated that red and white onion varieties were not adversely affected by the application of Outlook through drip irrigation. The results were largely similar to the response of yellow bulb onions.

These results will be used to solicit changes to the current Outlook SLN labels to include red- and white-colored varieties. The outcome will depend on the feedback from the registrant as well as the Oregon Department of Agriculture and Idaho State Department of Agriculture. This use is needed in order to improve yellow nutsedge control in onions.

The current SLN label allowing the application of Outlook through drip irrigation applies only to yellow varieties, and will remain so until it is changed to include red and white onion types.

Growers are advised to be extra careful as they adopt this application technique because of the potential for onion injury if one is not precise in determining the area being treated and/or measuring the product. It is critical that Outlook herbicide be mixed into water and the solution metered into the drip irrigation system for 8 to 10 hours.

Acknowledgements

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Table 1. Onion plant stand (June 7) and the number of harvested bulbs for three red and three white onion cultivars in response to various Outlook®[a] (dimethenamid-p) herbicide rates applied through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

					Unmarketable[b]			Marketable number by grade[b]				
Variety	Bulb color	Treatment	Timing	Plant stand	Neck rot	No.2s	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		fl oz/acre			No. of bulbs/acre							
Red Beret	Red			99,293	293	293	5,573	12,467	52,947	2,200	0	67,613
Outlook		11	2 leaves (A)									
Outlook		10	14 d after A									
SV4643NT	Red			114,107	733	1,907	5,720	12,613	53,680	6,013	440	72,747
Outlook		11	2 leaves (A)									
Outlook		10	14 d after A									
Red Wing	Red			116,600	440	587	10,560	19,653	32,636	14,822	1,314	68,426
Outlook		11	2 leaves (A)									
Outlook		10	14 d after A									
Antarctica	White			107,067	733	587	1,760	2,933	42,680	24,347	6,013	75,973
Outlook		11	2 leaves (A)									
Outlook		10	14 d after A									
White Cloud	White			111,027	5,573	2,347	2,443	6,615	37,315	24,083	10,120	78,132
Outlook		11	2 leaves (A)									
Outlook		10	14 d after A									
SV4058NU	White			118,800	2,347	293	2,053	2,493	47,373	27,133	6,893	83,893
Outlook		11	2 leaves (A)									
Outlook		10	14 d after A									

[a] Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b] The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

Table 1. **(Continued)** Onion plant stand (June 7) and the number of harvested bulbs for three red and three white onion cultivars in response to various Outlook[a] (dimethenamid-p) herbicide rates applied through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

					Unmarketable[b]			Marketable number by grade[b]				
Variety	Bulb	Treatment	Timing	Plant stand	Neck rot	U.S No.2	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		fl oz/acre			------------------ No. of bulbs/acre ------------------							
Red Beret	Red			102,373	733	293	6,453	14,373	50,893	3,080	147	68,493
Outlook		7	2 leaves (A)									
Outlook		7	7 D after A									
Outlook		7	14 D after A									
SV4643NT	Red			99,293	0	2,640	3,227	8,800	49,427	8,067	1,320	67,613
Outlook		7	2 leaves (A)									
Outlook		7	7 D after A									
Outlook		7	14 D after A									
Red Wing	Red			116,893	293	440	8,360	18,627	53,973	1,027	147	73,773
Outlook		7	2 leaves (A)									
Outlook		7	7 D after A									
Outlook		7	14 D after A									
Antarctica	White			108,973	587	440	1,907	3,960	48,107	23,613	3,227	78,907
Outlook		7	2 leaves (A)									
Outlook		7	7 D after A									
Outlook		7	14 D after A									
White Cloud	White			119,240	4,400	2,493	3,080	5,133	43,560	22,587	7,920	79,200
Outlook		7	2 leaves (A)									
Outlook		7	7 D after A									
Outlook		7	14 D after A									
SV4058NU	White			118,213	2,053	440	2,200	4,840	51,040	21,413	6,160	83,453
Outlook		7	2 leaves (A)									
Outlook		7	7 D after A									
Outlook		7	14 D after A									

[a] Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b] The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

Table 1. **(Continued)** Onion plant stand (June 7) and the number of harvested bulbs for three red and three white onion cultivars in response to various Outlook[a] (dimethenamid-p) herbicide rates applied through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

					Unmarketable[b]			Marketable number by grade[b]				
Variety	Bulb	Treatment	Timing	Plant stand	Neck rot	No.2	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		fl oz/acre			No. of bulbs/acre							
Red Beret	Red			87,413	587	440	3,813	11,000	44,293	4,107	440	59,840
Outlook		6	2 leaves (A)									
Outlook		5	7 D after A									
Outlook		5	14 D after A									
Outlook		5	21 D after A									
SV4643NT	Red			101,787	733	2,200	1,907	8,507	42,387	6,893	2,200	59,987
Outlook		6	2 leaves (A)									
Outlook		5	7 D after A									
Outlook		5	14 D after A									
Outlook		5	21 D after A									
Red Wing	Red			111,760	147	440	4,107	13,053	60,133	3,813	293	77,293
Outlook		6	2 leaves (A)									
Outlook		5	7 D after A									
Outlook		5	14 D after A									
Outlook		5	21 D after A									
Antarctica	White			100,760	733	1,320	1,760	3,227	35,053	26,400	8,507	73,187
Outlook		6	2 leaves (A)									
Outlook		5	7 D after A									
Outlook		5	14 D after A									
Outlook		5	21 D after A									
White Cloud	White			120,413	3,813	1,760	2,933	4,400	42,973	23,760	10,853	81,987
Outlook		6	2 leaves (A)									
Outlook		5	7 D after A									
Outlook		5	14 D after A									
Outlook		5	21 D after A									
SV4058NU	White			120,707	2,053	1,467	3,667	4,547	46,493	23,320	6,453	80,813
Outlook		6	2 leaves (A)									
Outlook		5	7 D after A									
Outlook		5	14 D after A									
Outlook		5	21 D after A									

Table 1. **(Continued)** Onion plant stand (June 7) and the number of harvested bulbs for three red and three white onion cultivars in response to various Outlook[a] (dimethenamid-p) herbicide rates applied through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

					Unmarketable[b]			Marketable number by grade[b]				
Variety	Bulb	Treatment	Timing	Plant stand	Neck rot	U.S No.2	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		fl oz/acre			---------- No of bulbs/acre ----------							
Red Beret	Red			107,360	293	147	11,440	17,307	46,933	2,347	293	66,880
Outlook		21	2 leaves (A)									
Outlook		21	14 D after A									
SV4643NT	Red			108,827	147	1,760	6,747	22,293	40,773	4,400	880	68,347
Outlook		21	2 leaves (A)									
Outlook		21	14 D after A									
Red Wing	Red			107,800	0	880	8,213	22,000	45,320	1,760	147	69,227
Outlook		21	2 leaves (A)									
Outlook		21	14 D after A									
Antarctica	White			98,853	587	587	3,520	4,107	37,107	19,947	7,920	69,080
Outlook		21	2 leaves (A)									
Outlook		21	14 D after A									
White Cloud	White			111,467	2,640	1,760	4,693	7,040	37,987	22,293	8,947	76,267
Outlook		21	2 leaves (A)									
Outlook		21	14 D after A									
SV4058NU	White			118,653	2,053	733	4,400	4,987	44,880	23,320	7,333	80,520
Outlook		21	2 leaves (A)									
Outlook		21	14 D after A									

[a] Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b] The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

Table 1. **(Continued)** Onion plant stand (June 7) and the number of harvested bulbs for three red and three white onion cultivars in response to various Outlook[a] (dimethenamid-p) herbicide rates applied through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

					Unmarketable[b]			Marketable number by grade[b]				
Variety	Bulb	Treatment	Timing	Plant	Neck Rot	No.2s	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		fl oz/acre			---------- No. of bulbs/acre ----------							
Red Beret	Red			99,147	880	1,907	3,960	11,880	53,973	6,307	440	72,600
Outlook		21	2 lf-Broadcast									
SV4643NT	Red			104,133	587	3,080	3,960	10,120	46,053	9,680	2,640	68,493
Outlook		21	2 lf-Broadcast									
Red Wing	Red			117,773	0	1,173	3,227	11,000	61,013	6,747	0	78,760
Outlook		21	2 lf-Broadcast									
Antarctica	White			101,347	1,613	1,320	1,907	2,787	28,453	26,400	12,613	70,253
Outlook		21	2 lf-Broadcast									
White Cloud	White			105,307	3,080	2,053	1,320	2,640	24,200	24,933	20,973	72,747
Outlook		21	2 lf-Broadcast									
SV4058NU	White			120,560	2,933	880	2,787	6,160	40,627	27,280	13,053	87,120
Outlook		21	2 lf-Broadcast									
Red Beret	Red			105,453	440	587	4,253	15,107	56,467	3,960	293	75,827
Handweeded												
SV4643NT	Red			115,720	587	1,760	4,253	10,707	56,907	6,893	147	74,653
Handweeded												
Red Wing	Red			109,560	587	440	2,933	15,253	55,440	5,133	293	76,120
Handweeded												
Antarctica	White			100,613	880	1,027	1,027	2,053	32,413	24,493	12,613	71,573
Handweeded												
White Cloud	White			118,213	2,787	1,907	2,493	2,053	37,400	30,507	12,907	82,867
Handweeded												
SV4058NU	White			120,707	1,907	293	1,467	2,933	46,200	28,160	9,387	86,680
Handweeded												
Variety LSD (0.05)				NS	NS	1,258	2,435	7,898	NS	8,879	2,784	NS
Treatment (0.05)				NS	NS	NS	850	2,706	NS	5,750	2,899	NS
Variety x Treatment (0.05)				NS	NS	NS	2,981	NS	NS	NS	4,515	NS

[a]Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b]The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

Table 2. Onion yield for three red and three white onion cultivars in response to various Outlook®[a] (dimethenamid-p) herbicide rates applied through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

				Unmarketable[b]			Marketable yield by grade[b]				
Variety	Bulb color	Treatment	Timing	Neck rot	No.2s	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		fl oz/acre		--			cwt/acre --				
Red Beret	Red			75.2	3.9	18.0	65.8	526.4	33.9	0.0	626.1
Outlook		11	2 leaves (A)								
Outlook		10	14 d after A								
SV4643NT	Red			77.1	22.1	15.5	66.9	552.1	100.3	9.4	728.6
Outlook		11	2 leaves (A)								
Outlook		10	14 d after A								
Red Wing	Red			142.4	6.2	32.2	106.8	550.7	18.1	0.0	675.6
Outlook		11	2 leaves (A)								
Outlook		10	14 d after A								
Antarctica	White			23.7	8.2	3.9	14.9	522.0	429.1	136.6	1,102.5
Outlook		11	2 leaves (A)								
Outlook		10	14 d after A								
White Cloud	White			33.0	36.8	28.1	237.5	382.9	307.8	245.5	1,173.6
Outlook		11	2 leaves (A)								
Outlook		10	14 d after A								
SV4058NU	White			27.7	3.6	5.7	12.0	565.8	478.1	154.5	1,210.3
Outlook		11	2 leaves (A)								
Outlook		10	14 d after A								

[a] Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b] The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

Table 2. **(Continued)** Onion yield for three red and three white onion cultivars in response to various Outlook[a] (dimethenamid-p) herbicide rates applied through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

				Unmarketable[b]			Marketable yield by grade[b]				
Variety	Bulb color	Treatment	Timing	Neck rot	No.2s	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		fl oz/acre		---			cwt/acre	---			
Red Beret	Red			87.0	3.5	19.7	71.7	504.7	51.1	3.5	631.0
Outlook		7	2 leaves (A)								
Outlook		7	7 D after A								
Outlook		7	14 D after A								
SV4643NT	Red			43.5	31.7	7.7	44.9	504.9	142.9	30.7	723.4
Outlook		7	2 leaves (A)								
Outlook		7	7 D after A								
Outlook		7	14 D after A								
Red Wing	Red			112.8	4.8	22.4	94.7	534.0	16.3	2.4	647.4
Outlook		7	2 leaves (A)								
Outlook		7	7 D after A								
Outlook		7	14 D after A								
Antarctica	White			25.7	5.1	5.9	18.2	575.9	408.3	72.2	1,074.6
Outlook		7	2 leaves (A)								
Outlook		7	7 D after A								
Outlook		7	14 D after A								
White Cloud	White			41.5	30.7	8.9	26.8	516.8	411.1	191.0	1,145.8
Outlook		7	2 leaves (A)								
Outlook		7	7 D after A								
Outlook		7	14 D after A								
SV4058NU	White			29.7	7.0	6.5	24.8	588.8	366.0	142.3	1,121.9
Outlook		7	2 leaves (A)								
Outlook		7	7 D after A								
Outlook		7	14 D after A								

[a] Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b] The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

Table 2. **(Continued)** Onion yield for three red and three white onion cultivars in response to various Outlook[a] (dimethenamid-p) herbicide rates applied through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

				Unmarketable[b]			Marketable yield by grade[b]				
Variety	Bulb color	Treatment	Timing	Neck rot	No.2s	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		fl oz/acre		------------------------------ cwt/acre ------------------------------							
Red Beret	Red			51.4	7.9	10.9	57.1	448.4	67.5	9.9	582.9
Outlook		6	2 leaves (A)								
Outlook		5	7 D after A								
Outlook		5	14 D after A								
Outlook		5	21 D after A								
SV4643NT	Red			25.7	39.5	5.0	44.7	467.8	123.9	51.9	688.3
Outlook		6	2 leaves (A)								
Outlook		5	7 D after A								
Outlook		5	14 D after A								
Outlook		5	21 D after A								
Red Wing	Red			55.4	6.4	11.2	71.0	619.7	60.8	5.2	756.7
Outlook		6	2 leaves (A)								
Outlook		5	7 D after A								
Outlook		5	14 D after A								
Outlook		5	21 D after A								
Antarctica	White			23.7	24.3	4.7	16.0	425.1	465.0	200.3	1,106.4
Outlook		6	2 leaves (A)								
Outlook		5	7 D after A								
Outlook		5	14 D after A								
Outlook		5	21 D after A								
White Cloud	White			39.6	21.8	8.2	21.9	514.1	434.4	266.1	1,236.4
Outlook		6	2 leaves (A)								
Outlook		5	7 D after A								
Outlook		5	14 D after A								
Outlook		5	21 D after A								
SV4058NU	White			49.5	19.2	9.2	23.7	562.4	406.5	148.3	1,140.9
Outlook		6	2 leaves (A)								
Outlook		5	7 D after A								
Outlook		5	14 D after A								
Outlook		5	21 D after A								

[a] Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b] The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

Table 2. **(Continued)** Onion yield for three red and three white onion cultivars in response to various Outlook[a] (dimethenamid-p) herbicide rates applied through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

				Unmarketable[b]			Marketable yield by grade[b]				
Variety	Bulb color	Treatment	Timing	Neck rot	U.S No.2	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		fl oz/acre		-- cwt/acre	--						
Red Beret	Red			154.3	2.1	32.2	89.6	458.7	37.7	5.9	592.0
Outlook		21	2 leaves (A)								
Outlook		21	14 D after A								
SV4643NT	Red			91.0	24.5	18.6	89.3	472.4	76.0	19.9	657.6
Outlook		21	2 leaves (A)								
Outlook		21	14 D after A								
Red Wing	Red			110.8	13.1	25.4	106.4	433.7	28.1	3.4	571.5
Outlook		21	2 leaves (A)								
Outlook		21	14 D after A								
Antarctica	White			47.5	9.5	8.8	20.5	431.2	360.9	184.5	997.2
Outlook		21	2 leaves (A)								
Outlook		21	14 D after A								
White Cloud	White			63.3	29.2	13.2	35.0	462.2	409.3	226.4	1,132.8
Outlook		21	2 leaves (A)								
Outlook		21	14 D after A								
SV4058NU	White			59.3	7.6	13.0	24.2	525.0	405.2	171.9	1,126.2
Outlook		21	2 leaves (A)								
Outlook		21	14 D after A								

[a] Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b] The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

Table 2. **(Continued)** Onion yield for three red and three white onion cultivars in response to various Outlook[a] (dimethenamid-p) herbicide rates applied through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

				Unmarketable[b]			Marketable yield by grade[b]				
Variety	Bulb color	Treatment	Timing	Neck Rot	No.2s	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		fl oz/acre		----	----	----	cwt/acre	----	----	----	----
Red Beret Outlook	Red	21	2 lf-Broadcast	53.4	31.0	11.9	61.6	534.2	102.5	8.7	706.9
SV4643NT Outlook	Red	21	2 lf-Broadcast	53.4	52.8	10.5	51.6	492.3	168.9	62.7	775.6
Red Wing Outlook	Red	21	2 lf-Broadcast	43.5	16.6	14.6	57.2	637.1	109.2	0.0	803.5
Antarctica Outlook	White	21	2 lf-Broadcast	25.7	22.2	4.6	12.5	354.4	477.7	300.4	1,145.1
White Cloud Outlook	White	21	2 lf-Broadcast	17.8	33.9	3.7	13.3	306.2	462.3	529.7	1,311.6
SV4058NU Outlook	White	21	2 lf-Broadcast	37.6	8.9	7.3	29.2	469.9	485.8	315.4	1,300.3
Red Beret Handweeded	Red			57.4	8.6	12.7	80.9	559.9	67.7	6.4	714.8
SV4643NT Handweeded	Red			57.4	25.2	12.7	53.3	602.0	117.0	3.6	775.9
Red Wing Handweeded	Red			39.6	7.0	8.8	81.7	524.9	85.3	6.2	698.0
Antarctica Handweeded	White			13.8	22.5	1.8	10.7	400.0	440.5	296.7	1,147.8
White Cloud Handweeded	White			33.6	31.9	7.0	11.1	472.0	547.9	313.8	1,344.8
SV4058NU Handweeded	White			19.8	6.0	4.9	13.3	573.7	498.9	219.7	1,305.6
Variety LSD (0.05)				32.8	NS	NS	NS	NS	139.1	71.4	192.7
Treatment (0.05)				11.5	NS	4.1	NS	NS	NS	76.9	34.6
Variety x Treatment (0.05)				40.2	NS	NS	NS	NS	NS	107.2	NS

[a] Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b] The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

ONION YIELD AND SINGLE CENTERS IN RESPONSE TO APPLICATION OF OUTLOOK® THROUGH DRIP IRRIGATION WITH OR WITHOUT FERTILIZER

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018

Introduction

Approval for the application of dimethenamid-p (Outlook®) through drip irrigation to control yellow nutsedge in dry bulb onions grown in the Treasure Valley of eastern Oregon and southwestern Idaho was granted in 2016. In Oregon, the Section 24C Special Local Need (SLN) No. OR-160004 allows applications of Outlook through drip irrigation for onion growers in Malheur County only. In Idaho, SLN No. ID-160001 restricts the use to Ada, Canyon, Gem, Owyhee, Payette, and Washington counties. Both labels reference the chemigation section of the federal label regarding restrictions and directions on how to properly chemigate Outlook in onion production. The user is required to have both the entire Outlook container label and the SLN label in their possession at the time of application.

The research conducted at the Oregon State University's Malheur Experiment Station near Ontario, Oregon indicated improved yellow nutsedge control with Outlook applied through drip irrigation compared to broadcast spraying. The labels still limit the maximum use rate to 21 fl oz/acre/season (0.98 lb ai/acre/season). Sequential applications totaling 21 fl oz/acre/season are allowed. Applications through drip irrigation are allowed starting when onions are at the 2-leaf but not after the 6-leaf stage. The current registration restricts the applications through drip irrigation only to Spanish yellow onions and does not allow mixtures with fertilizer or any other pesticide.

The objective of this study was to evaluate the response of direct-seeded onions to a mixture of Outlook herbicide with liquid fertilizer applied through drip irrigation. The study used onion variety 'Vaquero' and URAN fertilizer.

Materials and Methods

A field study was conducted at the Malheur Experiment Station, Ontario, Oregon in 2018 to evaluate the response of onion variety 'Vaquero' to Outlook herbicide applied through drip irrigation with or without nitrogen (N) fertilizer. Onion seed of variety 'Vaquero' was planted on March 28 in double rows spaced 3 inches apart with 4.75-inch seed spacing within each row. Each double row was planted on beds spaced 22 inches apart. Immediately after planting, onion beds received a 7-inch band of Lorsban® 15G at 3.7 oz/1000 ft of row (0.125 lb ai/acre) and the soil surface was rolled. The soil was an Owyhee silt loam with a pH 7.2 and 1.8% organic matter. Application of herbicide/fertilizer solution was initiated when onion seedlings were at the 2-leaf stage on May 16.

The study had randomized complete blocks with four replicates. Individual plots were 7.33 ft wide (4 beds) by 42 ft long. The study area (except the hand-weeded check plots) was treated with pendimethalin (Prowl® H_2O) at 2.0 pt/acre (0.95 lb ai/acre) late pre-emergence on April 19. Postemergence application of Buctril® at 12 fl oz/acre (bromoxynil at 0.188 lb ai/acre) plus GoalTender® at 4 fl oz/acre (oxyfluorfen at 0.125 lb/ai acre) occurred when onion seedlings were at the 2- and 4-leaf stages. The study was sprayed with Poast® herbicide at 1.5 pt/acre (sethoxydim at 0.287 lb ai/acre) to control grassy weeds.

In order to achieve uniform herbicide distribution in the top soil layer, each Outlook herbicide rate and URAN fertilizer to supply 20 lb N/acre was mixed into 35 gal of water and metered into the drip irrigation system at a continuous uniform rate of 5 gal/hour during the middle of the irrigation period. Applications were initiated when onion plants were at the 2-leaf stage on May 16. Sequential applications on a weekly or biweekly schedule continued through June 5 (Tables 1 and 2).

Treatments with Outlook plus URAN fertilizer to supply 20 lb N/acre were applied on May 16, 22, 29, and June 5, 2018. Treatments receiving only Outlook solution were fertilized using URAN solution to supply 20 lb N/acre the day after the Outlook plus fertilizer treatments. Additional fertilizer to supply 50 lb N/acre was applied through drip irrigation on June 14, 29, and July 5, and 10, 2018. All other operations including insect control followed recommended local production practices.

Single Center Assessment

After harvest, 25 bulbs from the center two rows in each plot were rated for single centers following the methods as described by Shock et al. 2005. Twenty-five consecutive onions ranging in diameter from 3½ to 4¼ inches were rated. The onions were cut equatorially through the bulb middle and separated into single-centered (bullet) and multiple-centered bulbs. The multiple-centered bulbs had the long axis of the inside diameter of the first single ring measured. These multiple-centered onions were ranked according to the inside diameter of the first entire single ring: small had diameters less than 1½ inches, medium had diameters from 1½ to 2¼ inches, and large had diameters greater than 2¼ inches. Onion bulbs were considered "functionally single centered" for processing if they were single centered (bullet) or had a small multiple center (<1½ inches).

Plant tops were flailed and onion bulbs were lifted on September 11 and bulbs were hand-harvested from the two center beds on September 12. Bulbs were graded for yield and quality on September 22 based on USDA standards as follows: bulbs without blemishes (U.S. No. 1), split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, bulbs infected with the fungus *Fusarium oxysporum* (plate rot), bulbs infected with the fungus *Aspergillus niger* (black mold), and bulbs infected with unidentified bacteria in the external scales (classified as neck rot). The U.S. No. 1 bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield consisted of U.S. No.1 bulbs greater than 2¼ inches.

Data were subjected to analysis of variance and the treatment means were compared using protected LSD at the 0.05% level of confidence.

Results

Onion emergence was observed on April 18, 2018. Evaluations on June 8 (3 days after the last application of Outlook through drip irrigation) indicated plant population ranging from 106,856 to 109,339 plants/acre for sequential applications of up to 7 fl oz/acre, which was similar to 105,088 plants/acre for the grower standard and 106,715 plants/acre for the hand-weeded treatment (Table 1).

The number of marketable onion bulbs reflected onion plant stand (Table 1). The number of small bulbs was variable across treatments ranging from 1,484 to 3,264 bulbs/acre. The number of No. 2s and bulbs with neck rot was similar across treatments.

The highest marketable yield was obtained when Outlook was sequentially chemigated at 7 fl oz/acre with fertilizer (1,313 cwt/acre) or without fertilizer (1,391 cwt/acre) (Table 2). That marketable yield was comparable to the grower standard (1,388 cwt/acre) and hand-weeded control (1,447 cwt/acre). Marketable yield for the small bulb category was variable across treatments and ranged from 2.5 to 7.2 cwt/acre. There were no yield differences among treatments for the number No. 2s and neck rot bulb categories.

Sequential application of Outlook at 21 fl oz/acre on a biweekly schedule produced the lowest marketable yield regardless of whether Outlook was applied alone (1,218 cwt/acre) or mixed with fertilizer (1,238 cwt/acre) compared to 1,447 cwt/acre for the hand-weeded check.

Onion single center results are presented in Table 3. The percentage of functionally single-centered onion bulbs was highly variable across treatments. The percentage of functionally single bulbs was similar for the hand-weeded treatment, grower standard, and weekly sequential application of Outlook at 7, or 6 fl oz/acre followed by 5, 5, 5 fl oz/acre.

These results indicated no adverse effects when Outlook at 7 fl oz/acre was applied through the irrigation drip with or without URAN fertilizer solution to onion variety ‘Vaquero’ starting at the 2-leaf stage. It is not clear why the marketable yield was reduced when the weekly sequential application of Outlook at 6, 5, 5, 5 fl oz/acre was used with or without fertilizer. The study will be repeated in 2019 to confirm these results.

Acknowledgements

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References

Shock, C.C, E. Feibert, and L.D. Saunders. 2005. Single-centered and supercolossal bulbs from yellow onion cultivars. HortTechnology 15:399-408.

Table 1. Onion plant stand on June 8 and number of harvested bulbs in response to various Outlook® (dimethenamid-p) herbicide treatments applied with or without liquid fertilizer through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2018.

					Marketable bulb number by grade[c]					Unmarketable[c]		
	With	Rate[a]	Timing[b]	Plant stand	Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	<2¼ in	No. 2	Neck rot
Treatment	fertilizer	fl oz/acre		No./acre	----	---- Number of bulbs/acre ----						----
Outlook	Yes	7	A = 2 leaf	109,402 a	105,339 a	22,848 bcd	40,059 a	37,536 abc	4,896 a	3,264 a	890	890
Outlook	Yes	7	14 days after A									
Outlook	Yes	7	21 days after A									
Outlook	No	7	A = 2 leaf	106,856 a	104,152 ab	27,744 abc	41,542 a	31,157 bc	3,709 abc	1,187 c	593	593
Outlook	No	7	7 days after A									
Outlook	No	7	14 D after A									
Outlook	Yes	6	A = 2 leaf	105,937 a	96,882 ab	24,332 bcd	34,569 ab	35,311 abc	2,671 bc	1,632 bc	890	593
Outlook	Yes	5	7 days after A									
Outlook	Yes	5	14 days after A									
Outlook	Yes	5	21 days after A									
Outlook	No	6	A = 2 leaf	108,766 a	103,114 ab	19,436 cd	37,981 ab	40,949 ab	4,748 ab	3,264 a	1929	445
Outlook	No	5	7 days after A									
Outlook	No	5	14 days after A									
Outlook	No	5	21 days after A									
Outlook	Yes	21	A = 2 leaf	97,097 b	95,696 b	25,816 bcd	32,047 b	33,234 abc	4,599 ab	1,632 bc	1039	742
Outlook	Yes	21	14 days after A									
Outlook	No	21	A = 2 leaf	106,786 a	100,592 ab	16,320 d	37,833 ab	42,581 a	3,857 abc	2,522 ab	1484	1335
Outlook	No	21	14 days after A									
Outlook-Grower standard		21	A = 2 leaf-broadcast	105,088 ab	101,630 ab	31,750 ab	39,168 ab	27,299 c	3,412 abc	1,484 bc	890	445
Hand-weeded check				106,715 a	102,520 ab	37,833 a	35,014 ab	27,448 c	2,225 c	1,632 bc	890	890
LSD (*P* = 0.05)				8,048	8,963	11,035	7147	10,963	2,216	1,159	NS	NS

[a] Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b] Herbicide application timing; A = onions at 2-leaf stage (May 16, 2018); 7 days after A (May 22, 2018); 14 days after A (May 29, 2018); 21 days after A (Jun 5, 2018).

[c] The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

Table 2. Onion yield in response of various Outlook® (dimethenamid-p) herbicide treatments applied with and without liquid fertilizer through drip irrigation at the Malheur Experiment Station, Ontario, OR, 2017.

				Marketable yield by grade[c]					Unmarketable[c]		
	With	Rate[a]	Timing[b]	Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	<2¼ in	No. 2	Neck rot
Treatment	fertilizer	fl oz/acre		cwt/acre							
Outlook	Yes	7	A = 2 leaf	1,313.3 abc	393.2 bcd	553.8 a	349.9 ab	16.4 ab	7.2 a	4.2	2.6
Outlook	Yes	7	14 days after A								
Outlook	Yes	7	21 days after A								
Outlook	No	7	A = 2 leaf	1,391.3 ab	510.3 abc	569.3 a	297.9 ab	13.8 ab	2.5 c	2.3	2.3
Outlook	No	7	7 days after A								
Outlook	No	7	14 D after A								
Outlook	Yes	6	A = 2 leaf	1,273.9 bc	456.2 bcd	475.4 ab	332.2 ab	10.0 ab	4.3 abc	5.3	2.8
Outlook	Yes	5	7 days after A								
Outlook	Yes	5	14 days after A								
Outlook	Yes	5	21 days after A								
Outlook	No	6	A = 2 leaf	1,266.9 bc	352.8 cd	525.6 ab	370.1 a	18.5 a	6.9 ab	11.5	4.0
Outlook	No	5	7 days after A								
Outlook	No	5	14 days after A								
Outlook	No	5	21 days after A								
Outlook	Yes	21	A = 2 leaf	1,237.7 c	478.3 bcd	439.5 b	303.2 ab	16.7 ab	4.4 abc	6.6	2.5
Outlook	Yes	21	14 days after A								
Outlook	No	21	A = 2 leaf	1,217.9 c	298.1 d	523.9 ab	380.2 a	15.7 ab	6.4 ab	12.2	6.3
Outlook	No	21	14 days after A								
Outlook-Grower standard		21	A = 2 leaf-broadcast	1,388.4 ab	581.9 ab	538.3 a	257.2 b	10.9 ab	3.6 bc	5.6	1.9
Hand-weeded check				1,447.2 a	698.1 a	486.8 ab	254.0 b	8.4 b	3.7 bc	8.7	4.4
LSD (*P* = 0.05)				147.2	207.1	98.7	103.6	9.5	3.4	NS	NS

[a] Herbicide rate; Outlook (dimethenamid-p) 5 fl oz/acre = 0.234 lb ai/acre; 6 fl oz/acre = 0.28 lb ai/acre; 7 fl oz/acre = 0.328 lb ai/acre; 21 fl oz/acre = 0.98lb ai/acre.

[b] Herbicide application timing; A = onions at 2-leaf stage (May 16, 2018); 7 days after A (May 22, 2018); 14 days after A (May 29, 2018); 21 days after A (Jun 5, 2018).

[c] The bulbs were graded according to diameter: small (<2¼ inches), medium (2¼-3 inches), jumbo (3-4 inches), colossal (4-4¼ inches), and supercolossal (>4¼ inches). Marketable yield is composed of medium, jumbo, colossal, and supercolossal grades. Unmarketable bulbs are split bulbs (No. 2s), bulbs infected with the fungus *Botrytis allii* in the neck or side, or bulbs infected with the fungus *Fusarium oxysporum* (plate rot).

Table 3. Onion bulb single centers in response to application of Outlook® (dimethenamid-p) through drip irrigation with or without fertilizer at the Malheur Experiment Station, Ontario, OR 2018.

				Multiple center[b]			Single center[b]	
				Large	Medium	Small		
Treatment	With fertilizer	Rate	Application timing[a]	>2.25"	1.5 - 2.25"	<1.5”	Bullet	Functionally[c] single
		fl oz/acre		--	--	%	--	--
Outlook	Yes	7	A-2 Leaf	20 ab	24 ab	7 a	50 abc	57 bc
Outlook	Yes	7	14 days after A					
Outlook	Yes	7	21 days after A					
Outlook	No	7	A-2 Leaf	17 ab	18 ab	6 a	60 ab	66 ab
Outlook	No	7	7 days after A					
Outlook	No	7	14 days after A					
Outlook	Yes	6	A-2 Leaf	13 ab	26 a	8 a	54 abc	62 abc
Outlook	Yes	5	7 days after A					
Outlook	Yes	5	14 days after A					
Outlook	Yes	5	21 days after A					
Outlook	No	6	A-2 Leaf	9 b	21 ab	8 a	62 a	70 ab
Outlook	No	5	7 days after A					
Outlook	No	5	14 days after A					
Outlook	No	5	21 days after A					
Outlook	Yes	21	A-2 Leaf	23 a	27 a	8 a	42 c	50 c
Outlook	Yes	21	14 days after A					
Outlook	No	21	A-2 Leaf	12 ab	28 a	15 a	46 bc	61 bc
Outlook	No	21	14 days after A					
Outlook-Grower standard		21	A-2 Leaf-broadcast	13 ab	20 ab	13 a	58 ab	71 ab
Hand-weeded control				9 b	14 b	13 a	64 a	77 a
LSD (P = 0.05)				12	11	NS	15	16
Standard Deviation				8	7.4	6.3	9.9	10.7

[a] Herbicide application timing; A = onions at 2-leaf stage (May 16, 2018); 7 days after A (May 22, 2018); 14 days after A (May 29, 2018); 21 days after A (Jun 5, 2018).

[b] Means followed by same letter do not significantly differ (P = 0.05, LSD).

[c] Functionally single-centered bulbs are the small multiple-centered plus the bullet-centered onions.

EFFECTS OF DRIP APPLICATIONS OF FONTELIS® FUNGICIDE FOR PINK ROOT MANAGEMENT

Stuart Reitz, Ian Trenkel, Kyle Wieland, Clinton C. Shock, Erik B. G. Feibert, and Alicia Rivera, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018

Objective

Evaluate in-season applications of Fontelis® fungicide for the management of pink root in onions.

Introduction

Pink root caused by the soil-borne fungus *Setophoma terrestris* (= *Phoma terrestris*) is pervasive disease of onions in the Treasure Valley. Infected roots are less able to supply water and nutrients to the plant, which ultimately limits bulb size. The fungus survives in the soil and on roots and debris of onions and other susceptible crops for a number of years.

Currently, long crop rotations, fall fumigation with chloropicrin or metam sodium, and the use of more resistant onion varieties are the best options to suppress pink root. Crop rotations are limited by the ability of the fungus to survive for long periods of time and the long history of onion production in the Treasure Valley. Host plant resistance also tends to decline with high soil temperatures.

In-season fungicide applications may complement these other management tactics to reduce the impact of pink root on onions. In previous research at the Malheur Experiment Station and elsewhere, penthiopyrad (Fontelis®, DuPont) has performed better than some other soil applied fungicides for management of pink root. Fontelis can be applied through drip irrigation, which moves it through the root zone where the pathogen resides.

In this trial, we evaluated different numbers of Fontelis applications made through the growing season for their effect on pink root on three yellow onion cultivars.

Materials and Methods

This trial was conducted at the Malheur Experiment Station in a field that had not been in onion production for at least 6 years. The field was fumigated with Vapam® at 15 gal/acre and bedded at 22 inches in the fall of 2017.

Three onion varieties were selected for this trial (cv ‘Granero’, ‘Joaquin, and ‘Vaquero’) Onion seed of all varieties was planted at 143,000 seeds/acre on March 28, 2018.

The field was drip irrigated with drip tape laid at 4-inch depth between two onion beds during planting. The drip tape had emitters spaced 12 inches apart and an emitter flow rate of 0.22

gal/min/100 ft (T-Tape, Rivulis USA, San Diego, CA). The distance between the tape and the center of each double row of onions was 11 inches.

Onions were irrigated automatically to maintain the soil water tension (SWT) in the onion root zone below 20 cb. Soil water tension was measured with six granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Riverside, CA) installed at 8-inch depth in the center of the double row. Sensors had been calibrated to SWT. Irrigations were run by a controller programmed to irrigate twice a day applying 0.48 inch of water per irrigation. A Watermark Electronic Module (WEM, Irrometer Co.) was adjusted to override controller irrigations if the SWT was below 20 cb. Four Watermark sensors were connected to the WEM.

Fontelis Applications

Drip applications were made by injecting Fontelis solutions through the drip lines. Each application was made at 24 fl oz/acre. Fontelis was added to a 60-gal tank of water and the solution was injected with an Ozawa pump running at 10 gal/hour for 6 hours. Water alone was run for 1 hour before injection applications began and for 1 hour after injections ended to ensure that the Fontelis was pushed out to the outer rows of each plot.

The trial was laid out as a randomized complete block with four replications of each of four Fontelis treatments for each of the three varieties. The untreated control received no Fontelis treatments. Plots in treatment 1 received one application of Fontelis on May 28 when onions were at 2- to 3-leaf stage. Plots in treatment 2 received two applications of Fontelis, the first on May 28 and the second on June 12. Plots in treatment 3 received three applications of Fontelis, the first on May 28, the second on June 12 at the 5- to 6-leaf stage, and the third on June 27 at the 8- to 9-leaf stage (Table 1).

Table 1. Treatments and application dates to assess the effect of Fontelis® on pink root suppression in onions. Malheur Experiment Station, Ontario, OR, 2018.

Treatment	Fontelis application 1 (24 fl. oz/acre)	Fontelis application 2 (24 fl. oz/acre)	Fontelis application 3 (24 fl. oz/acre)
Untreated	---	---	---
Treatment 1 (Fontelis 1x)	May 28 (2-3 leaf) 61 DAP[a]	---	---
Treatment 2 (Fontelis 2x)	May 28 (2-3 leaf) 61 DAP	June 12 (5-6 leaf) 75 DAP	---
Treatment 3 (Fontelis 3x)	May 28 (2-3 leaf) 61 DAP	June 12 (5-6 leaf) 75 DAP	June 27 (8-9 leaf) 91 DAP

[a] DAP = days after planting

Data Collection

Assessments of plant condition were made on June 4, 7 days after the first application; July 10, 28 days after the second application date, and August 23, 72 days after the third application date. One each sample date, five bulbs were selected from each of the inner and outer double row of onions in each bed, for a total of 10 bulbs per plot on each sample date. Bulbs were taken to the laboratory for data collection.

The diameter of each bulb was measured with calipers. The number of total roots and roots displaying pink root symptoms were recorded.

On September 13, onions from the middle two double rows in each plot were lifted. They were topped by hand, bagged on September 18 and placed in storage. The onions from each plot were graded on November 5 and 6. During grading, bulbs were separated according to quality: bulbs without blemishes (No. 1s), split bulbs (No. 2s), neck rot (bulbs infected with the fungus *Botrytis allii* in the neck or side), plate rot (bulbs infected with the fungus *Fusarium oxysporum*), and black mold (bulbs infected with the fungus *Aspergillus niger*). The No. 1 bulbs were graded according to diameter: small, medium, jumbo, colossal, and supercolossal. Bulb counts per 50 lb of supercolossal onions were determined for each plot of every variety by weighing and counting all supercolossal bulbs during grading. Marketable yield consisted of No.1 bulbs in the medium or larger size classes (larger than 2¼ inches).

Results and Conclusions

Figure 1 shows the change in total numbers of roots and pink roots per plant in the untreated control for each of the three varieties in the trial. Early in the season on June 4, the three varieties had similar numbers of total roots and pink roots per bulb. All three varieties showed decreasing numbers of roots over the season, with Vaquero having the greatest decline in root mass. The number of pink roots increased over the season; yet again, the increase was greater for Vaquero than for Granero and Joaquin. This change in root system health likely confirms that Vaquero is more susceptible than Granero or Joaquin to pink root. Symptoms of pink root become more pronounced and evident as soil temperatures increase. Heavily infected roots die and then slough off, leading to declines in numbers of roots over the course of the season.

On the first sample date (June 4), 7 days after the first Fontelis application, onions in all of the Fontelis applications had significantly more total roots than did corresponding untreated onions. There were no further Fontelis treatment effects on root mass over the season. However, there were significant differences in root mass among the three varieties. Granero and Joaquin had more total roots than did Vaquero. Granero and Joaquin also had fewer pink roots than did Vaquero at the end of the season (July 10 and August 28 samples). Across all Fontelis treatments, Granero had the lowest decline in root mass than the other two varieties over the growing season (Fig. 2).

As a result of the varietal differences in total roots and pink roots, Vaquero had a significantly greater percentage of pink roots than did either Granero or Joaquin.
Fontelis did not appear to significantly affect total root mass or incidence of pink root. Total numbers of roots and numbers of pink roots were always higher for Vaquero than for Granero and Joaquin regardless of Fontelis treatment.

Fontelis applications tended to reduce the severity of pink root. The best results were with one or two Fontelis applications. Although based on a single year of data, there was evidence that three applications of Fontelis adversely affected onion growth and plant health. These adverse effects were consistent across varieties (Figs. 3-6).

Fontelis applications did not affect bulb size during the growing season. Granero had significantly larger bulbs on the August 22 sample date than either Joaquin or Vaquero across Fontelis treatments (Fig. 4).

Although Fontelis applications did not affect total marketable yield (Fig. 5), Fontelis did shift the size profiles for varieties, especially for Joaquin and Vaquero (Figs. 5 and 6). Approximately 55% of Granero bulbs in the untreated treatment were in the colossal and supercolossal size class. However, treatment with Fontelis increased the proportion of bulbs in these large size classes by 11%. These increases were 34% for Joaquin and 62% for Vaquero (Fig. 6).

Application of Fontelis early in the onion growth stage (i.e., 2- to 3-leaf stage) can complement other management tactics to reduce the severity of pink root. Application of Fontelis shifted the size profile toward larger onion bulbs. This effect may be especially beneficial for varieties that are more susceptible to pink root.

Acknowledgments

We appreciate the technical assistance of Kelsey Alexander, Brooke Bezona, Mary Phipps, Hannah Rose, and Allison Simmons. We appreciate the technical support of Nunhems Seed, DuPont, and Clearwater Supply. The project was supported by the Idaho-Eastern Onion Committee.

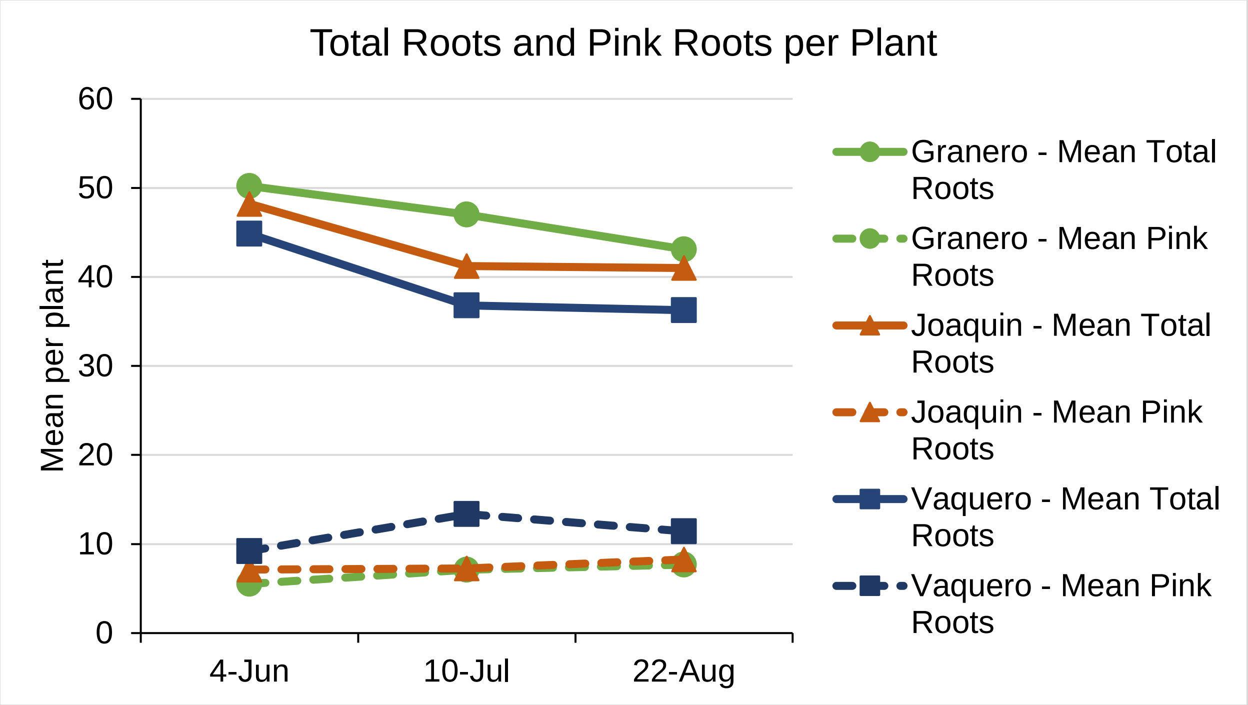

Figure 1. Changes in total roots and pink roots per plant over the season for onions not treated with Fontelis®. Over the course of the growing season, Vaquero had fewer total roots but more pink roots than Granero and Joaquin.

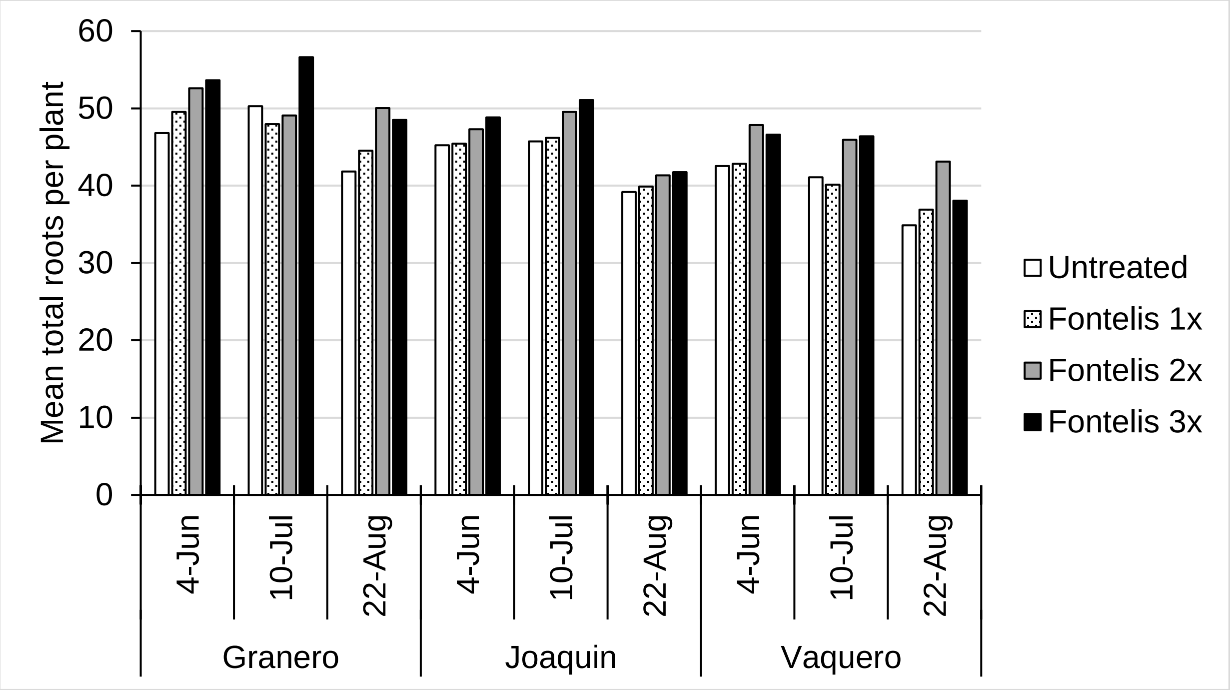

Figure 2. Total roots on three onion varieties treated with different numbers of Fontelis applications. Malheur Experiment Station, Ontario, OR, 2018.

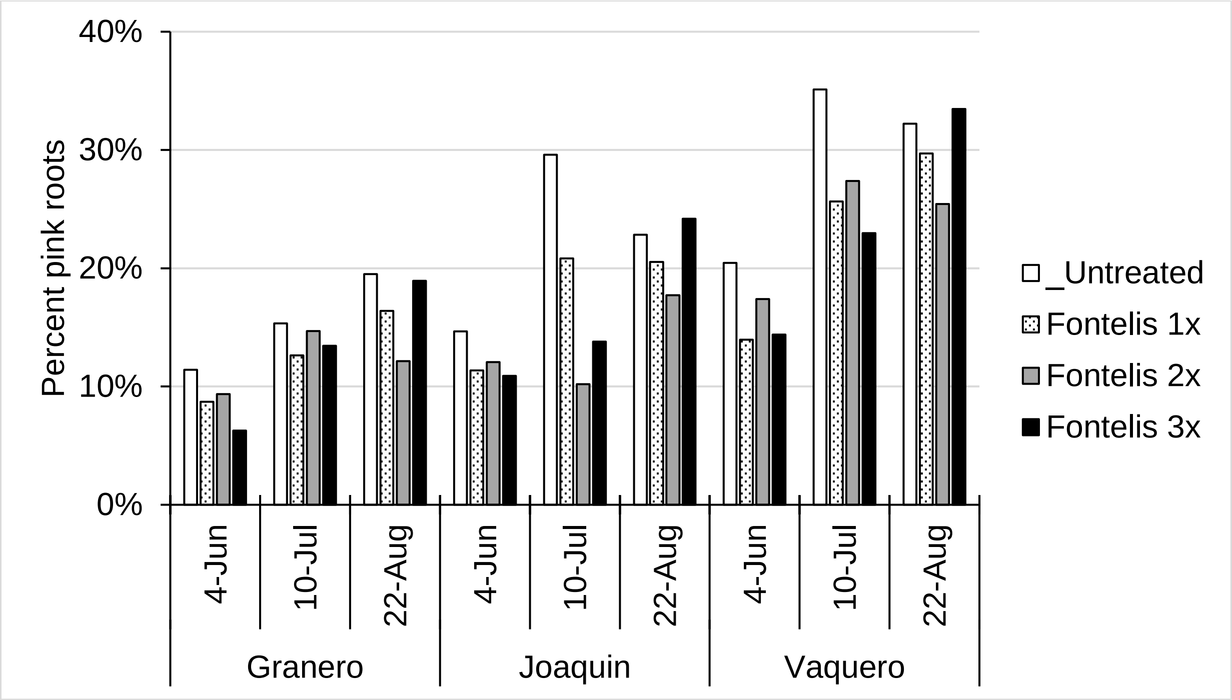

Figure 3. Percentage of roots on three onion varieties showing symptoms of pink root following different treatments with Fontelis® applications. Malheur Experiment Station, Ontario, OR, 2018.

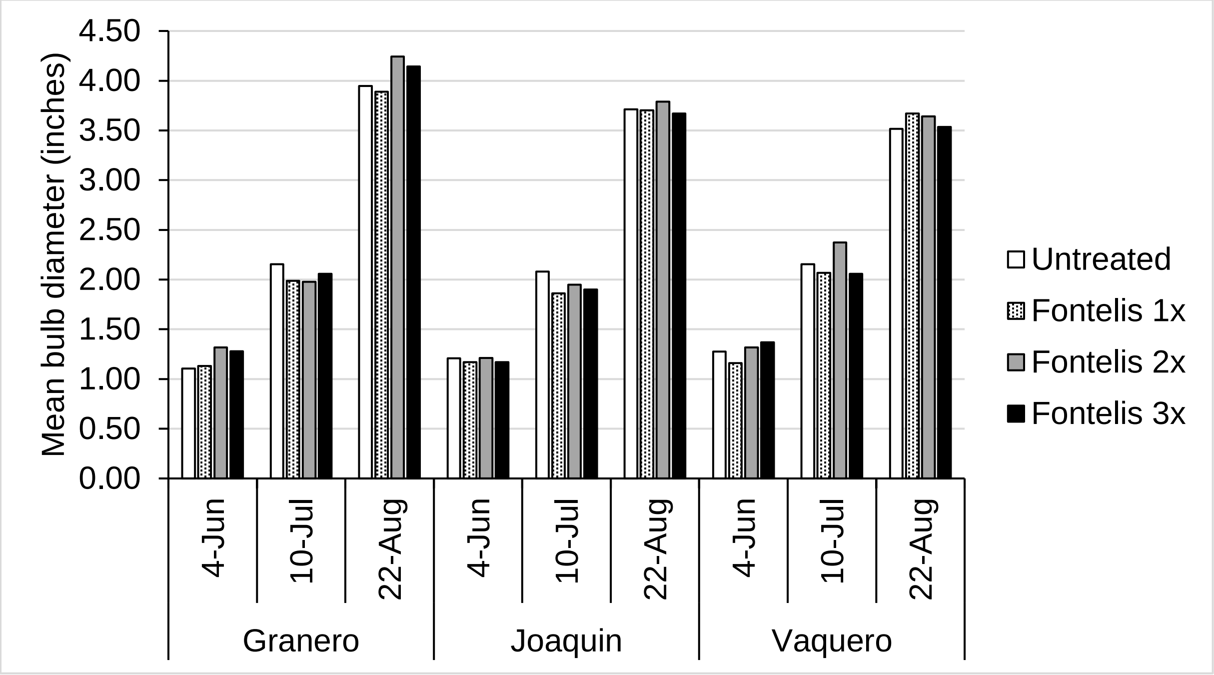

Figure 4. Effects of Fontelis® applications on onion bulb size, as measured by bulb diameter, over the growing season. Malheur Experiment Station, Ontario, OR, 2018.

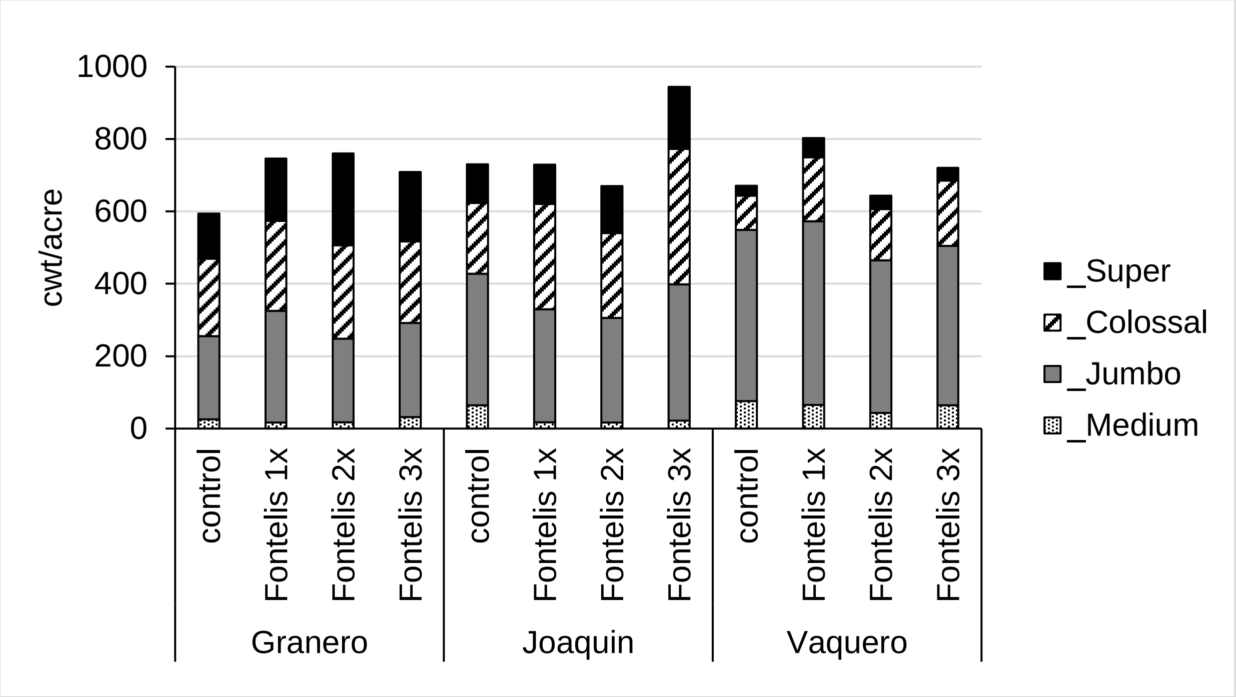

Figure 5. Yield in cwt per acre according to variety and number of Fontelis® treatments for pink root management. Malheur Experiment Station, Ontario, OR, 2018.

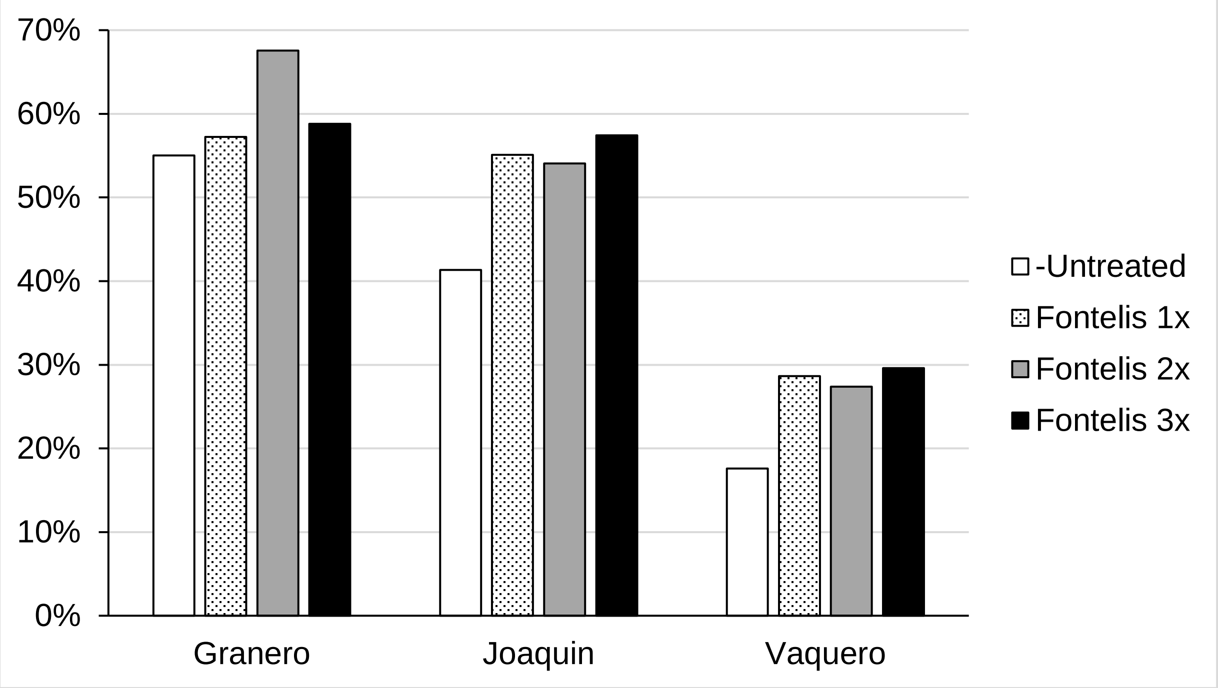

Figure 6. Percentage of colossal and supercolossal size bulbs by variety and number of Fontelis® treatments for pink root management. Malheur Experiment Station, Ontario, OR, 2018.

MONITORING ONION PESTS ACROSS THE TREASURE VALLEY – 2018

Stuart Reitz, Malheur County Extension, Oregon State University, Ontario, OR

Objective

Provide growers with regional assessments of pest abundance in commercial fields.

Introduction

Growers continue to be challenged in how to manage thrips and Iris yellow spot virus (IYSV) that thrips vector. The Idaho-Eastern Oregon region has a range of different subregions, and thrips and virus pressure varies across these subregions. A number of growers have asked for assistance in monitoring pest pressure within their particular districts so they can make better informed management decisions.

Methods

Six to eight commercial fields in each of seven growing areas were monitored for thrips and IYSV on a weekly basis. Those areas were 1) Ontario, 2) Vale, 3) Oregon Slope/Weiser, 4) Nyssa, 5) Adrian, 6) Fruitland, and 7) Parma. Thirty-five of the fields were yellow onions, 11 were red onion fields, and 1 was a white onion field.

Averages of adult and immature thrips, and IYSV incidence for each district were reported to growers, crop advisors, and others each week from May 11 to August 10 when plants began to senesce and fields were being prepared for harvest.

Results and Conclusions

Overall thrips pressure was lower in 2018 than in several previous years. Figure 1 shows mean total thrips per plant in untreated plots at the Malheur Experiment Station from 2013 to 2018.

Adult thrips were first detected in fields during the first survey on May 11 in all areas except Parma and Vale. Plants in the 12 fields with thrips were at the 2-leaf stage. By the following week, adult thrips had colonized at least some fields in all growing areas, and immature thrips were present in fields in all growing areas. Thrips populations built up rapidly in early June. The percentage of plants with thrips went from 12% on May 11 to 38% on May 18. Almost all plants had thrips (>90% of plants infested) from June 8 through July 13. As tops began to go down during late July in early season varieties, thrips started to disperse from fields (Fig. 2 and 3). The white onion field in this year's monitoring provides indication of how plant maturity can affect thrips abundance. This field adjoined an earlier planted red onion field. The whites continued to grow vigorously through the end of July and into August while the reds were senescing at this time.

Thrips populations continued to increase in the whites during this time as numbers in the reds rapidly declined.

Adult thrips numbers peaked at the end of June and beginning of July (Fig. 4). Immature thrips numbers peaked about 1 week later than the peak of adults in most fields (Fig. 5).

The first plants infected with IYSV were detected on June 15 in the Ontario and Oregon Slope areas. Iris yellow spot virus was found in all growing areas by the end of June, but the incidence, in general, did not increase rapidly until plants matured and insecticide applications had ceased (Fig. 6). Infections on individual plants in 2018 did not appear to be very severe or extensive (i.e., relatively few lesions per plant). The low incidence and severity of IYSV in 2018 suggest that direct feeding damage from thrips would have been more important in determining yield losses than virus damage.

Thrips populations varied across the growing regions and fluctuated depending on insecticide applications (Figs. 1-5). Fields on the Oregon Slope tended to have the fewest thrips and lowest incidence of IYSV (Figs. 1 and 2). Fields in Ontario, especially around Cairo Junction, and the Fruitland area had the highest incidence of IYSV.

Acknowledgments

I appreciate the assistance of the cooperating growers and crop advisors. This project was funded by the Idaho-Eastern Oregon Onion Committee.

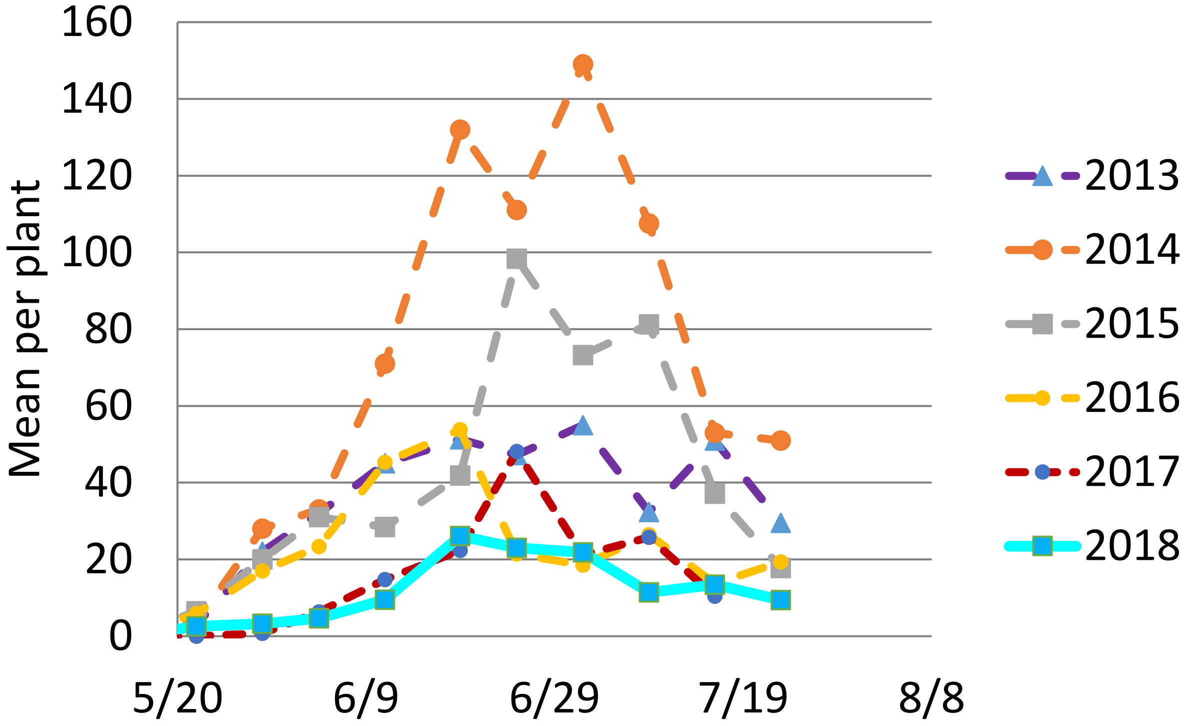

Figure 1. Mean total thrips per plant in untreated onion plots at the Malheur Experiment Station from 2013 to 2018.

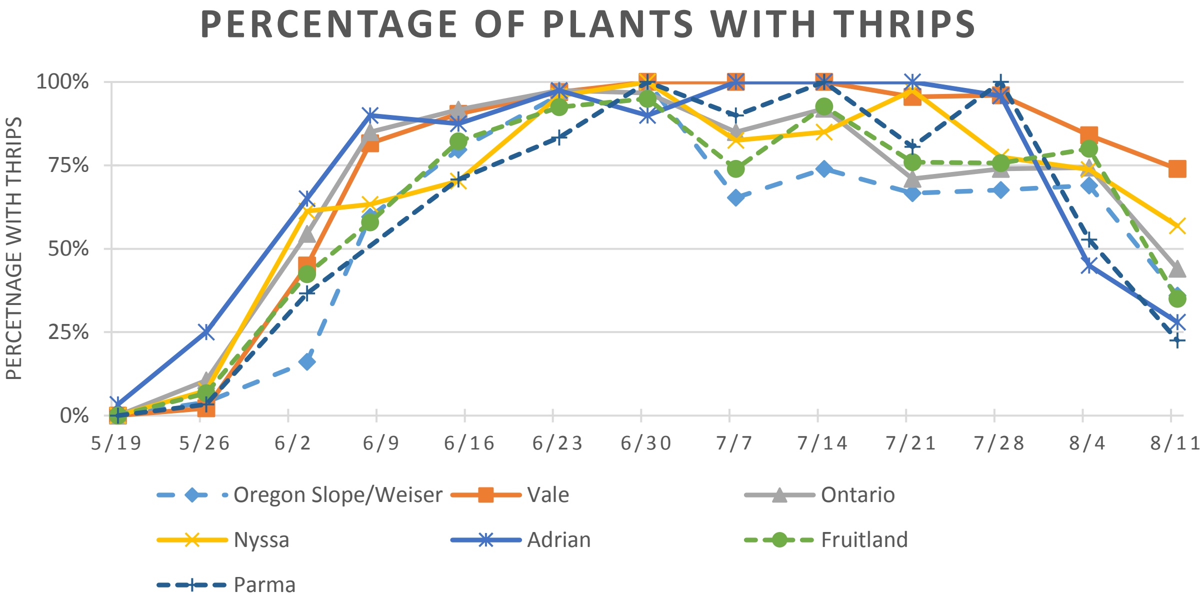

Figure 2. Average percentage of onion plants with thrips present during the 2018 season from different growing areas of the Treasure Valley.

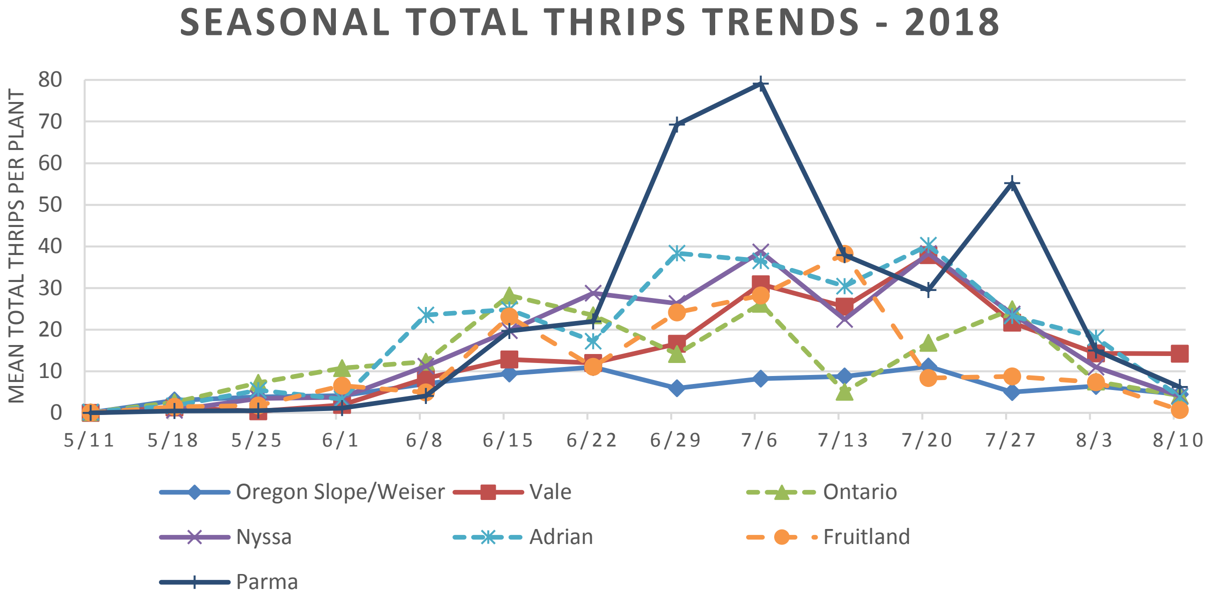

Figure 3. Seasonal trends of total thrips in onion growing areas of the Treasure Valley during 2018.

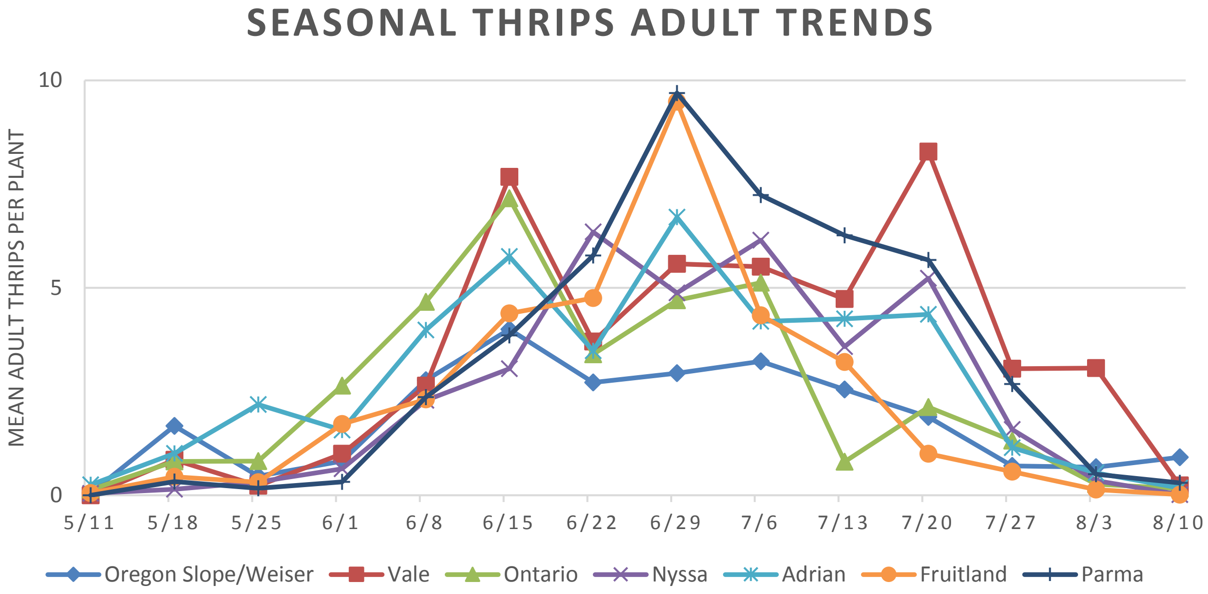

Figure 4. Seasonal trends of adult thrips in onion growing areas of the Treasure Valley during 2018.

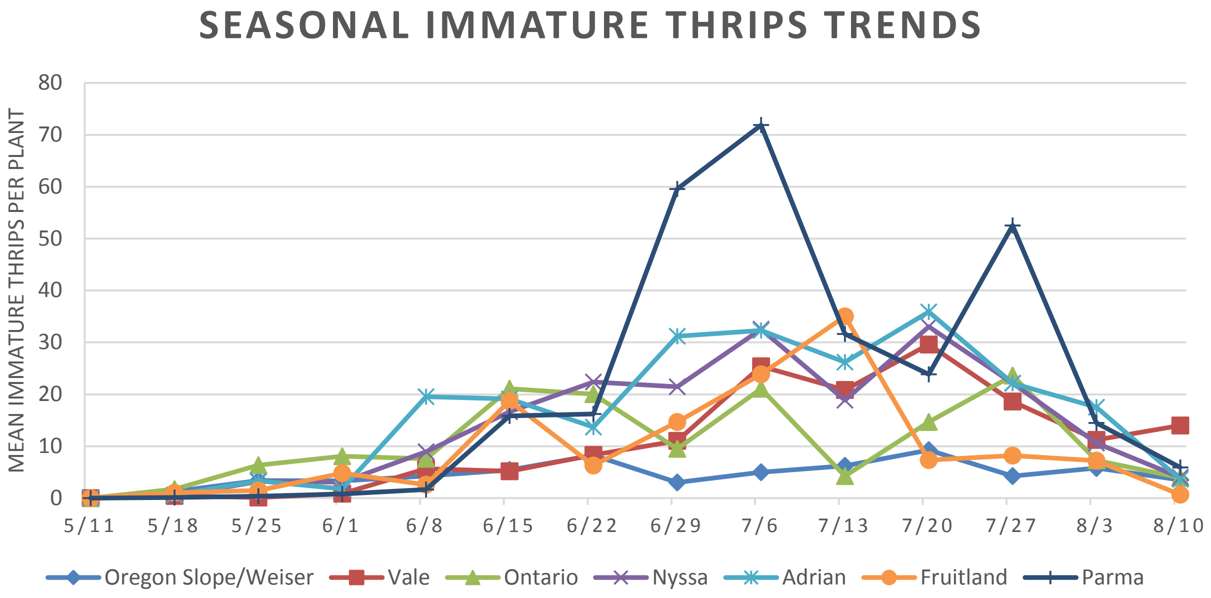

Figure 5. Seasonal trends of immature thrips in onion growing areas of the Treasure Valley during 2018.

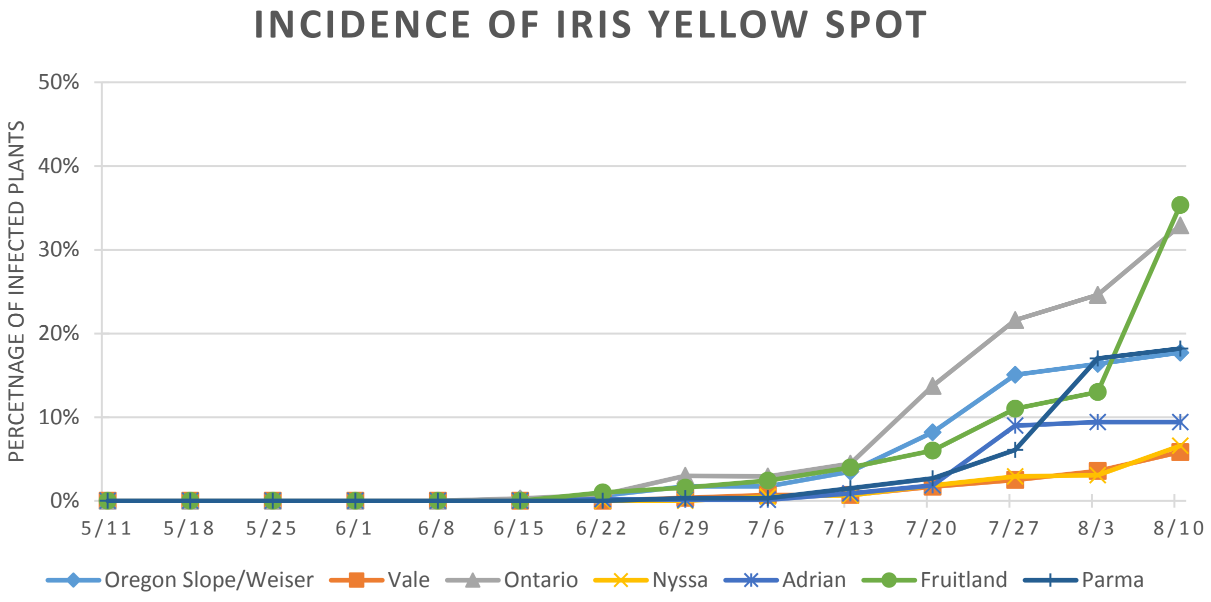

Figure 6. Seasonal incidence of Iris yellow spot virus in commercial onion fields from different growing areas of the Treasure Valley during 2018. Values are the mean percentage of infected plants per field for each area.

THRIPS AND IRIS YELLOW SPOT VIRUS MANAGEMENT IN THE TREASURE VALLEY

Stuart Reitz, Ian Trenkel, Kyle Wieland, Clinton C. Shock, Erik B. G. Feibert, and Alicia Rivera, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018

Objective

Evaluate different treatment sequences of insecticides for thrips and Iris yellow spot virus management.

Introduction

Onion thrips and Iris yellow spot virus (IYSV), which is transmitted by onion thrips, are major limiting factors for onion production in the Treasure Valley. The high concentration of onion fields, and the long, hot growing season in the valley makes management of onion thrips and IYSV particularly challenging.

Insecticides remain the primary tool for thrips management. However, insecticide-based management faces difficulties because there is a limited set of registered insecticides with efficacy against onion thrips, and thrips are able to rapidly develop resistance to various classes of insecticides. Therefore, it is important to assess the effectiveness of currently registered insecticides and to determine when during the season different insecticides may be used most effectively. It is also important to determine the effectiveness of new products and how they may be integrated into an overall thrips management program.

Therefore, we conducted two field trials to evaluate different insecticide management programs, with products applied in various sequences over the growing season. The foliar application trial consisted of 20 different treatment regimens (including experimental/unregistered insecticides, which are not shown) (Tables 2 and 3). A second trial was designed to compare treatment regimens in which products were applied by drip application versus corresponding foliar application. This trial included 12 different treatment regimens (Tables 2 and 5).

Materials and Methods

Cultural Practices

Onion seed (cv ‘Vaquero’) was planted at 143,000 seeds/acre on March 28, 2018.

The field was drip irrigated with drip tape laid at 4-inch depth between two onion beds during planting. The drip tape had emitters spaced 12 inches apart and an emitter flow rate of 0.22 gal/min/100 ft (T-Tape, Rivulis USA, San Diego, CA). The distance between the tape and the center of each double row of onions was 11 inches.

Onions were irrigated automatically to maintain the soil water tension (SWT) in the onion root zone below 20 cb. Soil water tension was measured with six granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Riverside, CA) installed at 8-inch depth in the center of the double row. Sensors had been calibrated to SWT. Irrigations were run by a controller programmed to irrigate twice a day applying 0.48 inch of water per irrigation. A Watermark Electronic Module (WEM, Irrometer Co.) was adjusted to override controller irrigations if the SWT was below 20 cb. Four Watermark sensors were connected to the WEM.

Weed management included an application of Roundup® on April 13, just before onion emergence; and GoalTender® at 4 oz/acre, Brox® 2EC at 16 oz/acre, and Shadow® 3EC at 5.3 oz/acre on May 8; Prowl® H2O at 2 pt/acre on May 19; GoalTender® at 8 oz/acre, Brox 2EC at 20 oz/acre, and Shadow 3EC at 5.3 oz/acre on May 30.

Foliar Insecticide Trial Applications

Insecticides were applied weekly from May 25 to July 13, according to the schedule and rates listed in Tables 2 and 3. Insecticides were applied with a CO_2 backpack sprayer using a 4-nozzle boom with 11004 nozzles at 30 psi and 35 gal/acre. Each treatment plot was 4 double rows wide by 23 ft long.

Drip Insecticide Trial Applications

In the drip application trial, insecticide applications were made on approximately 10-day intervals from May 25 to August 6 (Tables 2 and 5). The drip trial included the standard foliar applications of Movento®, Agri-Mek®, Radiant®, and Lannate® for comparison (Treatment 4 in this trial).

Drip applications were made by injecting insecticide solutions for 6 hours. Solutions were mixed and buffered in 60 gal of water. Injections were made with Ozawa pumps running at 10 gal/hour. Water was applied for 1 hour before applications began and for 1 hour after insecticide injections were completed.

Foliar applications were made with a CO_2 backpack sprayer using a 4-nozzle boom with 11004 nozzles at 30 psi and 35 gal/acre. Each treatment plot was 4 double rows wide by 23 ft long.

Data Collection

Weekly thrips counts were made, starting on May 7 (before insecticide applications began). After insecticide applications began, thrips were counted 3-4 days following an application. Thrips counts were made by counting the number of thrips on 10 consecutive plants in one of the middle two rows of each plot. Adult and larval (immature) thrips were counted separately.

Onions in each plot were evaluated visually for severity of symptoms of IYSV and thrips feeding damage after insecticide treatments had been completed. Assessments were made on July 30 for the foliar trial and on August 8 for the drip trial. Ten consecutive plants in one of the middle two rows of each plot were rated on a scale of 0 to 4 of increasing severity of symptoms or feeding damage. Separate ratings were made for the inner, middle, and outer leaves of each plant to estimate damage occurrence over the course of the growing season.

The rating scale was as follow (Table 1):

Table 1. Rating scales used to assess severity of Iris yellow spot and thrips feeding damage on onions.

Rating	IYSV lesions (% foliage with lesions)	Feeding damage (% foliage with scarring)
0	0	0
1	1–25	1–25
2	26–50	26–50
3	51–75	51–75
4	76–100	76–100

Onions from the middle two double rows in each plot were lifted on September 13. They were topped by hand, bagged on September 18 and placed in storage. The onions from each plot were graded on November 5 and 6. During grading, bulbs were separated according to quality: bulbs without blemishes (No. 1s), split bulbs (No. 2s), neck rot (bulbs infected with the fungus *Botrytis allii* in the neck or side), plate rot (bulbs infected with the fungus *Fusarium oxysporum*), and black mold (bulbs infected with the fungus *Aspergillus niger*). The No. 1 bulbs were graded according to diameter: small, medium, jumbo, colossal, and supercolossal. Bulb counts per 50 lb of supercolossal onions were determined for each plot of every variety by weighing and counting all supercolossal bulbs during grading. Marketable yield consisted of No.1 bulbs in the medium or larger size classes (larger than 2¼ inches).

Results and Conclusions

Foliar Application Trial

Thrips began to colonize onions in early May and reached the threshold level for the trial (4 thrips/plant) by May 22. Applications in both trials began on May 25 (Figs. 1 and 4). Thrips populations began to peak in late June, which has been the typical pattern in the Ontario/Cairo Junction area. However, populations rapidly collapsed soon after that, which has not been typical. In the untreated control, populations began to decline after the first week of July. Overall, thrips pressure in the trial was lower than in recent years, with the greatest average in the control reaching only about 26 per plant (Fig. 1). Thrips feeding damage and IYSV severity were relatively low for the season (Table 4).

As is typical, most thrips on onions were immatures (~75%). Because of the ability of adults to move from plant to plant, we typically do not see large differences in adult populations among insecticide treatments. The largest treatment effects are a result of the effect on immature thrips.

The standard reference program of two applications of Movento, followed by two of Agri-Mek, two of Radiant, and two of Lannate still performed well under this season’s conditions (Treatment program 2). Thrips numbers increased late in the season with the final Lannate applications, which was a pattern seen in other treatment programs with late season use of Lannate (Fig. 4). Figure 4(A) shows the percentage difference in thrips between treatment 19 and the untreated control after the first 2 of 8 Lannate applications, and then the percentage difference after the last 2 of 8 Lannate applications. The increase in thrips numbers at the end of the Lannate applications indicates it may become less effective with more applications within a season.

The effect of Movento was enhanced by combining it with an adulticide (e.g., Treatment 17, the first application of Movento with Radiant).

In situations where applications need to begin earlier in the spring than late May, applying Movento later in the season (by 1–2 weeks) rather than at the start may also make better use of its activity against immature thrips when thrips populations reach their peak in late June. For example, Treatment 3, which started Aza-Direct plus M-Pede®, followed by Movento mixed with Aza-Direct and then M-Pede, reduced the number of larval thrips at the population peak (Figs. 1 and 2).

This year's trial included a number of programs with Minecto® Pro, which combines the active ingredients of Agri-Mek and Exirel®. It performed well whether used early or late in the season but not dramatically better than Agri-Mek (Figs. 1 and 2).

Treatment program 3 had the numerically highest yield and a favorable size profile. This pattern is similar to previous year's results with this program (Fig. 3). In part, it delays Movento applications until later in the season, which helps to control peak populations of immature thrips. In addition, it does not use Lannate late in the season, which may help avoid later season spikes in thrips numbers (Figs. 1, 2, 4).

Table 2. Characteristics of insecticides tested for efficacy against onion thrips. Sequences with unregistered products are not listed. **<u>Please consult the label to determine appropriate uses for all pesticides</u>**. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Product	Company	Rate (product per acre)	Adjuvant	Active ingredient	pH	Mode of action group
Agri-Mek SC	Syngenta	3.5 fl oz	MSO 0.5% v/v	abamectin	6.5	6
Aza-Direct	Gowan	16 fl oz	-	azadirachtin	6.0	unknown
Captiva	Gowan	7/11 fl oz		capsacin oleoresin, garlic oil, soybean oil	7.0	Unknown
Exirel	FMC	13.5 fl oz	MSO 0.5% v/v	Cyantraniliprole	5.0	28
Lannate LV	DuPont	3 pt	NIS 0.25% v/v	methomyl	5.0	1A
M-Pede	Gowan	5.6 pt	-	potassium salts of fatty acids	6.0	unknown
Minecto Pro	Syngenta	10 fl oz	MSO 0.5% v/v NIS 0.25% v/v	Abamectin / Cyantraniliprole	6.0	6 / 28
Movento HL	Bayer	2.5 fl oz	MSO 0.5% v/v Dyne-Amic 0.25% v/v	spirotretramat	6.5	23
Radiant	Dow	8 fl oz	Dyne-Amic 0.25% v/v	spinetoram	7.0	5
Venerate	Marrone	8 qt	-	*Burkholderia strain A396*	6.0	Heat-killed bacteria
Verimark	FMC	10.3 fl oz	-	Cyantraniliprole	5.0	28

Table 3. Insecticide regimens and application dates in the standard insecticide treatment program. Only treatment regimens with registered products are listed. Applications were made once per week. Malheur Experiment Station, Oregon State University, Ontario, OR.

Date	**25-May**	**1-Jun**	**8-Jun**	**15-Jun**	**22-Jun**	**29-Jun**	**6-Jul**	**13-Jul**
Treatment	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**
1	Control	-	-	-	-	-	-	-
2	Movento (old form)	Movento (old form)	Agri-Mek	Agri-Mek	Radiant	Radiant	Lannate	Lannate
3	M-Pede+ Aza-Direct	M-Pede+ Aza-Direct	Movento HL + Aza-Direct	M-Pede + Movento HL	Minecto	Minecto	Radiant + M-Pede	Radiant + M-Pede
6	Movento HL	Movento HL	Minecto	Minecto	Radiant	Radiant	Lannate	Lannate
7	Movento HL	Movento HL	Radiant	Radiant	Minecto	Minecto	Lannate	Lannate
8	Movento HL	Movento HL	Radiant	Radiant	Lannate	Lannate	Minecto	Minecto
9	Movento HL	Movento HL	Radiant	Radiant	Exirel	Exirel	Lannate	Lannate
10	Movento HL	Movento HL	Radiant	Radiant	Lannate	Lannate	Exirel	Exirel
15	Movento HL	Movento HL	Agri-Mek	Agri-Mek	Radiant	Radiant	Lannate	Lannate
16	Movento HL	Movento HL	Agri-Mek	Agri-Mek	Radiant	Radiant	Lannate	Lannate
17	Movento HL + Radiant	Movento HL	Minecto	Minecto	Radiant	Radiant	Lannate	Lannate
18	Lannate	Lannate	Lannate	Lannate	Lannate	Lannate	Lannate	Lannate
19	Exirel	Exirel	Movento HL	Movento HL	Radiant	Radiant	Lannate	Lannate

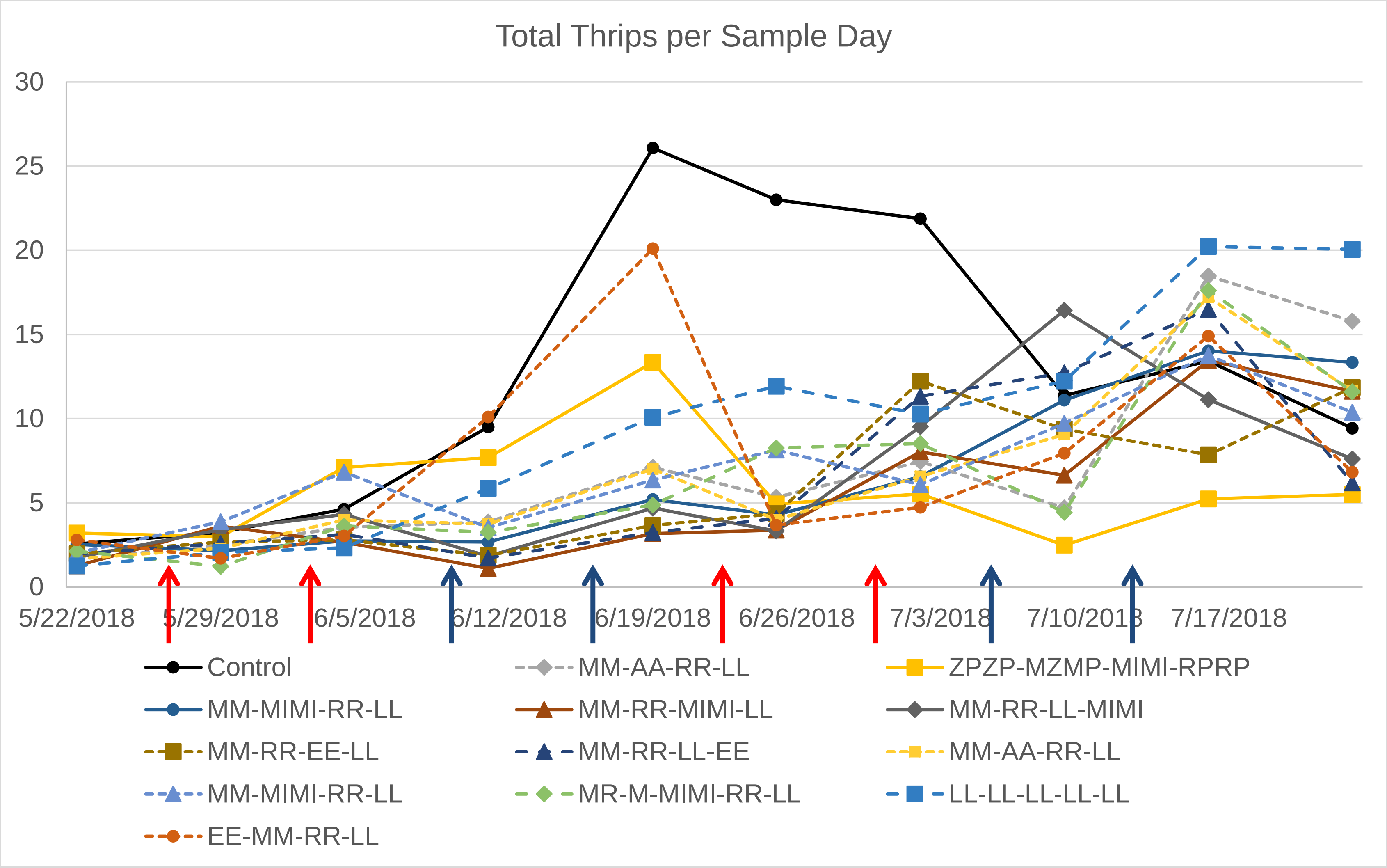

Figure 1. Average total thrips per plant in the foliar insecticide trial at the Malheur Experiment Station, 2018. Insecticide abbreviations: A = Agri-Mek, L = Lannate, M = Movento, MI = Minecto Pro, P = M-Pede, R = Radiant, Z = Aza-Direct. See Tables 1 and 2 for additional information on applications.

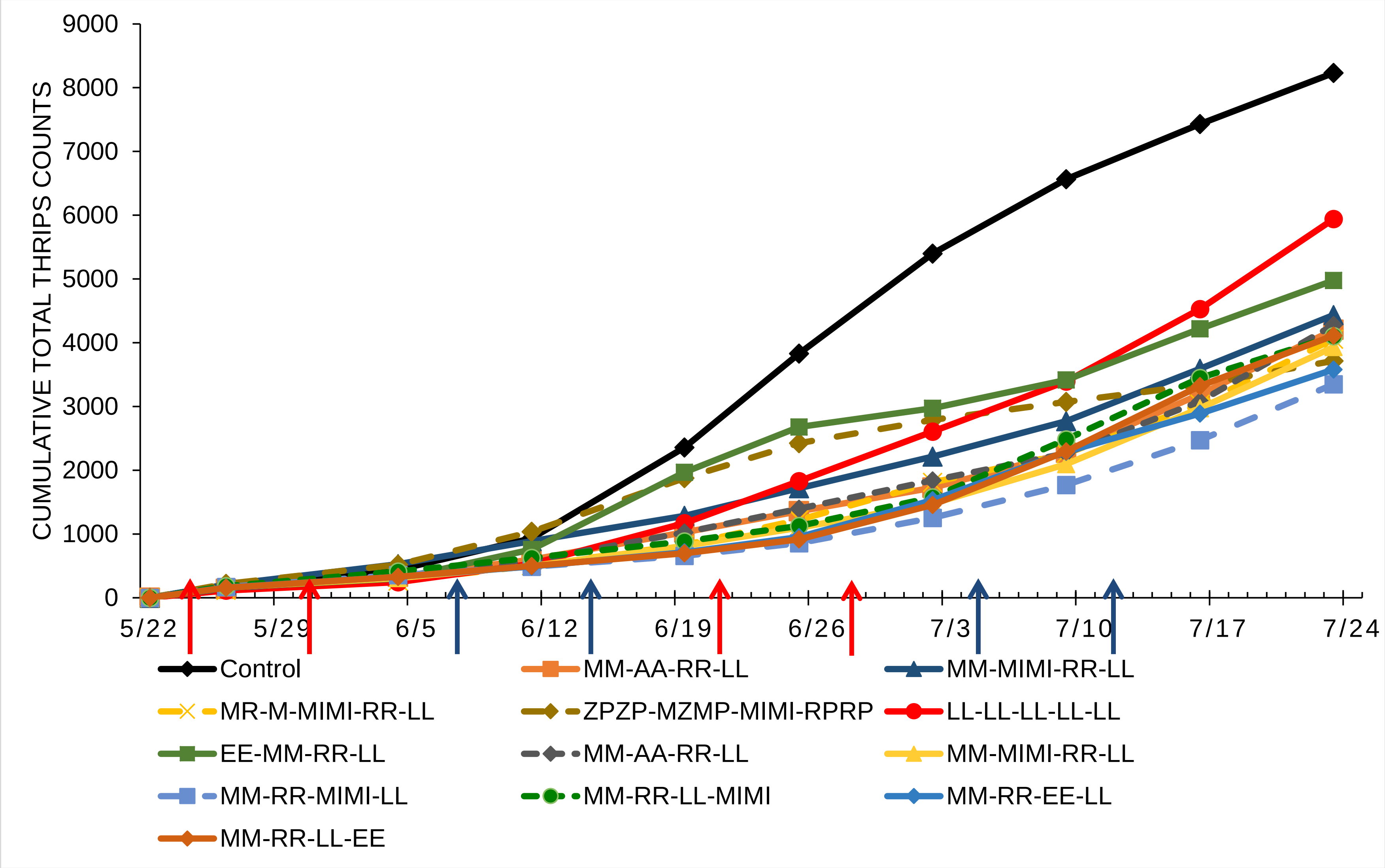

Figure 2. Cumulative thrips counts for the standard foliar insecticide trial in which applications were made weekly, Malheur Experiment Station, Oregon State University, Ontario, OR. Arrows along the date axis show when applications were made. Insecticide abbreviations: A = Agri-Mek, L = Lannate, M = Movento, MI = Minecto Pro, P = M-Pede, R = Radiant, Z = Aza-Direct. See Tables 1 and 2 for additional information on applications.

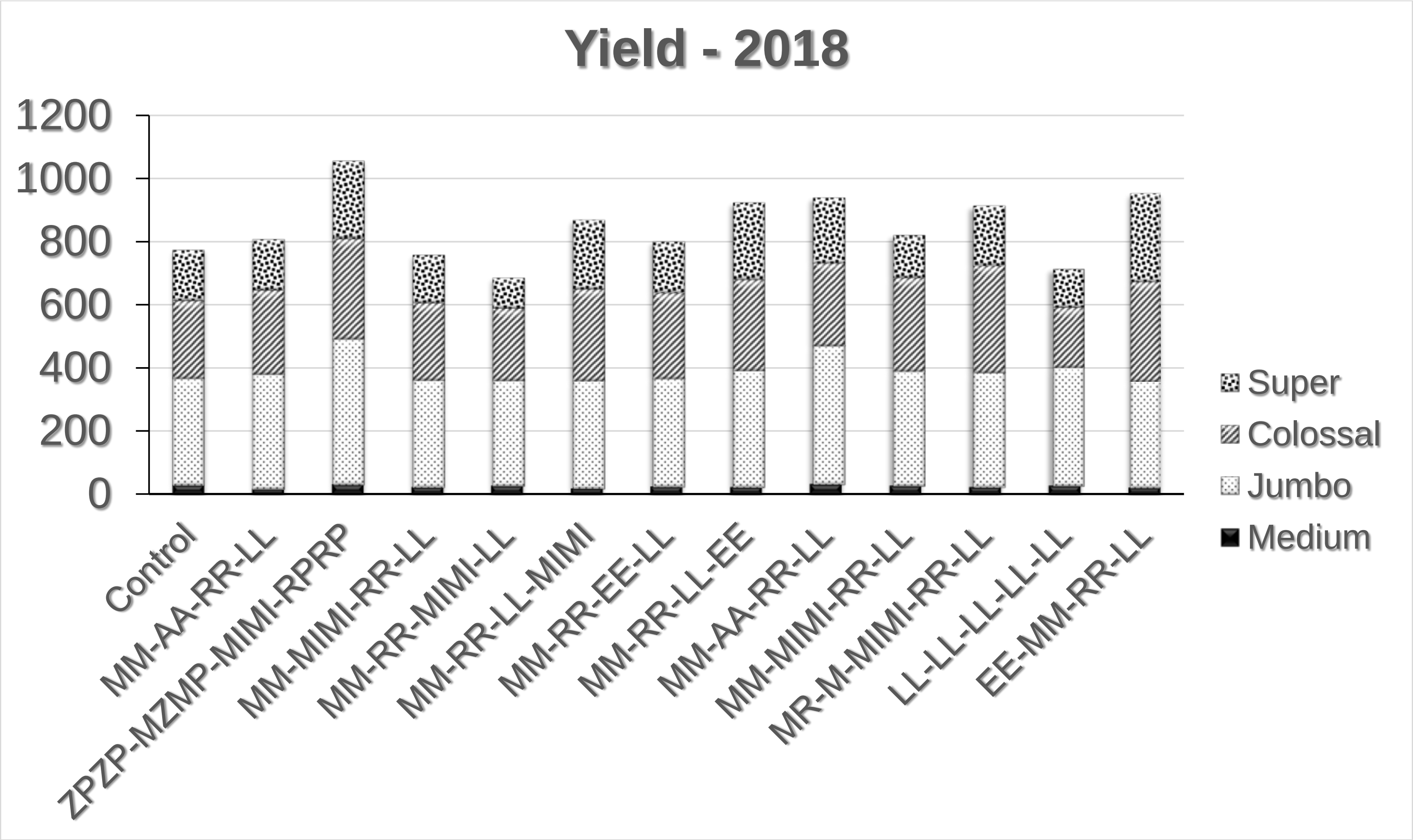

Figure 3. Marketable onion yield (cwt/acre) results by size category for the drip application trial, Malheur Experiment Station, Oregon State University, Ontario, OR. Insecticide abbreviations: A = Agri-Mek, E = Exirel, L = Lannate, M = Movento, MI = Minecto Pro, P = M-Pede, R = Radiant, Z = Aza-Direct. See Tables 1 and 2 for additional information on applications. Note Program 2 (MM-AA-RR-LL uses the old Movento formulation; all others use the new Movento HL formulation).

Table 4. Severity of Iris yellow spot virus and thrips damage to onions in 2018 in the standard foliar application trial, Malheur Experiment Station, Oregon State University, Ontario, OR. Ratings are the mean rating for 10 plants per plot taken on July 30, 2018 after insecticide applications had been completed. Ratings are on a 0-4 scale. See Tables 1 and 2 for descriptions of treatments.

Treatment	**Mean virus damage rating**	**Mean thrips damage rating**
1 - Control	0.80	0.98
2 - MM-AA-RR-LL	0.45	0.55
3 - ZPZP-MZMP-MIMI-RPRP	0.73	0.58
6 - MM-MIMI-RR-LL	0.55	0.65
7 - MM-RR-MIMI-LL	0.53	0.63
8 - MM-RR-LL-MIMI	0.58	0.65
9 - MM-RR-EE-LL	0.63	0.63
10 - MM-RR-LL-EE	0.58	0.83
15 - MM-AA-RR-LL	0.60	0.45
16 - MM-AA-RR-LL	0.65	0.78
17 - MR-M-MIMI-RR-LL	0.73	0.85
18 - LL-LL-LL-LL	0.48	0.68
19 - EE-MM-RR-LL	0.53	0.83
	LSD = 0.25	LSD = 0.27

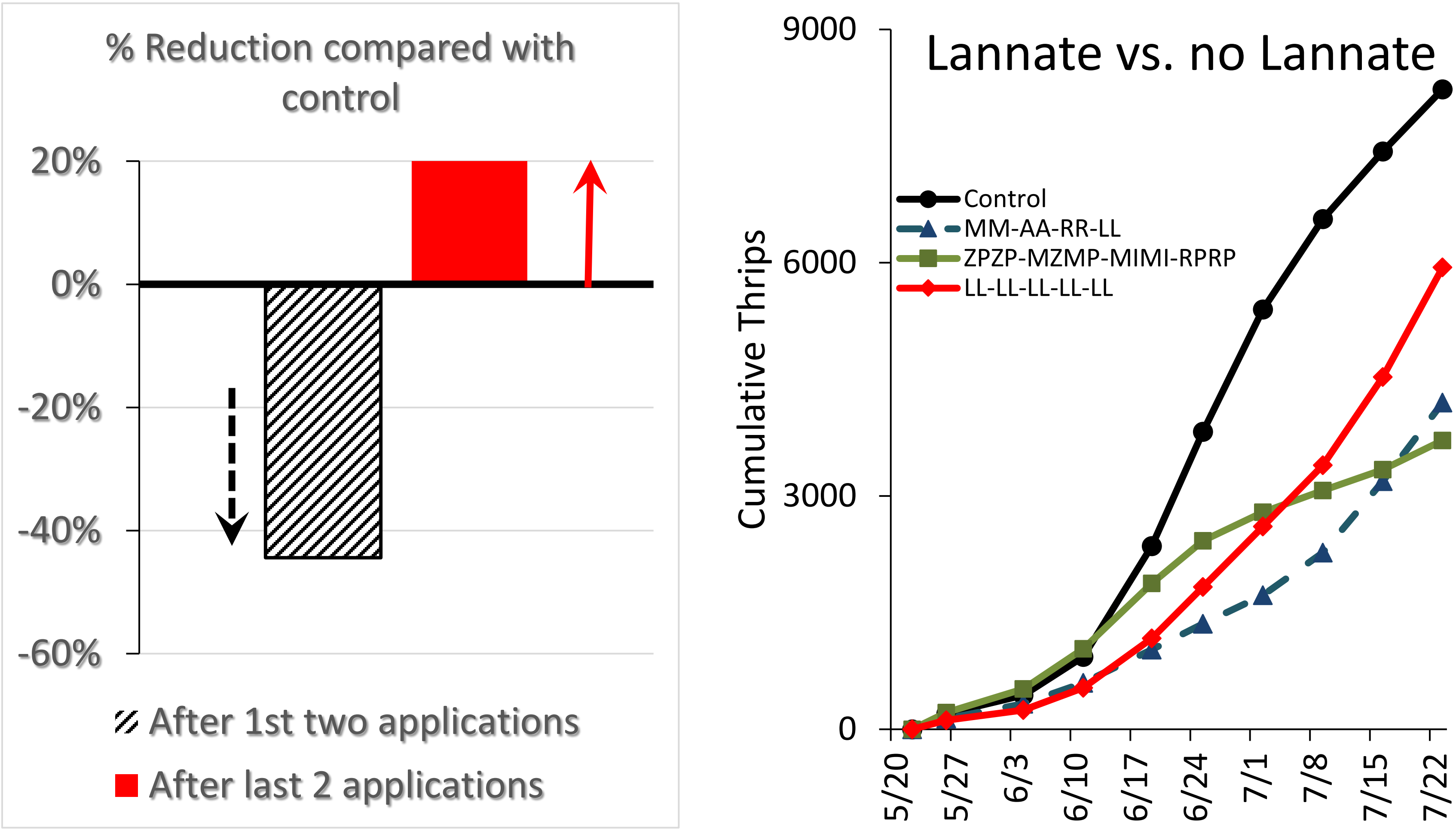

Figure 4. The effect of repeated applications of Lannate on thrips populations. (A) Bar on the left shows the percent reduction in thrips in plots that received two consecutive applications of Lannate compared with thrips in untreated plots. (B) Bar on the right shows the percent increase in thrips in plots that had received 8 applications of Lannate compared with thrips in the untreated plots. Treatment abbreviations in the legand: A = Agri-Mek, L = Lannate, M = Movento, MI = Minecto Pro, P = M-Pede, R = Radiant, Z = Aza-Direct.

Drip Application Trial

Thrips populations remained above the trial threshold of four per plant through the application schedule (August 8), indicating the need to continue thrips treatments into August for later maturing varieties, such as Vaquero. Although thrips populations persisted through the growing season, pressure was relatively low compared with other seasons (Table 6). Iris yellow spot virus did become more prevalent late in the season, as evidenced by the higher severity scores in the drip trial (Table 6) compared with the foliar trial (Table 4), in which ratings were taken 2 weeks earlier.

The best performing programs (Treatments 7 and 11) delayed applications of Movento to the third and fourth application intervals so that Movento remained active through the peak abundance of thrips in late June to mid-July. These programs did not combine an adulticide with Movento, which may have further enhanced control.

The use of Exirel, the foliar version of cyantraniliprole, or Verimark®, the drip version of cyantraniliprole at the beginning of the insecticide program gave comparable results for thrips control as the standard program with Movento at the beginning of the program (Figs. 5 and 6).

Exirel provided better control later in the season (5th and 6th application intervals) than did corresponding drip applications of Verimark (Treatment 11 with Exirel vs. Treatment 10 with Verimark).

It is important to note that Exirel and Verimark act as antifeedants, so thrips may still be alive on plants, but they cease feeding and causing damage.

Foliar applications of Aza-Direct (12 fl oz/acre) gave comparable control of thrips as drip applications of Aza-Direct (32 fl oz/acre).

In terms of yield, the programs with delayed applications of Movento (Treatments 7, 11, 12) had the highest yields. These programs averaged more than 15% greater marketable yields than programs with delayed applications of Movento and 21% greater yields of colossal and supercolossal onions.

Acknowledgments

We appreciate the technical assistance of Kelsey Alexander, Brooke Bezona, Mary Phipps, Hannah Rose, and Allison Simmons. The project was supported by the Idaho-Eastern Onion Committee, Bayer, Gowan, Syngenta, and FMC.

Table 5. Insecticide regimens and application dates in the drip (D) insecticide treatment program (F = foliar). Only treatment regimens with registered products are listed. See Table 1 for more information on insecticides. Malheur Experiment Station, Oregon State University, Ontario, OR.

Application Date	**5/25**	**6/5**	**6/15**	**6/25**	**7/5**	**7/16**	**7/26**	**8/6**
			Application Number					
Treatment	1st	2nd	3rd	4th	5th	6th	7th	8th
1	Control	-	-	-	-	-		
2	Verimark (D) 10.3 fl oz	Verimark (D) 10.3 fl oz	Agri-Mek (F) 3.5 fl oz	Agri-Mek (F) 3.5 fl oz	Radiant (F) 8 fl oz	Radiant (F) 8 fl oz	Lannate (F) 3 pt	Lannate (F) 3 pt
3	Movento HL (F) 2.5 oz	Movento HL (F) 2.5 oz	Verimark (D) 10.3 oz	Verimark (D) 10.3 oz	Radiant (F) 8 fl oz	Radiant (F) 8 fl oz	Agri-Mek (F) 3.5 fl/oz	Agri-Mek (F) 3.5 fl/oz
4	Movento HL (F) 2.5 oz	Movento HL (F) 2.5 oz	Agri-Mek (F) 3.5 fl oz	Agri-Mek (F) 3.5 fl oz	Radiant (F) 8 fl oz	Radiant (F) 8 fl oz	Lannate (F) 3 pt	Lannate (F) 3 pt
5	Exirel (F) 13.4 oz	Exirel (F) 13.4 oz	Agri-Mek (F) 3.5 fl oz	Agri-Mek (F) 3.5 fl oz	Radiant (F) 8 fl oz	Radiant (F) 8 fl oz	Lannate (F) 3 pt	Lannate (F) 3 pt
6	Verimark (D) 10.3 oz	Verimark (D) 10.3 oz	Agri-Mek (F) 3.5 fl oz	Agri-Mek (F) 3.5 fl oz	Radiant (F) 8 fl oz	Radiant (F) 8 fl oz	Lannate (F) 3 pt	Lannate (F) 3 pt

Application Date	**5/25**	**6/5**	**6/15**	**6/25**	**7/5**	**7/16**	**7/26**	**8/6**
			Application Number					
Treatment	1st	2nd	3rd	4th	5th	6th	7th	8th
7	Aza-Direct (D) 32 fl oz	Aza-Direct (D) 32 fl oz	Movento HL (F) 2.5 oz	Movento HL (F) 2.5 oz	Radiant (F) 8 fl oz	Radiant (F) 8 fl oz	Lannate (F) 3 pt	Lannate (F) 3 pt
8	Movento HL (F) 2.5 oz	Movento HL (F) 2.5 oz	Exirel (F) 13.4 fl oz	Exirel (F) 13.4 fl oz	Radiant (F) 8 fl oz	Radiant (F) 8 fl oz	Agri-Mek (F) 3.5 fl oz	Agri-Mek (F) 3.5 fl oz
10	Aza-Direct (D) 32 fl oz	Aza-Direct (D) 32 fl oz	Movento HL (F) 2.5 oz	Movento HL (F) 2.5 oz	Verimark (D) 10.3 oz	Verimark (D) 10.3 oz	Agri-Mek (F) 3.5 fl oz	Agri-Mek (F) 3.5 fl oz
11	Aza-Direct 12 fl oz + M-Pede (2%) (F)	Aza-Direct 12 fl oz + M-Pede (2%) (F)	Movento HL (F) 2.5 oz	Movento HL (F) 2.5 oz	Exirel (F) 13.4 fl oz	Exirel (F) 13.4 fl oz	Agri-Mek (F) 3.5 fl oz	Agri-Mek (F) 3.5 fl oz
12	Aza-Direct (D) 32 fl oz	Aza-Direct (D) 32 fl oz	Verimark (D) 10.3 oz	Verimark (D) 10.3 oz	Radiant (F) 8 fl oz	Radiant (F) 8 fl oz	Agri-Mek (F) 3.5 fl oz	Agri-Mek (F) 3.5 fl oz

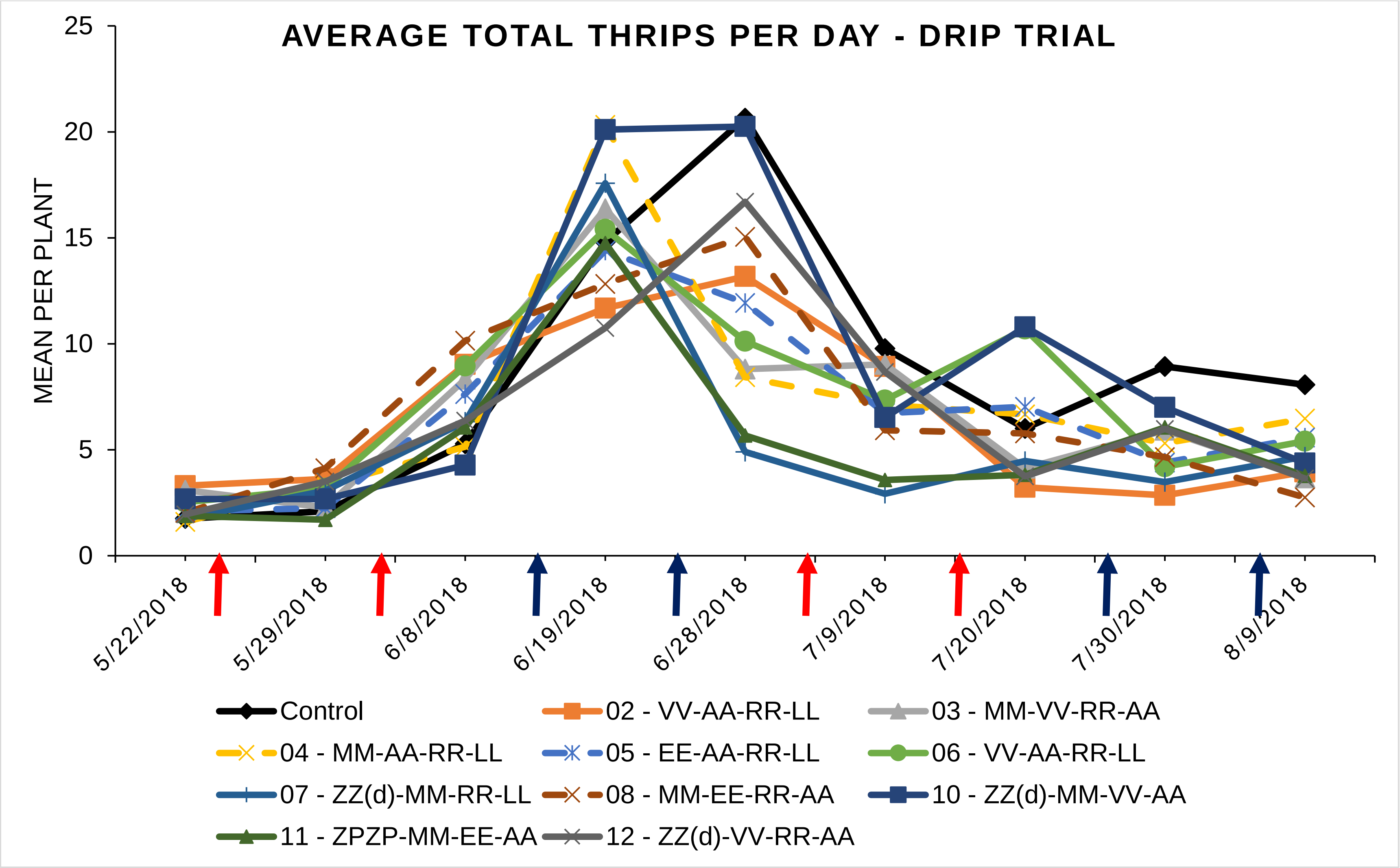

Figure 5. Average total thrips per plant in the foliar insecticide trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Insecticide abbreviations: A = Agri-Mek, L = Lannate, M = Movento, MI = Minecto Pro, P = M-Pede, R = Radiant, Z = Aza-Direct. See Tables 1 and 4 for additional information on applications.

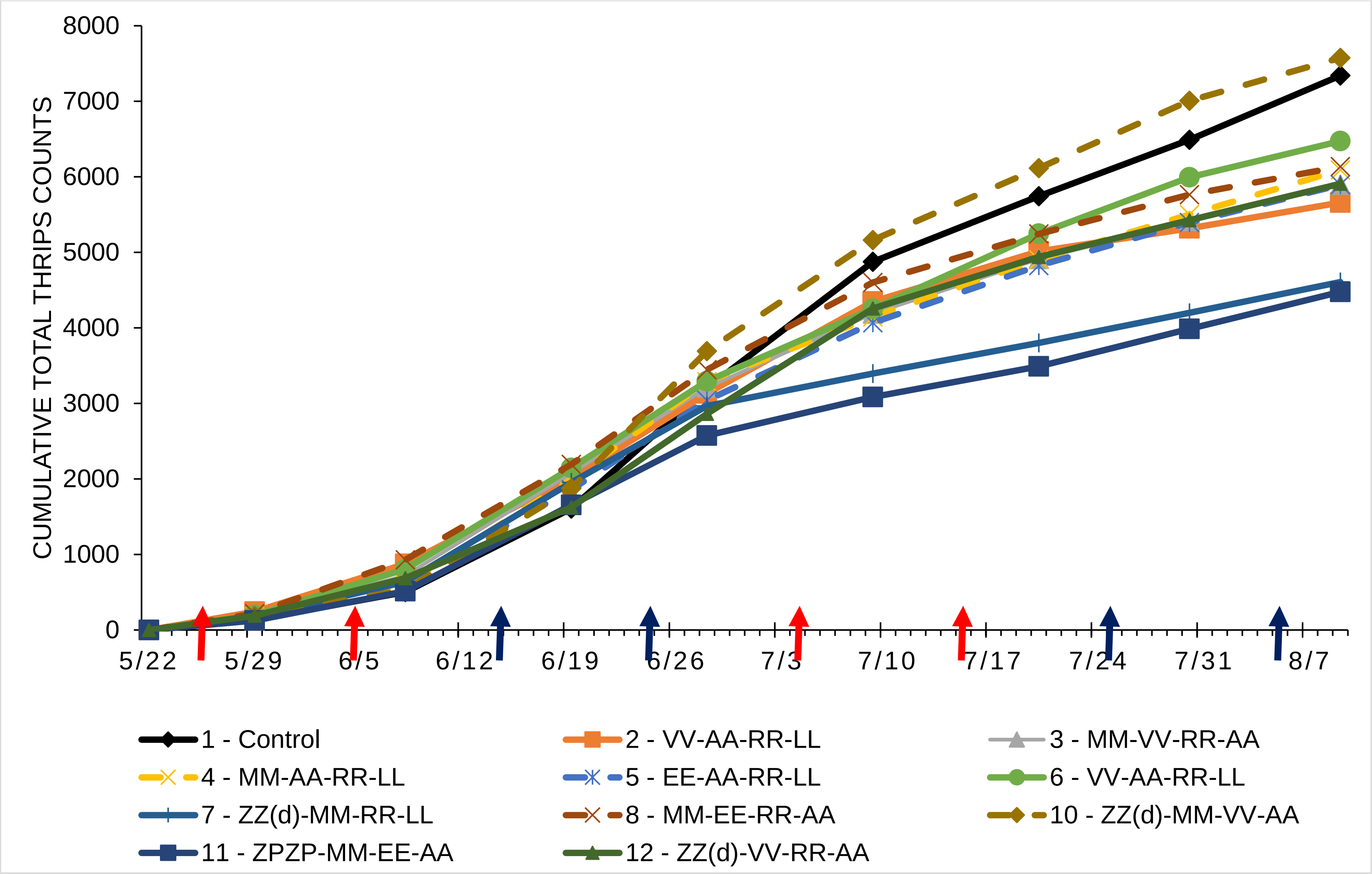

Figure 6. Cumulative thrips counts for the drip insecticide trial in which applications were approximately 10 days apart, Malheur Experiment Station, Oregon State University, Ontario, OR. Arrows along the date axis show when applications were made. Insecticide abbreviations: A = Agri-Mek, E = Exirel, L = Lannate, M = Movento, MI = Minecto Pro, P = M-Pede, V = Verimark.

Table 6. Severity of Iris yellow spot virus and thrips damage to onions in 2018, Malheur Experiment Station, Oregon State University, Ontario, OR. Ratings are the mean rating for 10 plants per plot taken on July 30, 2018 after insecticide applications had been completed. Ratings are on a 0-4 scale. See Tables 1 and 4 for description of the treatments.

Treatment	**Mean virus damage rating**	**Mean thrips damage rating**
1 - Control	1.83	1.90
2 - VV-AA-RR-LL	1.53	1.65
3 - MM-VV-RR-AA	1.50	1.45
4 - MM-AA-RR-LL	1.58	1.68
5 - EE-AA-RR-LL	1.68	1.63
6 - VV-AA-RR-LL	1.55	1.73
7 - ZZ(d)-MM-RR-LL	1.68	1.90
8 - MM-EE-RR-AA	1.48	1.45
10 - ZZ(d)-MM-VV-AA	1.68	1.88
11 - ZPZP-MM-EE-AA	1.48	1.70
12 - ZZ(d)-VV-RR-AA	1.53	1.58
	LSD = 0.25	LSD = 0.27

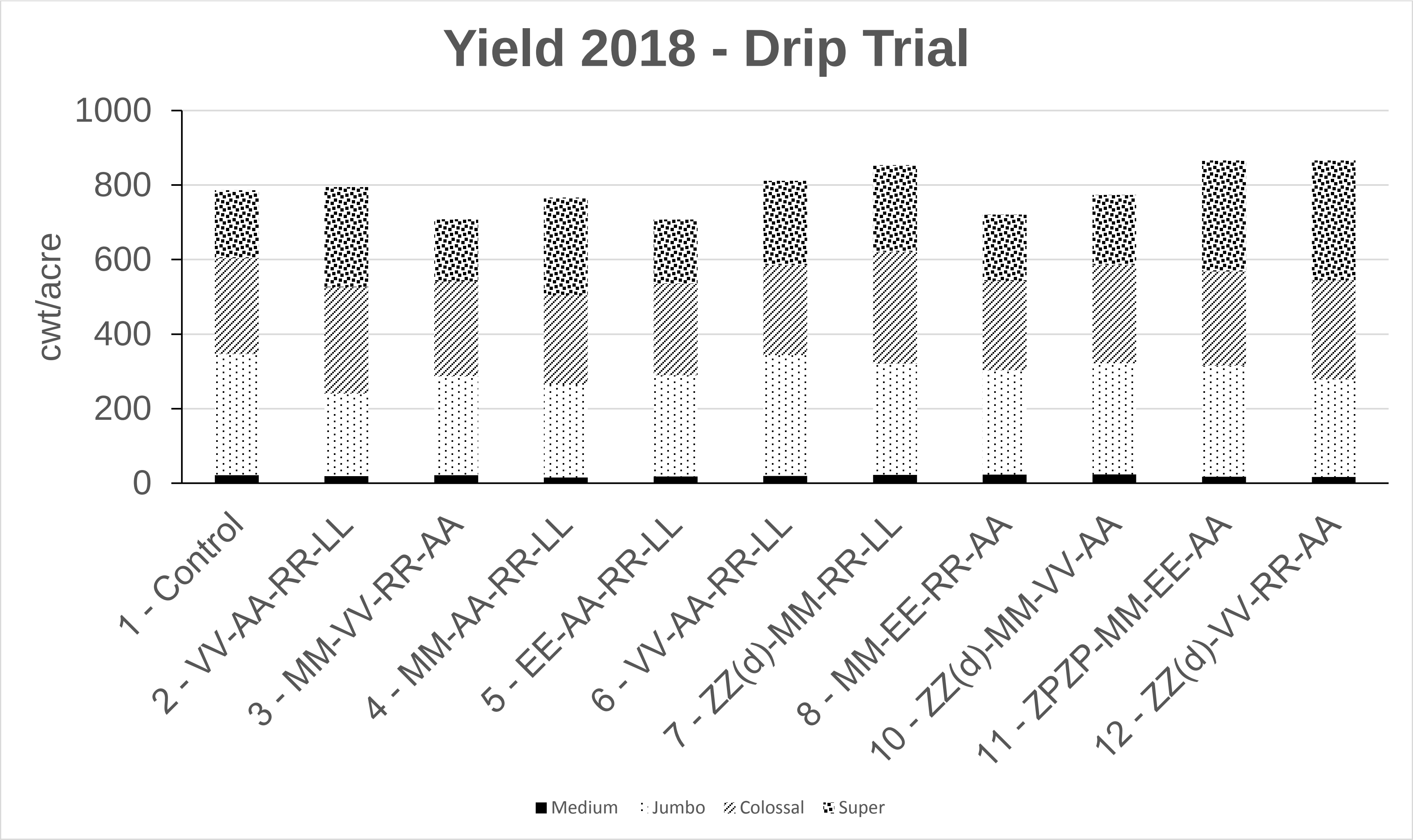

Figure 7. Marketable onion yield results by size category for the drip application trial, Malheur Experiment Station, Oregon State University, Ontario, OR. Insecticide abbreviations: A = Agri-Mek, E = Exirel, L = Lannate, M = Movento, MI = Minecto Pro, P = M-Pede, R = Radiant, V = Verimark, Z = Aza-Direct, (d) = drip application. See Tables 1 and 4 for additional information on applications.

NATIVE WILDFLOWER SEED YIELD IN RESPONSE TO MODEST IRRIGATION

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Introduction

Commercial seed production of native wildflowers is necessary to provide the quantity of seed needed for restoration of Intermountain West rangelands. Native wildflower plants may not be well adapted to croplands. Native plants are often not competitive with crop weeds in cultivated fields, and this poor competitiveness with weeds could limit wildflower seed production. Both sprinkler and furrow irrigation could provide supplemental water for seed production, but these irrigation systems risk further encouraging weeds. Also, sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. By burying drip tape at a 12-inch depth and avoiding wetting the soil surface, we designed experiments to assure flowering and seed set without undue encouragement of weeds or opportunistic diseases. The trials reported here tested effects of three low rates of irrigation on seed yield of 14 native wildflower species (Table 1).

Table 1. Wildflower species planted at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Common name	Longevity	Row spacing (inches)
Chaenactis douglasii	Douglas' dustymaiden	perennial	30
Crepis intermedia[a]	limestone hawksbeard	perennial	30
Cymopterus bipinnatus[b]	Hayden's cymopterus	perennial	30
Enceliopsis nudicaulis	nakedstem sunray	perennial	30
Heliomeris multiflora	showy goldeneye	perennial	30
Ipomopsis aggregata	scarlet gilia	biennial	15
Ligusticum canbyi	Canby's licorice-root	perennial	30
Ligusticum porteri	Porter's licorice-root	perennial	30
Machaeranthera canescens	hoary tansyaster	perennial	30
Nicotiana attenuata	coyote tobacco	perennial	30
Phacelia linearis	threadleaf phacelia	annual	15
Phacelia hastata	silverleaf phacelia	perennial	15
Thelypodium milleflorum	manyflower thelypody	biennial	30
Achillea millefolium	common yarrow	perennial	30

[a] Planted in the fall of 2011.
[b] Recently classified as *Cymopterus nivalis* S. Watson “snowline springparsley.” Planted in the fall of 2009.

Materials and Methods

Plant establishment

Each wildflower species was planted on 60-inch beds in rows 450 ft long on Nyssa silt loam at the Malheur Experiment Station, Ontario, Oregon. The soil had a pH of 8.3 and 1.1% organic matter. In October 2012, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth in the center of each bed to irrigate the rows in the plot. The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 psi with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour.

On October 30, 2012, seed of 11 species (Table 1) was planted in either 15-inch or 30-inch rows using a custom-made small-plot grain drill with disc openers. All seed was planted on the soil surface at 20-30 seeds/ft of row. After planting, sawdust was applied in a narrow band over the seed row at 0.26 oz/ft of row (558 lb/acre). Following planting and sawdust application, the beds were covered with row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO), which covered four rows (two beds) and was applied with a mechanical plastic mulch layer. *Cymopterus bipinnatus* was planted on November 25, 2009, and *Crepis intermedia* was planted on November 28, 2011 as previously described using similar methods.

Weeds were controlled by hand-weeding as necessary.

Starting in March following fall planting, the row cover was removed. Immediately following the removal of the row cover, bird netting was placed over the seedlings on no. 9 galvanized wire hoops to prevent bird feeding on young seedlings and new shoots. During seedling emergence, wild bird seed was placed several hundred feet from the trial to attract quail away from the trials. Bird netting was removed in early May. Bird netting was applied and removed each spring.

On April 13, 2012, 50 lb nitrogen (N)/acre, 10 lb phosphorus (P)/acre, and 0.3 lb iron (Fe)/acre was applied to all plots of *Cymopterus bipinnatus* and *C. intermedia* as liquid fertilizer injected through the drip tape.

Cultural practices in 2013

On July 26, all plots of *Machaeranthera canescens* were sprayed with Capture® at 19 oz/acre (0.3 lb ai/acre) for aphid control. On October 31, seed of *Phacelia linearis* was planted as previously described.

Due to poor stand, seed of *Chaenactis douglasii* was replanted on November 1, as previously described. Stand of *Nicotiana attenuata* was extremely poor and seed was unavailable for replanting.

Cultural practices in 2014

Stand of *Chaenactis douglasii*, which was replanted in the fall of 2013, was poor and did not allow evaluation of irrigation responses.

On November 11, *Phacelia linearis, Nicotiana attenuata,* and *Thelypodium milleflorum* were replanted as previously described. Lengths of row with missing stand in plots of *Chaenactis douglasii* were replanted by hand and row cover was not applied to the replanting.

Cultural practices in 2015

On November 2, *Nicotiana attenuata* and *Enceliopsis nudicaulis* were replanted as previously described. Before planting, the ground was not tilled, only cultipacked. On November 5, *Phacelia linearis, Chaenactis douglasii*, *Achillea millefolium*, and *Ipomopsis aggregata* were replanted as previously described.

Cultural practices in 2016

On November 22, *Nicotiana attenuata, Phacelia linearis,* and *Thelypodium milleflorum* were replanted as previously described.

Cultural practices in 2017

On October 19, Prowl® H_2O at 2 pt/acre was broadcast on all plots of *Enceliopsis nudicaulis*, *Crepis intermedia*, and *Thelypodium milleflorum* for weed control. On November 8, *Ipomopsis aggregata* was replanted. On November 14, *Nicotiana attenuata* was replanted.

Cultural practices in 2018

Liquid fertilizer containing 0.3 lb Fe/acre was injected using a brief pulse of water through the drip irrigation system to all plots of *Crepis intermedia*, *Thelypodium milleflorum,* and *Cymopterus bipinatus* on May 3.

Irrigation for seed production

In March 2010 for *Cymopterus bipinnatus,* and March 2013 for the other species, the planted strip of each wildflower species was divided into 12 30-ft-long plots. Each plot contained four rows of each species. The experimental design for each species was a randomized complete block with four replicates. The three treatments were a non-irrigated check, 1 inch of water per irrigation, and 2 inches of water per irrigation. Each treatment received four irrigations that were applied approximately every 2 weeks starting at bud formation and flowering. The amount of water applied to each treatment was calculated by the length of time necessary to deliver 1 or 2 inches through the drip system. Irrigations were regulated with a controller and solenoid valves.

The drip-irrigation system was designed to allow separate irrigation of each species due to different timings of flowering and seed formation. All species were irrigated separately except the two *Phacelia* spp. and the two *Ligusticum* spp. Flowering, irrigation, and harvest dates were recorded (Table 2) except for *Nicotiana attenuata*, which did not germinate in 2014 and the *Ligusticum* spp., which did not flower.

Harvest

All species were harvested manually in 2013. Due to a long flowering duration, seed of *Enceliopsis nudicaulis*, *Chaenactis douglasii,* and *Crepis intermedia* required multiple harvests. Seed of *E. nudicaulis* was harvested manually once a week. Seed of *Chaenactis douglasii* and *Crepis intermedia* was harvested weekly with a leaf blower in vacuum mode. In 2016, the duration of flowering for *C. intermedia* was much shorter and uniform in timing between irrigation treatments. In 2016-2018, seed of *C. intermedia* was harvested by mowing and bagging just prior to the seed heads opening. In 2016 a seed sample from each plot of *C. intermedia* was cleaned manually to determine the proportion of pure seed. A sample of light yellow (immature) seed and dark brown (mature) seed of *C. intermedia* was analyzed for viability (tetrazolium). In 2016, seed of *Chaenactis douglasii* was harvested manually once a week.

Machaeranthera canescens seed was harvested by cutting and windrowing the plants. After drying for 2 days the *M. canescens* plants were beaten on plastic tubs to separate the seed heads from the stalks. *Phacelia hastata* was harvested with a small-plot combine in 2014 and 2015. In

2016 and 2017, *P. hastata* was harvested manually due to the low stature of the plants. *Heliomeris multiflora* was harvested with a small plot combine in 2015 and 2016. The duration of flowering for *H. multiflora* tends to increase with increasing irrigation. In 2013 and 2014, the duration of flowering in the wetter plots of *H. multiflora* was much longer than in the drier plots, making a single mechanical harvest unfeasible. In 2015, the duration of flowering in the wetter plots of *H. multiflora* was shorter, enabling mechanical harvest. In 2016, plots of the driest treatment were harvested manually before the other plots, which were harvested mechanically on July 8. All plots of *H. multiflora* were harvested with a small plot combine in 2017.

Seed of all species was cleaned manually.

Statistical analysis

Seed yield means were compared by analysis of variance and by linear and quadratic regression. Seed yield (y) in response to irrigation or irrigation plus precipitation (x, inches/season) was estimated by the equation $y = a + b \cdot x + c \cdot x^2$. For the quadratic equations, the amount of irrigation (x') that resulted in maximum yield (y') was calculated using the formula $x' = -b/2c$, where a is the intercept, b is the linear parameter, and c is the quadratic parameter. For the linear regressions, the seed yield responses to irrigation were based on the actual greatest amount of water applied plus precipitation and the measured average seed yield.

Results and Discussion

Precipitation in the winter and spring in 2013 was lower and in 2017 was higher than the 5-year average (Table 3). In 2018, precipitation in the fall, winter, and spring was lower than average. Precipitation in the other years was close to the average. The accumulation of growing degree-days (50-86°F) was higher than average in 2013-2016 and in 2018 (Table 3). In 2017, the accumulation of growing degree-days was close to the average.

Achillea millefolium. Flowering and seed production in 2016, the first year after fall planting, was minimal. Seed yields of *A. millefolium* showed a quadratic response to irrigation in 2017 and 2018 with maximum seed yields of 235 lb/acre and 57 lb/acre at 6.2 and 7.9 inches of water applied in 2017 and 2018, respectively (Tables 4 and 5).

Chaenactis douglasii. Stands of *C. douglasii* were poor in 2013 and 2014 and did not permit evaluation of irrigation responses. Replanting in the fall of 2013-2015 was necessary to establish an adequate stand of *C. douglasii*, allowing evaluations of irrigation responses in 2015-2018. *Chaenactis douglasii* seed yields did not respond to irrigation in 2015-2017. In 2018, seed yield showed a quadratic response to irrigation with maximum seed yields of 85 lb/acre at 6.3 inches of water applied. Highest seed yields averaged 225 lb/acre over the 4 years.

Crepis intermedia. *Crepis intermedia* flowered and produced seed for the first time in 2015, the third year after fall planting in 2011. The uniform and short flowering of *C. intermedia* in 2016 allowed the seed from all plots to be harvested once. A single mechanical harvest is more efficient, but some of the seed could be immature because harvest needed to occur just before seed heads opened. In 2016, 77% of the seed harvested was mature and had a viability of 57%. The other 23% of the harvested seed was immature and had a viability of 5%. This suggests that a single harvest as conducted in this trial resulted in adequate seed quality. *Crepis intermedia* seed yields increased with increasing irrigation rate up to the highest rate of 8 inches in 2015. In 2016 and 2017, seed yields of *C. intermedia* did not respond to irrigation. In 2018, seed yield showed a quadratic response to irrigation with maximum seed yields of 151 lb/acre at 4 inches of water applied. Seed yields increased each year from 2015 to 2017 with highest seed yields of 302 lb/acre in 2017. Seed yields were lower in 2018.

Cymopterus bipinnatus. *Cymopterus bipinnatus* did not flower in either 2010 or 2011 and flowered very little in 2012. *Cymopterus bipinnatus* seed yields did not respond to irrigation in 2013 and 2016. In 2014, seed yields increased with increasing irrigation rate up to the highest rate of 8 inches. In 2015 and 2018, seed yields showed a quadratic response to irrigation with maximum seed yields at 4.2 and 4.8 inches of water applied in 2015 and 2018, respectively. In 2017, seed yields were highest with no irrigation. Averaged over the 6 years, seed yields were estimated to be highest with 5.2 inches of total applied irrigation water yielding 975 lb/acre of seed.

Enceliopsis nudicaulis. *Enceliopsis nudicaulis* seed yield was very low and did not respond to irrigation in 2013. In 2014, seed yield showed a quadratic response to irrigation with a maximum seed yield at 5.4 inches of water applied. Extensive die-off of *E. nudicaulis* occurred over the winter of 2014-2015 and was more severe in the plots receiving the highest amount of irrigation. Seed yields of *E. nudicaulis* were substantially reduced in 2015 and were highest without irrigation. In 2016, seed yield showed a quadratic response to irrigation with a maximum seed yield at 5.8 inches of water applied. In 2017, seed yields were highest without irrigation. Seed yields did not respond to irrigation in 2018. The replanting done in the fall of 2015 was successful, but stands continue to decline, especially in the irrigated plots. Highest seed yields averaged 26 lb/acre over the 4 years.

Heliomeris multiflora. *Heliomeris multiflora* seed yield increased with increasing irrigation rate up to the highest rate of 8 inches in 2013-2015; *H. multiflora* seed yield did not respond to irrigation in 2016 and 2017. In 2018, seed yields showed a quadratic response to irrigation with a maximum seed yield at 3.7 inches of water applied. Highest seed yields averaged 130 lb/acre over the 6 years.

Ipomopsis aggregata. *Ipomopsis aggregata* flowered very little in 2013, then flowered and set seed in 2014. The stand of *I. aggregata* died over the winter of 2014-2015, which indicated a biennial growth habit. *Ipomopsis aggregata* seed yields were highest with 4 inches of water applied in 2014 and 2017. Highest seed yields averaged 262 lb/acre over the 2 years.

Machaeranthera canescens. *Machaeranthera canescens* seed yields showed a quadratic response to irrigation with a maximum seed yield at 2.4 inches of water applied in 2013. In 2014, 2015, 2018, and averaged over the 3 years, seed yields of *M. canescens* did not respond to irrigation. Highest seed yields averaged 700 lb/acre over the 4 years. Partial die-off of *M. canescens* over the winter of 2015-2016 resulted in stand too uneven for an irrigation trial in 2016 and 2017. Natural reseeding occurred over the winter of 2016-2017, but the young plants did not flower in 2017.

Nicotiana attenuata. Stand establishment has been difficult with only one fall planting (2015) out of six resulting in adequate stand for the irrigation trial. Seed yields of *N. attenuata* showed a quadratic response to irrigation in 2016 with a maximum seed yield of 151 lb/acre at 4.6 inches of water applied

Phacelia hastata. Irrigation responses for *P. hastata* were evaluated for two sets of plots: the 6-year-old stand planted in 2012 and a new stand originating in 2015 from volunteer seed. *Phacelia hastata* (planted in the fall of 2012) seed yields showed a quadratic response to irrigation with a maximum seed yield at 5.3, 7.6, and 5.2 inches of water applied in 2013, 2014, and 2018, respectively. In 2015, seed yield of *P. hastata* did not respond to irrigation, possibly due to loss of stand in this weak perennial. The original stand of *P. hastata*, planted in the fall of 2012, was extremely poor in 2016 and seed was not harvested. Stand regenerated from natural reseeding in 2017, but seed was not produced.

Seed yields of *P. hastata* (started in the fall of 2014) increased with increasing irrigation rate up to the highest rate of 8 inches in 2015. In 2016 and 2018, seed yields of *P. hastata* showed a quadratic response to irrigation with a maximum seed yield at 4 and 6.8 inches of water applied in 2016 and 2018, respectively. In 2017, seed yields of *P. hastata* did not respond to irrigation. Averaged over the 4 years, seed yields of *P. hastata* showed a quadratic response to irrigation with a maximum seed yield of 162 lb/acre and 83 lb/acre at 6.2 and 5.5 inches of water applied for the 2012 and 2014 stands, respectively. The two stands of *P. hastata* showed a pattern of increased seed yields in the second year, a decline in the third year, and an increase in the fourth year.

Phacelia linearis. Seed yields of *P. linearis* showed a quadratic response to irrigation in 2013 with a maximum seed yield at 6.2 inches of water applied. In 2014, seed yields of *P. linearis* did not respond to irrigation. Highest seed yields averaged 240 lb/acre over the 2 years.

The replanting of *P. linearis* in the fall of 2014 and 2015 did not result in adequate stands. *Phacelia linearis* was replanted in the fall of 2016 in a different location in the field but stand in the spring of 2017 was extremely poor.

Thelypodium milleflorum. Seed yield of *T. milleflorum* did not respond to irrigation in any of the 3 years of seed production (Tables 4 and 5). Highest seed yields averaged 152 lb/acre over the 3 years.

Stands of *Ligusticum porteri* and *L. canbyi* were poor and uneven and did not permit evaluation of irrigation responses.

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Table 2. Native wildflower flowering, irrigation, and seed harvest dates by species. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013-2018. Table 2 is continued on the next page.

	Flowering dates			Irrigation dates		
Year	Start	Peak	End	Start	End	Harvest
***Achillea millefolium,* common yarrow**						
2017	26-Apr	7-Jun	12-Jul	2-May	20-Jun	26-Jul
2018	30-Apr	13-Jun	30-Jun	16-May	27-Jun	3-Aug
***Chaenactis douglasii,* Douglas' dustymaiden**						
2013	23-May	30-Jun	15-Jul	22-May	3-Jul	2-Jul, 22-Jul
2014	20-May		15-Jul	13-May	24-Jun	poor stand
2015	5-May		10-Jul	5-May	17-Jun	weekly, 8-Jun to 15-Jul
2016	23-May		22-Jul	23-May	8-Jul	weekly, 17-Jun to 7-Jul
2017	25-May	7-Jun	19-Jul	9-May	20-Jun	weekly, 16-Jun to 6-Jul
2018	10-May	13-Jun	10-Jul	16-May	27-Jun	weekly, 13-Jun to 15-Jul
***Machaeranthera canescens,* hoary tansyaster**						
2013	13-Aug		1-Oct	17-Jul	28-Aug	2-Oct
2014	20-Aug	17-Sep	5-Oct	22-Jul	2-Sep	6-Oct
2015	10-Aug	17-Sep	1-Oct	11-Aug	22-Sep	6-Oct, 15-Oct
2016	17-Aug	20-Sep	10-Oct			partial winter die-off
2017	29-Aug		20-Oct			
2018	20-Aug		22-Oct	23-Aug	20-Sep	22-Oct
***Phacelia hastata,* silverleaf phacelia**						
2013	17-May		30-Jul	22-May	3-Jul	30-Jul (0 in), 7-Aug, 19-Aug (8 in)
2014	5-May		10-Jul	29-Apr	10-Jun	14-Jul
2015 (1st year)	28-Apr	26-May	7-Aug	20-May	30-Jun	6-Aug
2015 (3rd year)	28-Apr	26-May	7-Aug	29-Apr	10-Jun	7-Jul (0 in), 21-Jul (4, 8 in)
2016	28-Apr		17-Jun	27-Apr	7-Jun	23-Jun
2017	8-May	7-Jun		2-May	20-Jun	25-Jul
2018	6-May		20-Jun	16-May	27-Jun	27-Jun
***Phacelia linearis,* threadleaf phacelia**						
2013	3-May	16-May	15-Jun	2-May	12-Jun	2-Jul
2014	5-May	4-Jun	1-Jul	1-May	10-Jun	7-Jul
2015		winter die-off				
***Enceliopsis nudicaulis,* nakedstem sunray**						
2013	30-Jun		15-Sep	3-Jul	14-Aug	weekly, 8-Aug to 30-Aug
2014	5-May	1-Jul	30-Jul	6-May	17-Jun	weekly, 14-Jul to 30-Aug
2015	28-Apr	13-May	5-Aug	29-Apr	10-Jun	weekly, 2-Jun to 15-Aug
2016	20-Apr		30-Jul	3-May	14-Jun	weekly, 27-Apr to 29-Jul
2017	11-May	7-Jun	20-Aug	23-May	6-Jul	weekly, 4-Jun to 15-Aug
2018	30-Apr	26-Jun	30-Jul	16-May	27-Jun	weekly, 27-Apr to 27-Jul

Table 2. (Continued.) Native wildflower flowering, irrigation, and seed harvest dates by species. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013-2018.

	Flowering dates			Irrigation dates		
Year	Start	Peak	End	Start	End	Harvest
***Heliomeris multiflora,* showy goldeneye**						
2013	15-Jul		30-Aug	5-Jun	17-Jun	8-Aug, 15-Aug, 28-Aug
2014	20-May	20-Jun	30-Aug	13-May	24-Jun	weekly, 15-Jul to 15-Aug
2015	5-May	26-May	10-Jul	5-May	17-Jun	13-Jul
2016	5-May	15-Jun	30-Sep	9-May	22-Jun	8-Jul
2017	12-May	7-Jun	30-Jul	9-May	20-Jun	17-Jul
2018	12-May	13-Jun	20-Jul	16-May	27-Jun	1-Aug
***Cymopterus bipinnatus,* Hayden's cymopterus**						
2013	5-Apr		15-May	12-Apr	22-May	10-Jun
2014	7-Apr		29-Apr	7-Apr	20-May	16-Jun
2015	25-Mar		24-Apr	1-Apr	13-May	8-Jun
2016	15-Mar		25-Apr	31-Mar	9-May	7-Jun
2017	27-Mar		1-May	19-Apr	6-Jun	16-Jun
2018	15-Mar		3-May	18-Apr	30-May	5-Jun
***Ipomopsis aggregata,* scarlet gilia**						
2013	31-Jul	very little flowering		31-Jul	11-Sep	
2014	22-Apr	13-May	30-Jul	23-Apr	3-Jun	20-Jun
2015		winter die-off				
2016		No flowering		7-Jun	22-Jul	
2017	1-May	15-May	27-Jun	2-May	20-Jun	23-Jun
2018		No flowering		16-May	27-Jun	
***Thelypodium milleflorum,* manyflower thelypody**						
2013		No flowering				
2014	22-Apr	5-May	10-Jun	23-Apr	3-Jun	2-Jul
2015		No flowering				
2016	11-Apr	6-May	8-Jun	11-Apr	23-May	21-Jun
2017		No flowering				
2018	27-Apr	10-May	10-Jun	3-May	13-Jun	18-Jun
***Crepis intermedia,* limestone hawksbeard**						
2015	28-Apr	5-May	1-Jun	21-Apr	3-Jun	weekly, 1-Jun to 2-Jul
2016	29-Apr		25-May	27-Apr	7-Jun	26-May
2017	15-May		7-Jun	9-May	20-Jun	8-Jun
2018	3-May		25-May	3-May	13-Jun	31-May
***Nicotiana attenuata*, coyote tobacco**						
2016	16-May		31-Jul	16-May	22-Jun	weekly, 21-Jun to 29-Jul
2017	1-May		15-Aug			

Table 3. Precipitation and growing degree-days at the Malheur Experiment Station, Ontario, OR, 2013-2018.

	Precipitation (inch)			Growing degree-days (50-86°F)
Year	Spring	Winter + spring	Fall + winter + spring	Jan–Jun
2013	0.9	2.4	5.3	1319
2014	1.7	5.1	8.1	1333
2015	3.2	5.9	10.4	1610
2016	2.2	5.0	10.1	1458
2017	4.0	9.7	12.7	1196
2018	1.9	4.9	5.8	1342
5-year average:	2.4	5.6	9.3	25-year average: 1207

Table 4. Native wildflower seed yield (lb/acre) in response to season-long irrigation rate (inches). Malheur Experiment Station, Oregon State University, Ontario, OR, 2013-2018. Table 4 is continued on the next page.

		Irrigation rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
		-------------- lb/acre --------------			
Achillea millefolium	2017	59.2	213.3	220.4	99.8
	2018	7.3	45.1	57.1	NS
	Average	23.2	93.2	94.0	46.0
Chaenactis douglasii	2015	132.1	137.6	183.3	NS[a]
	2016	29.1	16.0	27.2	NS
	2017	707.1	711.1	627.3	NS
	2018	7.9	74.7	79.6	12.5
	Average	208.3	213.7	225.4	NS
Crepis intermedia	2015	68.6	55.5	166.3	63.2
	2016	83.6	87.0	77.8	NS
	2017	301.5	268.1	287.1	NS
	2018	98.3	151.0	100.2	16.1
	Average	138.0	140.4	155.5	NS
Cymopterus bipinnatus	2013	194.2	274.5	350.6	NS
	2014	1236.2	1934.0	2768.5	844.7
	2015	312.3	749.0	374.9	240.7
	2016	1501.4	2120.6	1799.0	546.6 [b]
	2017	245.4	178.6	95.8	NS
	2018	87.0	149.5	122.5	15.8
	Average	618.8	956.4	868.2	153.2
Enceliopsis nudicaulis	2013	2.3	6.8	5.9	NS
	2014	1.5	34.6	29.1	20.7
	2015	15.7	3.2	4.4	7.3
	2016	10.5	47.6	45.9	34.9
	2017	105.0	43.2	25.0	59.6
	2018	20.2	20.5	20.1	NS
	Average	25.9	26.2	21.7	NS

Table 4. (Continued.)Native wildflower seed yield (lb/acre) in response to season-long irrigation rate (inches). Malheur Experiment Station, Oregon State University, Ontario, OR, 2013-2018.

		Irrigation rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
		-------------- lb/acre --------------			
Heliomeris multiflora	2013	28.7	57.6	96.9	NS
	2014	154.6	200.9	271.7	107.3[b]
	2015	81.7	115.6	188.2	58.2
	2016	92.3	89.2	98.0	NS
	2017	87.8	75.9	89.9	NS
	2018	44.5	73.9	34.3	23.4
	Average	84.0	101.4	129.8	24.7
Ipomopsis aggregata	2014	47.1	60.9	63.6	9.0
	2017	241.0	315.8	188.8	74.5
	Average	180.3	261.7	145.1	97.2
Machaeranthera canescens	2013	206.1	215	124.3	73.6
	2014	946.1	1210.2	1026.3	NS
	2015	304.1	402.6	459.1	NS
	2018	330.3	426.3	380.6	NS
	Average	586.1	701.6	634.3	NS
Nicotiana attenuata	2016	49.4	151.0	95.8	81.4
Phacelia hastata	2013	35.3	102.7	91.2	35.7
(planted fall 2012)	2014	87.7	305.7	366.4	130.3
	2015	78.8	79.3	65.0	NS
	2018	32.8	108.6	89.6	59.4
	Average	58.6	149.1	153.0	37.0
Phacelia hastata	2015	0.0	21.4	50.4	13.7
(planted fall 2014)	2016	82.5	125.2	83.1	26.8
	2017	20.3	23.2	23.2	NS
	2018	57.1	128.5	140.2	68.3
	Average	40.0	79.6	74.2	22.0
Phacelia linearis	2013	121.4	306.2	314.2	96
	2014	131.9	172.9	127.2	NS
	Average	126.7	239.5	220.7	87.2
Thelypodium milleflorum	2014	200.5	246.2	205.6	NS
	2016	121.9	110.0	63.3	NS
	2018	61.4	61.4	64.1	NS
	Average	131.5	151.7	117.0	NS

[a]Not significant. [b]LSD (0.10).

Table 5. Regression analysis for native wildflower seed yield (y) in response to irrigation (x) (inches/season) using the equation $y = a + b \bullet x + c \bullet x^2$. For the quadratic equations, the amount of irrigation that resulted in maximum yield was calculated using the formula: -b/2c, where b is the linear parameter and c is the quadratic parameter. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013-2018. Table 5 is continued on the next page.

Species	Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
							lb/acre	inches/season
Achillea millefolium	2017	59.2	56.9	-4.6	0.75	0.01	235.4	6.2
	2018	7.3	12.7	-0.8	0.49	0.1	57.1	7.9
	Average	23.2	26.2	-2.2	0.72	0.01	102.3	6.0
Chaenactis douglasii	2015	125.4	6.4		0.08	NS[a]		
	2016	25.1	-0.2		0.01	NS		
	2017	707.1	12.0	-2.7	0.09	NS		
	2018	7.9	24.4	-1.9	0.99	0.001	85.1	6.3
	Average	207.2	2.1		0.04	NS		
Crepis intermedia	2015	49.0	11.4		0.31	0.10	176.6	8.0
	2016	83.6	2.4	-0.4	0.07	NS		
	2017	292.8	-1.8		0.01	NS		
	2018	98.3	26.1	-3.2	0.41	0.10	151.0	4.0
	Average	135.5	2.4		0.07	NS		
Cymopterus bipinnatus	2013	194.9	19.6		0.07	NS		
	2014	1214.6	190.6		0.41	0.05	2739.4	8.0
	2015	312.3	210.5	-25.3	0.46	0.10	749.6	4.2
	2016	1501.4	272.4	-29.4	0.34	NS		
	2017	308.1	-24.4		0.38	0.10	308.1	0.0
	2018	87.0	26.8	-2.8	0.60	0.05	151.3	4.8
	Average	618.8	137.6	-13.3	0.52	0.05	974.6	5.2
Enceliopsis nudicaulis	2013	3.1	0.4		0.16	NS		
	2014	1.5	13.1	-1.2	0.6	0.05	37.3	5.5
	2015	13.4	-1.4		0.29	0.10	13.4	0.0
	2016	10.5	14.1	-1.2	0.57	0.05	51.6	5.8
	2017	99.1	-10.0		0.44	0.05	99.1	0.0
	2018	20.3	0.0		0.01	NS		
	Average	25.9	0.7	-0.1	0.04	NS		

[a] Not significant. There was no statistically significant trend in seed yield in response to amount of irrigation.

Table 5. (Continued.) Regression analysis for native wildflower seed yield (y) in response to irrigation (x) (inches/season) using the equation $y = a + bx + cx^2$. For the quadratic equations, the amount of irrigation that resulted in maximum yield was calculated using the formula: $-b/2c$, where b is the linear parameter and c is the quadratic parameter. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013-2018.

Species	Year	intercept	linear	quadratic	R^2	P	Maximum yield	Water applied for maximum yield
							lb/acre	inches/season
Heliomeris multiflora	2013	27	8.5		0.38	0.05	95.0	8.0
	2014	150.5	14.6		0.27	0.10	267.3	8.0
	2015	75.2	13.3		0.48	0.05	181.8	8.0
	2016	90.7	0.7		0.01	NS		
	2017	83.5	0.3		0.01	NS		
	2018	44.5	16.0	-2.2	0.72	0.01	74.1	3.7
	Average	82.1	5.7		0.44	0.05	128.0	8.0
Ipomopsis aggregata	2014	48.5	2.1		0.23	NS		
	2017	241.0	43.9	-6.3	0.52	0.05	317.5	3.5
	Average	180.3	45.1	-6.2	0.24	NS		
Machaeranthera canescens	2013	206.1	14.7	-3.1	0.54	0.05	223.5	2.4
	2014	946.1	122	-14	0.13	NS		
	2015	311.1	19.4		0.02	NS		
	2018	330.3	41.7	-4.4	0.03	NS		
	Average	586.1	51.7	-5.7	0.09	NS		
Nicotiana attenuata	2016	49.4	45.0	-4.9	0.50	0.05	152.7	4.6
Phacelia hastata	2013	35.3	26.7	-2.5	0.66	0.01	106.6	5.3
(planted fall 2012)	2014	87.7	74.2	-4.9	0.76	0.01	368.6	7.6
	2015	78.8	2.0	-0.5	0.04	NS		
	2018	32.8	30.8	-3.0	0.49	0.05	112.9	5.2
	Average	58.6	33.4	-2.7	0.84	0.001	162.0	6.2
Phacelia hastata	2015	-1.3	6.3		0.88	0.001	49.2	8.0
(planted fall 2014)	2016	82.5	21.3	-2.6	0.72	0.01	125.2	4.0
	2017	20.3	1.1	-0.1	0.04	NS		
	2018	57.1	25.3	-1.9	0.57	0.05	143.0	6.8
	Average	40.0	15.5	-1.4	0.69	0.01	82.8	5.5
Phacelia linearis	2013	121.4	68.3	-5.5	0.69	0.01	333.4	6.2
	2014	131.9	21.1	-2.7	0.11	NS		
	Average	126.7	44.7	-4.1	0.48	0.1	248.5	5.5
Thelypodium milleflorum	2014	200.5	22.2	-2.7	0.12	NS		
	2016	121.9	1.4	-1.1	0.35	NS		
	2018	61.0	0.3		0.01	NS		
	Average	131.5	11.9	-1.7	0.16	NS		

[a] Not significant. There was no statistically significant trend in seed yield in response to amount of irrigation.

BEEPLANT SEED YIELD IN RESPONSE TO MODEST IRRIGATION

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Summary

Beeplants (*Cleome* spp.) are annual native range species in the Intermountain West. Beeplant is visited by many classes of pollinators and are thought to be supportive of a wide range of pollinators. Beeplant seed is desired for rangeland restoration activities, but little cultural practice information is known for its seed production. The seed yield response of *Cleome serrulata* (Rocky Mountain beeplant) and *C. lutea* (yellow spiderflower or yellow beeplant) to irrigation was studied. Four biweekly irrigations applying either 0, 1, or 2 inches of water (total of 0, 4, or 8 inches/season) were evaluated over multiple years. Beeplant stands were established through fall plantings each year and were maintained without weed competition. *Cleome serrulata* seed yield was maximized by 8 inches of water applied per season in 2011, but did not respond to irrigation in the following years (2012-2018). *Cleome lutea* seed yield was highest with no irrigation in 2016. *Cleome lutea* seed yield did not respond to irrigation in 2012, 2014, 2015, and 2018. *Cleome lutea* stands were lost to flea beetles in 2013 and to poor emergence in 2017. Flea beetle control is essential for seed production.

Introduction

Native wildflower seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native wildflower (forb) seed is stable and consistent seed productivity over years.

In natural rangelands, the annual variation in spring rainfall and soil moisture results in highly unpredictable water stress at flowering, seed set, and seed development, which for other seed crops is known to compromise seed yield and quality.

Native wildflower plants are not well adapted to croplands; they do not compete well with crop weeds in cultivated fields, which could also limit their seed production. Both sprinkler and furrow irrigation could provide supplemental water for seed production, but these irrigation systems risk further encouraging weeds. Also, sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. By burying drip tapes at 12-inch depth and avoiding wetting the soil surface, we designed experiments to assure flowering and seed set without undue encouragement of weeds or opportunistic diseases. The trials reported here tested the effects of three low rates of irrigation on the seed yield of *Cleome serrulata* (Rocky Mountain beeplant) and *C. lutea* (yellow beeplant).

Materials and Methods

Plant establishment

Each species was planted in separate strips containing four rows 30 inches apart (a 10-ft-wide strip) and about 450 ft long on Nyssa silt loam at the Malheur Experiment Station, Ontario, Oregon. The soil had a pH of 8.3 and 1.1% organic matter. In October 2010, two drip tapes 5 ft apart (T-Tape TSX 515-16-340) were buried at 12-inch depth to irrigate the four rows in the plot. Each drip tape irrigated two rows of plants. The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 psi with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour.

Starting in 2010, seed of *Cleome serrulata* was planted in mid-November each year in 30-inch rows using a custom-made small-plot grain drill with disc openers. All seed was planted on the soil surface at 20-30 seeds/ft of row in the same location each year. After planting, sawdust was applied in a narrow band over the seed row at 0.26 oz/ft of row (558 lb/acre). Following planting and sawdust application, the beds were covered with row cover. The row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO) covered four rows (two beds) and was applied with a mechanical plastic mulch layer. Starting in 2011, seed of *C. lutea* was also planted each year. After the newly planted wildflowers had emerged, the row cover was removed in April each year.

Starting in 2013, each spring after the row cover was removed, bird netting was placed over the *Cleome serrulata* and *C. lutea* plots to protect seedlings from bird feeding. The bird netting was placed over No. 9 galvanized wire hoops.

Flea beetle control

An unidentified species of flea beetle was observed feeding on leaves of *Cleome serrulata* and *C. lutea* in April 2012. On April 29, 2012, all plots of *C. serrulata* and *C. lutea* were sprayed with Capture® at 5 oz/acre to control flea beetles. On June 11, 2012, *C. serrulata* was again sprayed with Capture at 5 oz/acre to control a reinfestation of flea beetles.

Flea beetle feeding occurred earlier in 2013 than in 2012. Upon removal of the row cover in March 2013, the flea beetle damage for both species at seedling emergence was extensive and resulted in full stand loss. Flea beetles were not observed on either species in 2014.

On March 20, 2015, after removal of the row cover, all plots of *C. serrulata* and *C. lutea* were sprayed with Capture at 5 oz/acre to control flea beetles. On April 3, 2015, all plots of *C. serrulata* and *C. lutea* were sprayed with Entrust® at 2 oz/acre (0.03 lb ai/acre) to control flea beetles.

On March 18, 2016, after removal of the row cover, all plots of *C. serrulata* and *C. lutea* were sprayed with Radiant® at 8 oz/acre and on April 6, all plots were sprayed with Capture at 5 oz/acre to control flea beetles. On June 30, all plots of *C. serrulata* were sprayed with Sivanto® at 14 oz/acre to control flea beetles.

The following insecticides were applied to both species for flea beetle control in 2017: April 11, Radiant at 8 oz/acre; May 4, Capture at 5 oz/acre; July 14, Capture at 5 oz/acre and Rimon® at 12 oz/acre; July 25 and August 4, Rimon at 12 oz/acre.

The insecticide Agri-Mek® at 16 oz/acre was applied on April 18, 2018 to both species for flea beetle control. Flea beetles were not observed on *C. lutea* after April 18. The following insecticides were applied to *C. serrulata* for flea beetle control: Capture at 5 oz/acre on April 27, 2018 and Rimon at 12 oz/acre on June 13.

Weeds were controlled by hand weeding as necessary.

Irrigation for seed production

In April 2011, each strip of each wildflower species was divided into 12 30-ft plots. Each plot contained four rows of each species. The experimental design for each species was a randomized complete block with four replicates. The three treatments were a nonirrigated check, 1 inch of water applied per irrigation, and 2 inches of water applied per irrigation. Each treatment received 4 irrigations that were applied approximately every 2 weeks starting with bud formation and flowering. The amount of water applied to each treatment was calculated by the length of time necessary to deliver 1 or 2 inches through the drip system. Irrigations were regulated with a controller and solenoid valves.

The drip-irrigation system was designed to allow separate irrigation of each species due to different timings of flowering and seed formation. Flowering, irrigation, and harvest dates were recorded (Table 1). In 2014, after the four bi-weekly irrigations ended, *C. serrulata* and *C. lutea* received three additional bi-weekly irrigations starting on August 12 in an attempt to extend the flowering and seed production period. On August 12, 50 lb nitrogen/acre, 30 lb phosphorus/acre, and 0.2 lb iron/acre were applied through the drip tape to all *Cleome* plots.

Flowering and harvest

The two species have a long flowering and seed-set period (Table 1), making mechanical harvesting difficult. Mature seed pods were harvested manually 2 to 4 times each year.

Table 1. *Cleome serrulata* and *C. lutea* flowering, irrigation, and seed harvest dates by species. Malheur Experiment Station, Oregon State University, Ontario, OR.

		Flowering dates			Irrigation dates		
Species	Year	Start	Peak	End	Start	End	Harvest
Cleome serrulata	2011	25-Jun	30-Jul	15-Aug	21-Jun	2-Aug	26-Sep
	2012	12-Jun	30-Jun	30-Jul	13-Jun	25-Jul	24-Jul to 30-Aug
	2013	Full stand loss					
	2014	4-Jun	24-Jun	22-Jul	20-May	1-Jul	11-Jul to 30-Jul
	2015	20-May	24-Jun	15-Sep	20-May	30-Jun	1-Jul to 15-Aug
	2016	23-May		20-Sep	16-May	29-Jun	28-Jun to 15-Aug
	2017	7-Jun		29-Sep	6-Jun	15-Sep	31-Jul, 4-Oct
	2018	29-May		1-Oct	30-May	5-Jul	16-Jul to 20-Aug
Cleome lutea	2012	16-May	15-Jun	30-Jul	2-May	13-Jun	12-Jul to 30-Aug
	2013	Full stand loss, flea beetle damage					
	2014	29-Apr	4-Jun	22-Jul	23-Apr	3-Jun	23-Jun to 30-Jul
	2015	8-Apr	13-May	6-Jul	17-Apr	27-May	4-Jun to 30-Jul
	2016	13-Apr	13-May	25-Jul	18-Apr	31-May	14-Jun to 22-Jul
	2017	5-May		10-Aug		poor stand	
	2018	23-Apr	13-Jun	20-Aug	3-May	13-Jun	1-Jun to 15-Jul

Statistical analysis

Seed yield means were compared by analysis of variance and by linear and quadratic regression. Seed yield (y) in response to irrigation or irrigation plus precipitation (x, inches/season) was estimated by the equation $y = a + b \cdot x + c \cdot x^2$. For the quadratic equations, the amount of irrigation (x') that resulted in maximum yield (y') was calculated using the formula $x' = -b/2c$, where a is the intercept, b is the linear parameter, and c is the quadratic parameter. For the linear regressions, the seed yield responses to irrigation were based on the actual greatest amount of water applied plus precipitation and the measured average seed yield.

Results and Discussion

Spring precipitation in 2012 and 2016 was close to the average of 2.9 inches (Table 2). Spring precipitation in 2013 and 2014 was lower than the average and spring precipitation in 2011 and 2017 was higher than the average. The total growing degree-days (50-86°F) in June and July in 2012-2017 were higher than average (Table 2) and were associated with early flowering and seed harvest.

Cleome serrulata, Rocky Mountain beeplant

In 2011, seed yields increased with increasing irrigation up to the highest tested of 8 inches (Tables 3 and 4). Seed yields did not respond to irrigation the other years. There was no plant stand in 2013 due to early, severe flea beetle damage. The additional irrigations starting on August 12, 2014 did result in an extension/resumption of flowering, but seed harvested in mid-

October was not mature. Flowering in 2015-2017 continued through the end of September, but as in 2014, seed set in September of 2015 and 2016 did not mature. Seed set in September 2017 matured and was harvested. Seed set and seed production were extremely poor in 2016. Continued flea beetle infestations could have caused the poor seed set. A more intensive control program than the three insecticide applications in 2016 might have been necessary. Birds were also observed feeding on seedpods and might have been responsible for the low seed yields. Five insecticide applications were made in 2017. Seed yields in 2017 were higher than in 2016 and similar to 2014 and 2015.

The year 2011 had the highest seed yield and also had the lower than average accumulated growing degree-days, suggesting the possibility of a negative effect of higher temperatures on sustained flowering and seed set. All other years (2012-2018) had higher than average growing degree-days and low yields.

Cleome lutea, **yellow spiderflower or yellow beeplant**

Seed yields did not respond to irrigation in 2012, 2014, 2015, or 2018 (Tables 3 and 4). In 2016 seed yields were highest with no irrigation. There was no plant stand in 2013. Early attention to flea beetle control is essential for *C. lutea* seed production. The additional irrigations starting on August 12, 2014 did not result in an extension or resumption of flowering. In 2017, emergence was poor and uneven and did not allow an evaluation of irrigation responses.

Acknowledgements

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Table 2. Early season precipitation and growing degree-days at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2018.

	Precipitation (inch)			Growing degree-days (50-86°F)
Year	Spring	Winter +spring	Fall + winter + spring	March - August
2011	4.8	9.3	14.5	2222
2012	2.6	6.1	8.4	2664
2013	0.9	2.4	5.3	2774
2014	1.7	5.1	8.1	2775
2015	3.2	5.9	10.4	2949
2016	2.2	5.0	10.1	2779
2017	4.0	9.7	12.7	2668
2018	1.9	4.9	5.8	2729
8-year average:	2.7	6.1	9.4	25-year average: 2560

Table 3. *Cleome serrulata* and *C. lutea* seed yield (lb/acre) in response to irrigation rate (inches/season). Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2018.

		Irrigation rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
		------------ lb/acre -----------			
Cleome serrulata	2011	446.5	499.3	593.6	100.9[a]
	2012	184.3	162.9	194.7	NS[b]
	2013		No stand		
	2014	66.3	80	91.3	NS
	2015	54.0	41.0	37.9	NS
	2016	0.8	2.1	1.6	NS
	2017	46.5	52.3	34.8	NS
	2018	0.6	0.7	0.5	NS
	Average	100.2	105.1	119.4	NS
Cleome lutea	2012	111.7	83.7	111.4	NS
	2013	No stand			
	2014	207.1	221.7	181.7	NS
	2015	136.9	80.5	113.0	NS
	2016	65.6	48.9	35.0	18.7
	2017		poor stand		
	2018	1.4	0.6	0.7	NS
	Average	104.5	87.1	88.4	NS

[a] LSD (0.10).

[b] Not significant: There was no statistically significant trend in seed yield in response to the amount of irrigation.

Table 4. Regression analysis for *Cleome serrulata* and *C. lutea* seed yield (y) in response to irrigation (x) (inches/season) using the equation $y = a + b \cdot x + c \cdot x^2$. Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2018.

Cleome serrulata

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2011	439.6	18.4		0.35	0.05	586.7	8
2012	175.4	1.3		0.01	NS[a]		
2014	66.7	3.1		0.16	NS		
2015	52.4	-2.0		0.08	NS		
2016	0.8	0.6	-0.1	0.19	NS		
2017	46.5	4.4	-0.7	0.11	NS		
2018	0.6	0.04	-0.01	0.06	NS		
Average	98.6	2.4		0.32	0.1	117.8	8

Cleome lutea

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2012	102.4	-0.031		0.01	NS		
2014	207.1	10.4	-1.7	0.2	NS		
2015	122.0	-3.0		0.08	NS		
2016	65.2	-3.8		0.45	0.05	65.2	0.0
2018	1.2	-0.1		0.10	NS		
Average	101.4	-2.0		0.2	NS		

[a] Not significant.

NATIVE BUCKWHEAT SEED YIELD IN RESPONSE TO MODEST IRRIGATION

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Summary

Native buckwheats (*Eriogonum* spp.) are important small perennial shrubs in the Intermountain West. Buckwheat seed is desired for rangeland restoration activities, but little cultural practice information is available for seed production of native buckwheat. The seed yield of *Eriogonum umbellatum* and *E. heracleoides* was evaluated over multiple years in response to four biweekly irrigations applying either 0, 1, or 2 inches of water (total of 0, 4, or 8 inches/season). Seed yield of *E. umbellatum* responded to irrigation plus spring precipitation in 11 of the 13 years, with 5 to 11 inches of water applied plus spring precipitation maximizing yields, depending on year. Averaged over 13 years, seed yield of *E. umbellatum* showed a quadratic response to irrigation rate plus spring precipitation and was estimated to be maximized at 210 lb/acre/year by irrigation plus spring precipitation of 8.2 inches. Over eight seasons, seed yield of *E. heracleoides* responded to irrigation only in 2013, a dry year when seed yield was maximized by 4.9 inches of applied water. Averaged over 8 years, seed yield of *E. heracleoides* showed a quadratic response to irrigation rate; the highest yield was achieved with 5 inches of water applied.

Introduction

Native wildflower seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native wildflower (forb) seed is stable and consistent seed productivity over years.

In native rangelands, the natural variations in spring rainfall and soil moisture result in highly unpredictable water stress at flowering, seed set, and seed development, which for other seed crops is known to compromise seed yield and quality.

Native wildflower plants are not well adapted to croplands because they often are not competitive with crop weeds in cultivated fields, which could limit wildflower seed production. Both sprinkler and furrow irrigation could provide supplemental water for seed production, but these irrigation systems risk further encouraging weeds. Also, sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. By burying drip tapes at 12-inch depth and avoiding wetting the soil surface, we designed experiments to assure flowering and seed set without undue encouragement of weeds or opportunistic diseases. The trials reported here tested the effects of three low rates of irrigation on the seed yield of

Eriogonum umbellatum (sulphur-flower buckwheat) and *E. heracleoides* (parsnipflower buckwheat).

Materials and Methods

Plant establishment

Seed of *Eriogonum umbellatum* was received in late November in 2004 from the Rocky Mountain Research Station (Boise, ID). The plan was to plant the seed in the fall of 2004, but due to excessive rainfall in October, the ground preparation was not completed and planting was postponed to early 2005. To try to ensure germination, we submitted the seed to cold stratification. The seed was soaked overnight in distilled water on January 26, 2005, after which the water was drained and the seed soaked for 20 min in a 10% by volume solution of 13% bleach in distilled water. The water was drained and the seed was placed in thin layers in plastic containers. The plastic containers had lids with holes drilled in them to allow air movement. These containers were placed in a cooler set at approximately 34°F. Every few days the seed was mixed and, if necessary, distilled water added to maintain seed moisture.

In late February 2005, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between 2 30-inch rows of a Nyssa silt loam with a pH of 8.3 and 1.1% organic matter. The drip tape was buried in alternating inter-row spaces (5 ft apart). The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 psi with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour.

On March 3, 2005, seed of *E. umbellatum* was planted in 30-inch rows using a custom-made small-plot grain drill with disc openers. All seed was planted at 20-30 seeds/ft of row at 0.25-inch depth. The trial was irrigated with a mini-sprinkler system (R10 Turbo Rotator, Nelson Irrigation Corp., Walla Walla, WA) from March 4 to April 29 for even stand establishment. Risers were spaced 25 ft apart along the flexible polyethylene hose laterals that were spaced 30 ft apart and the water application rate was 0.10 inch/hour. A total of 1.72 inches of water was applied with the mini-sprinkler system. *Eriogonum umbellatum* started emerging on March 29. Starting June 24, the field was irrigated with the drip system. A total of 3.73 inches of water was applied with the drip system from June 24 to July 7. The field was not irrigated further in 2005.

Plant stands for *E. umbellatum* were uneven, and it did not flower in 2005. In early October 2005, more seed was received from the Rocky Mountain Research Station for replanting. The empty lengths of row were replanted by hand. The seed was replanted on October 26, 2005. In the spring of 2006, the plant stands were excellent.

In early November 2009, drip tape was buried as described above in preparation for planting

E. heracleoides. On November 25, 2009 seed of *E. heracleoides* was planted in 30-inch rows using a custom-made small-plot grain drill with disc openers. All seed was planted on the soil surface at 20-30 seeds/ft of row. After planting, sawdust was applied in a narrow band over the seed row at 0.26 oz/ft of row (558 lb/acre). Following planting and sawdust application, the beds were covered with row cover. The row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO) covered four rows (two beds) and was applied with a mechanical plastic mulch layer. The field was irrigated for 24 hours on December 2, 2009 due to very dry soil conditions.

After *E. heracleoides* emerged, the row cover was removed in April 2010. The irrigation treatments were not applied to *E. heracleoides* in 2010, and stands were not adequate for yield estimates. Gaps in the rows were replanted by hand on November 5, 2010. The replanted seed was covered with a thin layer of a mixture of 50% sawdust and 50% hydro-seeding mulch (Hydrostraw LLC, Manteno, IL) by volume. The mulch mixture was sprayed with water using a backpack sprayer.

Irrigation for seed production

The planted strips were divided into plots 30 ft long (*E. umbellatum* in April 2006 and *E. heracleoides* in April 2011). Each plot contained four rows of each species. The experimental designs were randomized complete blocks with four replicates. The three treatments were a nonirrigated check, 1 inch of water applied per irrigation, and 2 inches of water applied per irrigation. Each treatment received 4 irrigations that were applied approximately every 2 weeks starting at bud formation and flowering. The amount of water applied to each treatment was calculated by the length of time necessary to deliver 1 or 2 inches through the drip system. Irrigations were regulated with a controller and solenoid valves. Irrigation dates are found in Table 1.

Flowering, harvesting, and seed cleaning

Flowering dates for each species were recorded annually (Table 1). The *E. umbellatum* plots produced seed in 2006, in part because they had emerged in the spring of 2005. *Eriogonum heracleoides* started flowering in 2011. Each year, the middle two rows of each plot were harvested when seed of each species was mature (Table 1). Seed was harvested with a small-plot combine every year, except 2013 and 2016 when seed was harvested manually. *Eriogonum umbellatum* and *E. heracleoides* seeds did not separate from the flowering structures in the combine. In 2006, the unthreshed seed of *E. umbellatum* was taken to the U.S. Forest Service Lucky Peak Nursery (Boise, ID) and run through a dewinger to separate seed. The seed was further cleaned in a small clipper seed cleaner. In subsequent years, the unthreshed seed of both species was run through a meat grinder to separate the seed. The seed was further cleaned in a small clipper seed cleaner.

Cultural practices

On October 27, 2006, 50 lb phosphorus/acre and 2 lb zinc/acre were injected through the drip tape to all plots of *E. umbellatum*.

The herbicides pendimethalin (Prowl®) and sethoxydim (Poast®) have been used for weed control. On November 17, 2006, November 9, 2007, April 15, 2008, December 4, 2009, March 18, 2009, November 17, 2010, November 9, 2011, November 7, 2012, February 26, 2014, March 13, 2015, November 11, 2015, October 27, 2016, and October 19, 2017 all plots of *E. umbellatum* had Prowl at 1 lb ai/acre broadcast on the soil surface for weed control. All plots of *E. heracleoides* had Prowl at 1 lb ai/acre broadcast on the soil surface for weed control on November 9, 2011, November 7, 2012, February 26, 2014, March 13, 2015, October 27, 2016, and April 21, 2017.

On March 18, 2009, April 3, 2013, February 26, 2014, and November 11, 2015, Poast at 0.38 lb ai/acre was broadcast on the soil surface for weed control in all *E. umbellatum* plots. On February 26, 2014 and April 21, 2017, Poast at 0.38 lb ai/acre was broadcast on all plots of *E. heracleoides*. In addition to herbicides, hand weeding was used as necessary to control weeds.

Statistical analysis

Seed yield means were compared by analysis of variance and by linear and quadratic regression. Seed yield (y) in response to irrigation or irrigation plus precipitation (x, inches/season) was estimated by the equation $y = a + b \bullet x + c \bullet x^2$. For the quadratic equations, the amount of irrigation (x') that resulted in maximum yield (y') was calculated using the formula $x' = -b/2c$, where a is the intercept, b is the linear parameter, and c is the quadratic parameter. For the linear regressions, the seed yield responses to irrigation were based on the actual greatest amount of water applied plus precipitation and the measured average seed yield.

For each species, seed yields for each year were regressed separately against 1) applied water; 2) applied water plus spring precipitation; 3) applied water plus winter and spring precipitation; and 4) applied water plus fall, winter, and spring precipitation. Winter and spring precipitation occurred in the same year that yield was determined; fall precipitation occurred the prior year.

Adding the seasonal precipitation to the irrigation response equation has the potential to provide a closer estimate of the amount of water required for maximum seed yields of the *Eriogonum* species. Regressions of seed yield each year were calculated on all the sequential seasonal amounts of precipitation and irrigation, but only some of the regressions are reported below. The period of precipitation plus applied water that had the lowest standard deviation for irrigation plus precipitation over the years was chosen as the most reliable independent variable for predicting seed yield.

Results and Discussion

Spring precipitation in 2009, 2012, and 2014 was close to the average of 5.8 inches (Table 2). Spring precipitation in 2009-11, and 2017 was higher than the average and spring precipitation in 2007, 2008, 2013, 2014, and 2018 was lower than the average of 2.9 inches. The accumulated growing degree-days (50-86°F) from January through June in 2007, 2013-2016, and 2018 were higher than average (Table 2). Both buckwheats flowered and were harvested earlier in 2013-2016 than in 2011-2012 (Table 1), consistent with more early season growing degree-day accumulations (Table 2).

Seed yields

Eriogonum umbellatum, sulfur-flower buckwheat

Seed yield of *E. umbellatum* exhibited a positive linear response to irrigation rate in 2006 (Tables 3 and 4). In 2007-2009, 2012-2016, and 2018 seed yield showed a quadratic response to irrigation rate. In 2010 and 2017, there was no significant difference in yield between the irrigation treatments. In 2011, seed yield was highest with no irrigation. The 2010 and 2011 seasons had unusually cool and wet weather (Table 2). The accumulated spring plus winter precipitation in 2010, 2011, and 2017 was higher than average. The negative effect of irrigation on seed yield in 2011 might have been compounded by the presence of rust. Irrigation could have exacerbated the rust and resulted in lower yields.

Averaged over 13 years, seed yield showed a quadratic response to irrigation rate plus spring precipitation and was estimated to be maximized at 210 lb/acre/year by irrigation plus spring precipitation of 8.2 inches.

***Eriogonum heracleoides,* parsnipflower buckwheat**

For *E. heracleoides*, seed yield responded to irrigation only in 2013 and 2017. In 2013 and 2017, seed yields showed a quadratic response to irrigation with a maximum seed yield at 4.9 and 4.7 inches of water applied, respectively. Seed yields did not respond to irrigation in 2011, 2012, 2014-2016, or 2018 (Tables 3 and 4). Averaged over 8 years, seed yield of *E. heracleoides* showed a quadratic response to irrigation rate with the highest yield achieved with 5 inches of water applied.

Conclusions

Buckwheat flowering and harvests have been early in 2013-2016, probably due to warmer weather. The total irrigation requirements for these arid-land species were low and varied by species. *Eriogonum heracleoides* seed yields responded to irrigation only in 2013, a drier than average year, and in 2017. In the other years, natural rainfall was sufficient to maximize seed production in the absence of weed competition. Seed yield of *E. umbellatum* responded to irrigation plus spring precipitation in 11 of the 13 years, with irrigation plus spring precipitation of 8.2 inches maximizing yields.

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Table 1. *Eriogonum umbellatum* and *E. heracleoides* flowering, irrigation, and seed harvest dates by species in 2006-2018, Malheur Experiment Station, Oregon State University, Ontario, OR.

		Flowering dates			Irrigation dates		
Species	Year	Start	Peak	End	Start	End	Harvest
Eriogonum umbellatum	2006	19-May		20-Jul	19-May	30-Jun	3-Aug
	2007	25-May		25-Jul	2-May	24-Jun	31-Jul
	2008	5-Jun	19-Jun	20-Jul	15-May	24-Jun	24-Jul
	2009	31-May		15-Jul	19-May	24-Jun	28-Jul
	2010	4-Jun	15-Jun	15-Jul	28-May	8-Jul	27-Jul
	2011	8-Jun	30-Jun	20-Jul	20-May	5-Jul	1-Aug
	2012	30-May	20-Jun	4-Jul	30-May	11-Jul	24-Jul
	2013	8-May	27-May	27-Jun	8-May	19-Jun	9-Jul
	2014	20-May	4-Jun	1-Jul	13-May	24-Jun	10-Jul
	2015	13-May	26-May	25-Jun	29-Apr	10-Jun	2-Jul
	2016	16-May	26-May	25-Jun	27-Apr	7-Jun	1-Jul
	2017	25-May	7-Jun	10-Jul	23-May	6-Jul	26-Jul
	2018	14-May	13-Jun	30-Jun	3-May	13-Jun	24-Jul
Eriogonum heracleoides	2011	26-May	10-Jun	8-Jul	27-May	6-Jul	1-Aug
	2012	23-May	30-May	25-Jun	11-May	21-Jun	16-Jul
	2013	29-Apr	13-May	10-Jun	24-Apr	5-Jun	1-Jul
	2014	1-May	20-May	12-Jun	29-Apr	10-Jun	3-Jul
	2015	24-Apr	5-May	17-Jun	15-Apr	27-May	24-Jun
	2016	26-Apr	6-May	16-Jun	18-Apr	31-May	23-Jun
	2017	10-May		30-Jun	2-May	20-Jun	26-Jul
	2018	30-Apr	10-May	28-Jun	3-May	13-Jun	25-Jul

Table 2. Precipitation and growing degree-days at the Malheur Experiment Station, Ontario, OR, 2006-2018.

	Precipitation (inch)			Growing degree-days (50-86°F)
Year	Spring	spring + winter	spring + winter + fall	Jan–Jun
2006	3.4	10.1	14.5	1273
2007	1.9	3.8	6.2	1406
2008	1.4	3.2	6.7	1087
2009	4.1	6.7	8.9	1207
2010	4.3	8.4	11.7	971
2011	4.8	9.3	14.5	856
2012	2.6	6.1	8.4	1228
2013	0.9	2.4	5.3	1319
2014	1.7	5.1	8.1	1333
2015	3.2	5.9	10.4	1610
2016	2.2	5.0	10.1	1458
2017	4.0	9.7	12.7	1196
2018	1.9	4.9	5.8	1342
13-year average:	2.9	6.3	9.8	25-year average: 1207

Table 3. *Eriogonum umbellatum* and *E. heracleoides* seed yield in response to irrigation rate (inches/season) in 2006 through 2018. Malheur Experiment Station, Oregon State University, Ontario, OR.

		Irrigation rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
		----------- lb/acre -----------			
Eriogonum umbellatum	2006	155.3	214.4	371.6	92.9
	2007	79.6	164.8	193.8	79.8
	2008	121.3	221.5	245.2	51.7
	2009	132.3	223	240.1	67.4
	2010	252.9	260.3	208.8	NS[a]
	2011	248.7	136.9	121	90.9
	2012	61.2	153.2	185.4	84.4
	2013	113.2	230.1	219.8	77.5
	2014	257	441.8	402.7	82.9
	2015	136.4	124.4	90.7	NS
	2016	183.4	204.3	140.8	NS
	2017	115.6	116.4	96.5	NS
	2018	44.6	92.0	66.7	24.5
	Average	149.4	205.9	194.6	21.6
Eriogonum heracleoides	2011	55.2	71.6	49	NS[a]
	2012	252.3	316.8	266.4	NS
	2013	287.4	516.9	431.7	103.2
	2014	297.6	345.2	270.8	NS
	2015	83.6	148.2	122.3	NS
	2016	421.6	486.9	437.2	NS
	2017	221.9	319.1	284.6	62.5
	2018	187.9	169.0	127.2	NS
	Average	211.4	297.5	265.3	54.6

[a] Not significant. There was no statistically significant trend in seed yield in response to amount of irrigation.

Table 4. Regression analysis for *Eriogonum umbellatum* and *E. heracleoides* seed yield (y) in response to irrigation (x) (inches/season) using the equation $y = a + b \bullet x + c \bullet x^2$. For the quadratic equations, the amount of irrigation that resulted in maximum yield was calculated using the formula: $-b/2c$, where b is the linear parameter and c is the quadratic parameter. Malheur Experiment Station, Oregon State University, Ontario, OR.

Eriogonum umbellatum

Year	intercept	linear	quadratic	R^2	P	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2006	66.6	22.9		0.52	0.05	328.0	11.4	3.4
2007	18.7	35.0	-1.8	0.69	0.05	193.8	10.0	1.9
2008	66.9	41.4	-2.4	0.73	0.01	246.6	8.7	1.4
2009	-35.6	50.6	-2.3	0.6	0.05	242.7	11.0	4.1
2010	178.5	25.2	-1.8	0.08	NS[a]			4.3
2011	308.9	-16.0		0.58	0.01	232.7	4.8	4.8
2012	-30.7	40.2	-1.9	0.65	0.01	185.4	10.7	2.6
2013	71.9	51.9	-4.0	0.62	0.05	241.3	6.5	0.9
2014	107.7	98.4	-7.0	0.76	0.01	453.7	7.0	1.7
2015	-35.7	70.4	-5.3	0.55	0.10	199.4	6.7	3.2
2016	96.3	48.9	-4.4	0.47	0.10	233.5	5.6	2.2
2017	94.2	7.9	-0.6	0.16	NS			4.0
2018	-3.1	29.5	-2.3	0.46	0.10	92.9	6.5	1.9
Average	66.8	34.8	-2.1	0.76	0.01	209.7	8.2	2.9

Eriogonum heracleoides

Year	intercept	linear	quadratic	R^2	P	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2011	61.7	-0.8		0.01	NS		
2012	271.5	1.8		0.01	NS		
2013	287.4	96.7	-9.8	0.64	0.05	525.1	4.9
2014	297.6	27.2	-3.8	0.08	NS		
2015	83.6	27.5	-2.8	0.29	NS		
2016	421.6	30.7	-3.6	0.06	NS		
2017	221.9	54.7	-5.9	0.55	0.05	349.7	4.7
2018	191.7	-7.6		0.25	NS		
Average	211.4	36.3	-3.7	0.61	0.05	300.6	4.9

[a] Not significant, indicating that there was no statistically significant trend in seed yield in response to amount of irrigation in that year.

SEED PRODUCTION RESPONSES OF PRAIRIE CLOVER AND BASALT MILKVETCH TO IRRIGATION

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Summary

Legumes are important components of rangeland vegetation in the Intermountain West due to their supply of protein to wildlife and livestock and contribution of nitrogen to rangeland productivity. Seed of selected native legumes is needed for rangeland restoration, but cultural practices for native legume production are largely unknown. The seed yield response of three native legume species to irrigation was evaluated starting in 2011. Four biweekly irrigations applying either 0, 1, or 2 inches of water (a total of 0, 4, or 8 inches/season) were tested. Over the 8-year study, *Dalea searlsiae* (Searls' prairie clover) seed yield was maximized by 13-17 inches of water applied plus fall, winter, and spring precipitation per season. *Dalea ornata* (Blue Mountain or western prairie clover) seed yield was maximized by 13-16 inches of water applied plus fall, winter, and spring precipitation per season. In 2 of the 8 years with higher than average precipitation, seed yield of *Dalea searlsiae* and *D. ornata* did not respond to irrigation. Seed yield of *Astragalus filipes* (basalt milkvetch) did not respond to irrigation.

Introduction

Native wildflower seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native wildflower (forb) seed is stable and consistent seed productivity over years.

In natural rangelands, variations in spring rainfall and soil moisture result in highly unpredictable water stress at flowering, seed set, and seed development, which for other seed crops is known to compromise seed yield and quality.

Native wildflower plants are not well adapted to croplands; they are often not competitive with crop weeds in cultivated fields, and this could limit wildflower seed production. Both sprinkler and furrow irrigation can provide supplemental water for seed production, but these irrigation systems risk further encouraging weeds. Also, sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. By burying drip tapes at 12-inch depth and avoiding wetting the soil surface, we designed experiments to assure flowering and seed set without undue encouragement of weeds or opportunistic diseases. The trials reported here tested the effects of three low rates of irrigation on the seed yield of three native wildflower legume species (Table 1) planted in 2009.

Table 1. Wildflower species in the legume family planted in the fall of 2009 at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Common names	Growth habit
Dalea searlsiae	Searls' prairie clover	Perennial
Dalea ornata	Western prairie clover, Blue Mountain prairie clover	Perennial
Astragalus filipes	Basalt milkvetch	Perennial

Materials and Methods

Plant establishment

Each of three species was planted in four rows 30 inches apart in a 10-ft-wide strip about 450 ft long on Nyssa silt loam at the Malheur Experiment Station, Ontario, Oregon. The soil had a pH of 8.3 and 1.1% organic matter. In October 2009, two drip tapes 5 feet apart (T-Tape TSX 515-16-340) were buried at 12-inch depth to irrigate the four rows in the plot. Each drip tape irrigated two rows of plants. The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 psi with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour.

On November 25, 2009, seed of three species (Table 1) was planted in 30-inch rows using a custom-made small-plot grain drill with disc openers. All seed was planted on the soil surface at 20-30 seeds/ft of row. After planting, sawdust was applied in a narrow band over the seed row at 0.26 oz/ft of row (558 lb/acre). Following planting and sawdust application, the beds were covered with row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO), which covered four rows (two beds) and was applied with a mechanical plastic mulch layer. The field was irrigated for 24 hours on December 2, 2009 due to very dry soil conditions.

After the newly planted wildflowers emerged, the row cover was removed in April 2010. The variable irrigation treatments were not applied until 2011.

Each year, plots were hand-weeded as necessary. Seed from the middle two rows in each plot was harvested manually (Table 2).

Irrigation for seed production

In April 2011, each strip of each wildflower species was divided into 12 30-ft plots. Each plot contained four rows of each species. The experimental design for each species was a randomized complete block with four replicates. The three treatments were a nonirrigated check, 1 inch of water applied per irrigation, and 2 inches of water applied per irrigation. Each treatment received 4 irrigations applied approximately every 2 weeks starting at bud formation and flowering. The amount of water applied to each treatment was calculated by the length of time necessary to deliver 1 or 2 inches through the drip system. Irrigations were regulated with a controller and solenoid valves.

The drip-irrigation system was designed to allow separate irrigation of the species due to different timings of flowering and seed formation. The irrigation treatments of the two *Dalea* spp. were applied together. The *Astragalus filipes* was irrigated separately to correspond to the timing of its flowering and seed set. Flowering, irrigation, and harvest dates were recorded (Table 2).

Weed control

On October 27, 2016, and October 19, 2017, Prowl® at 1 lb ai/acre was broadcast on all plots of *D. ornata* and *D. searlsiae* for weed control. On April 21, 2017, Prowl at 1 lb ai/acre and Poast® at 30 oz/acre were broadcast on all plots of both species.

Seed beetle control

Harvested seed pods of *Dalea ornata, D. searlsiae*, and *Astragalus filipes* were extensively damaged from feeding by seed weevils in 2013 and 2014, indicating that control measures during and after flowering would be necessary to maintain seed yields. On May 21, 2015, Capture® 2EC at 6.4 oz/acre (0.1 lb ai/acre) and Rimon® at 12 oz/acre (0.08 lb ai/acre) were broadcast in the evening to minimize harm to pollinators. On May 28, 2015, Rimon at 12 oz/acre was broadcast in the evening to minimize harm to pollinators. Seed beetles were not observed during flowering in 2016-2018.

Statistical analysis

Seed yield means were compared by analysis of variance and by linear and quadratic regression. Seed yield (y) in response to irrigation or irrigation plus precipitation (x, inches/season) was estimated by the equation $y = a + b \cdot x + c \cdot x^2$. For the quadratic equations, the amount of irrigation (x') that resulted in maximum yield (y') was calculated using the formula $x' = -b/2c$, where a is the intercept, b is the linear parameter, and c is the quadratic parameter. For the linear regressions, the seed yield responses to irrigation were based on the actual greatest amount of water applied plus precipitation and the measured average seed yield.

Seed yields for each year were regressed separately against 1) applied water; 2) applied water plus spring precipitation; 3) applied water plus winter and spring precipitation; and 4) applied water plus fall, winter, and spring precipitation. Winter and spring precipitation occurred in the same year that yield was determined; fall precipitation occurred the prior year.

Adding the seasonal precipitation to the irrigation response equation has the potential to provide a closer estimate of the amount of water required for maximum seed yields. Regressions of seed yield each year were calculated on all the sequential seasonal amounts of precipitation and irrigation, but only some of the regressions are reported below. The period of precipitation plus applied water that had the lowest standard deviation for irrigation plus precipitation over the years was chosen as the most reliable independent variable for predicting seed yield. For *Astragalus filipes*, seed yield did not respond to irrigation; consequently, seed yield responses only to water applied are reported without trying to find the optimal amount of irrigation plus seasonal precipitation.

Results and Discussion

Precipitation accumulated in the previous fall, winter, and spring each year showed large variability (Table 3). The accumulation of growing degree-days (50-86°F) was increasingly higher than average from 2012 to 2016, and 2018, close to average in 2017, and was below average in 2011 (Table 3). Flowering and seed harvest were early in 2015 and 2016, probably due to warmer weather and greater accumulation of growing degree-days.

Dalea searlsiae, Searls' prairie clover

In 2012, and 2014-2016, seed yields showed a quadratic response to irrigation plus fall, winter, and spring precipitation (Table 5). Maximum seed yields were achieved with 15, 17, 17, and 15.4 inches of water applied plus fall, winter, and spring precipitation in 2012 and 2014-2016, respectively. In 2013, seed yields were very low due to seed weevils. In 2013 and 2018, seed yields were maximized by the highest amount of water applied plus fall, winter, and spring precipitation. In 2011, seed yields were highest with no irrigation plus 14.5 inches of fall, winter, and spring precipitation. In 2017, seed yields did not respond to irrigation. Averaged over the 8 years, maximum seed yields were 222 lb/acre achieved with 16.8 inches of water applied plus fall, winter, and spring precipitation.

Dalea ornata, Blue Mountain or western prairie clover

Seed yields showed a quadratic response to irrigation in 2012-2016, and 2018 with a maximum seed yield at 16.1, 13.3, 14.9, 14.9, 14.6, and 10.8 inches of water applied plus fall, winter, and spring precipitation, respectively (Tables 4 and 5). Seed yields in 2011 were highest with no irrigation plus 14.5 inches of fall, winter, and spring precipitation. In 2017, seed yields did not respond to irrigation. Averaged over the 7 years, maximum seed yields were 321 lb/acre achieved with 14.8 inches of water applied plus fall, winter, and spring precipitation.

Both *Dalea searlsiae* and *D. ornata* showed either a negative response or no response to irrigation in 2011 and 2017, years with higher than average fall, winter, and spring precipitation.

Astragalus filipes, basalt milkvetch

Seed yields responded to irrigation only in 2013, when 4 inches of applied water resulted in among the highest yield (Tables 4 and 5). Low seed yields of *Astragalus filipes* were related to low plant stand and high seed pod shatter that made seed recovery problematic.

Acknowledgements

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Table 2. Native wildflower flowering, irrigation, and seed harvest dates by species. Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2018.

		Flowering			Irrigation		
Species	Year	Start	Peak	End	Start	End	Harvest
Dalea searlsiae							
	2011	8-Jun	20-Jun	20-Jul	27-May	6-Jul	21-Jul
	2012	23-May	10-Jun	30-Jun	11-May	21-Jun	10-Jul
	2013	13-May		15-Jun	8-May	19-Jun	29-Jun
	2014	15-May	4-Jun	24-Jun	6-May	17-Jun	1-Jul
	2015	13-May	26-May	16-Jun	5-May	17-Jun	22-Jun
	2016	11-May	28-May	10-Jun	3-May	14-Jun	16-Jun
	2017	23-May	7-Jun	30-Jun	23-May	6-Jul	3-Jul
	2018	12-May		15-Jun	16-May	27-Jun	25-Jun
Dalea ornata							
	2011	8-Jun	20-Jun	20-Jul	27-May	6-Jul	22-Jul
	2012	23-May	10-Jun	30-Jun	11-May	21-Jun	11-Jul
	2013	13-May	21-May	15-Jun	8-May	19-Jun	28-Jun
	2014	15-May	4-Jun	24-Jun	6-May	17-Jun	1-Jul
	2015	5-May	26-May	22-Jun	5-May	17-Jun	25-Jun
	2016	3-May	26-May	10-Jun	3-May	14-Jun	13-Jun
	2017	23-May	7-Jun	29-Jun	23-May	6-Jul	5-Jul
	2018	12-May		13-Jun	16-May	27-Jun	25-Jun
Astragalus filipes							
	2011	20-May	26-May	30-Jun	13-May	23-Jun	18-Jul
	2012	28-Apr	23-May	19-Jun	11-May	21-Jun	5-Jul
	2013	3-May	10-May	25-May	8-May	19-Jun	28-Jun
	2014	5-May	13-May	28-May	29-Apr	10-Jun	24-Jun
	2015	17-Apr	13-May	1-Jun	21-Apr	3-Jun	16-Jun

Table 3. Early season precipitation and growing degree-days at the Malheur Experiment Station, Ontario, OR, 2006-2018.

	Precipitation (inch)			Growing degree-days (50-86°F)
Year	Spring	Winter + spring	Fall + winter + spring	Jan–Jun
2006	3.4	10.1	14.5	1273
2007	1.9	3.8	6.2	1406
2008	1.4	3.2	6.7	1087
2009	4.1	6.7	8.9	1207
2010	4.3	8.4	11.7	971
2011	4.8	9.3	14.5	856
2012	2.6	6.1	8.4	1228
2013	0.9	2.4	5.3	1319
2014	1.7	5.1	8.1	1333
2015	3.2	5.9	10.4	1610
2016	2.2	5.0	10.1	1458
2017	4.0	9.7	12.7	1196
2018	1.9	4.9	5.8	1342
13-year average:	2.9	6.3	9.8	25-year average: 1207

Table 4. Native wildflower seed yield in response to irrigation rate (inches/season). Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2018.

Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
			-------- lb/acre -------		
Dalea searlsiae					
	2011	262.7	231.2	196.3	50.1
	2012	175.5	288.8	303.0	93.6
	2013	14.8	31.7	44.4	6.1
	2014	60.0	181.4	232.2	72.9
	2015	221.2	330.7	344.2	68.3
	2016	148.7	238.8	222.3	56.0
	2017	222.2	223.6	206.2	NS[a]
	2018	152.5	133.7	221.0	74.9
	Average	157.2	207.5	221.2	33.0
Dalea ornata					
	2011	451.9	410.8	351.7	NS
	2012	145.1	365.1	431.4	189.3
	2013	28.6	104.6	130.4	38.8
	2014	119.4	422.9	476.3	144.1
	2015	212.9	396.7	267.2	109.6
	2016	246.3	307.9	312.4	NS
	2017	328.2	347.0	270.1	NS
	2018	71.4	159.1	129.7	NS
	Average	203.2	312.0	296.8	55.3
Astragalus filipes					
	2011	87	98.4	74	NS
	2012	22.7	12.6	16.1	NS
	2013	8.5	9.8	6.1	2.7[b]
	2014	56.6	79.3	71.9	NS
	2015	17.8	12.5	11.6	NS
	Average	38.5	35.2	36.0	NS

[a] NS = not significant, [b] LSD (0.10)

Table 5. Regression analysis for native wildflower seed yield (y) in response to irrigation (x) (inches/season) plus fall, winter, and spring precipitation using the equation $y = a + b \cdot x + c \cdot x^2$. For the quadratic equations, the amount of irrigation that resulted in maximum yield was calculated using the formula: $-b/2c$, where b is the linear parameter and c is the quadratic parameter. Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2018.

Dalea searlsiae

Year	intercept	linear	quadratic	*R*²	*P*	Maximum yield	Water applied plus precipitation for max.yield	Precipitation, fall, winter, spring
						(lb•acre⁻¹)	(inches/season)	(inches)
2011	383.3	-8.3		0.49	0.05	263.3	14.5	14.5
2012	-384.4	92.7	-3.1	0.62	0.05	309.3	15.0	8.4
2013	-4.1	3.7		0.54	0.01	45.1	13.3	5.3
2014	-400.8	74.8	-2.2	0.79	0.001	234.0	17.0	8.1
2015	-515.3	101.9	-3.0	0.56	0.05	350.4	17.0	10.4
2016	-548.3	102.8	-3.3	0.56	0.05	245.2	15.4	10.1
2017	92.1	17.7	-0.6	0.04	NS[a]			12.7
2018	85.3	8.6		0.31	0.10	203.5	13.8	5.8
Average	-99.3	38.3	-1.1	0.62	0.05	221.5	16.8	9.8

Dalea ornata

Year	intercept	linear	quadratic	*R*²	*P*	Maximum yield	Water applied plus precipitation for max.yield	Precipitation, fall, winter, spring
						(lb•acre⁻¹)	(inches/season)	(inches)
2011	635.9	-12.5		0.11	NS	454.9	14.5	14.5
2012	-815.6	154.8	-4.8	0.65	0.01	431.8	16.1	8.4
2013	-149.4	41.9	-1.6	0.88	0.001	130.4	13.4	5.3
2014	-1258.9	233.6	-7.8	0.87	0.001	486.6	14.9	8.1
2015	-1597.0	267.3	-8.9	0.64	0.05	399.0	14.9	10.4
2016	-1096.9	203.5	-6.9	0.55	0.10	393.0	14.6	10.1
2017	-368.8	92.9	-3.0	0.13	NS			12.7
2018	-262.0	78.8	-3.7	0.56	0.10	162.7	10.8	5.8
Average	-523.8	114.4	-3.9	0.79	0.001	320.9	14.8	9.8

[a] Not significant. There was no statistically significant trend in seed yield in response to the amount of irrigation.

LOMATIUM SEED YIELD RESPONSE TO IRRIGATION

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Summary

Lomatium species are important botanical components in the rangelands of the Intermountain West. Relatively little is known about the cultural practices necessary to produce *Lomatium* seed for use in rangeland restoration activities. The seed yield response to four biweekly irrigations applying either 0, 1, or 2 inches of water (total of 0, 4, or 8 inches/season) was evaluated for four *Lomatium* species over multiple years starting in 2007. In order to try to improve the accuracy of estimated irrigation water requirements, seed yield responses to irrigation plus precipitation during the previous spring; winter and spring; and fall, winter, and spring were also evaluated. On average, over 10 seed production seasons, *Lomatium dissectum* (fernleaf biscuitroot) seed yield was maximized by 7.7 to 9.5 inches of water applied plus spring precipitation depending on the seed source. On average, over 11 seed production seasons, *L. grayi* (Gray's biscuitroot) seed yield was maximized by 14.3 inches of water applied plus fall, winter, and spring precipitation. On average, over 12 seed production seasons, *L. triternatum* (nineleaf biscuitroot) seed yield was maximized by 11.2 inches of water applied plus spring precipitation. Over seven seed production seasons, *L. nudicaule* (barestem biscuitroot) seed yield responded to irrigation only in 2017. In five seed production seasons, seed yield of *L. suksdorfii* (Suksdorf's desertparsley) responded to irrigation only in 2015.

Introduction

Native wildflower seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native wildflower (forb) seed is stable and consistent seed production over years.

In native rangelands, the natural variation in spring rainfall and soil moisture results in highly unpredictable water stress at flowering, seed set, and seed development, which for other seed crops is known to compromise seed yield and quality.

Native wildflower plants are not well adapted to croplands and often are not competitive with crop weeds in cultivated fields, which could limit wildflower seed production. Supplemental water can be provided by sprinkler or furrow irrigation systems, but these irrigation systems risk further encouraging weeds. Sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. Burying drip tapes at 12-inch depth and avoiding wetting the soil surface could help assure flowering and seed set without undue encouragement of weeds or opportunistic diseases. The trials reported here tested the effects of three low rates of irrigation on the seed yield of five *Lomatium* species (Table 1).

Subsurface drip irrigation systems were tested for native seed production because they have two potential strategic advantages: a) low water use, and b) the buried drip tape provides water to the plants at depth, precluding most irrigation-induced stimulation of weed seed germination on the soil surface and keeping water away from native plant tissues that are not adapted to a wet environment.

Table 1. *Lomatium* species planted in the drip irrigation trials at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Common names
Lomatium dissectum	fernleaf biscuitroot
Lomatium triternatum	nineleaf biscuitroot, nineleaf desertparsley
Lomatium grayi	Gray's biscuitroot, Gray's lomatium
Lomatium nudicaule	barestem biscuitroot, barestem lomatium
Lomatium suksdorfii	Suksdorf's desertparsley

Materials and Methods

Plant establishment

Seed of *Lomatium dissectum, L. grayi,* and *L. triternatum* was received in late November in 2004 from the Rocky Mountain Research Station (Boise, ID). The plan was to plant the seed in fall 2004, but due to excessive rainfall in October, ground preparation was not completed and planting was postponed to early 2005. To try to ensure germination, we submitted the seed to cold stratification. The seed was soaked overnight in distilled water on January 26, 2005, after which the water was drained and the seed soaked for 20 min in a 10% by volume solution of 13% bleach in distilled water. The water was drained and the seed was placed in thin layers in plastic containers. The plastic containers had lids with holes drilled in them to allow air movement. These containers were placed in a cooler set at approximately 34°F. Every few days the seed was mixed and, if necessary, distilled water added to maintain seed moisture. In late February, seed of *L. grayi* and *L. triternatum* started to sprout.

In late February 2005, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between 2 30-inch rows of a Nyssa silt loam with a pH of 8.3 and 1.1% organic matter. The drip tape was buried in alternating inter-row spaces (5 ft apart). The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 psi with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour.

On March 3, 2005, seed of the three species (*L. dissectum*, *L. grayi*, and *L. triternatum*) was planted in 30-inch rows using a custom-made, small-plot grain drill with disc openers. All seed was planted at 20-30 seeds/ft of row at 0.5-inch depth. The trial was irrigated from March 4 to April 29 with a mini-sprinkler system (R10 Turbo Rotator, Nelson Irrigation Corp., Walla Walla, WA) for even stand establishment. Risers were spaced 25 ft apart along the flexible polyethylene hose laterals that were spaced 30 ft apart and the water application rate was 0.10 inch/hour. A total of 1.72 inches of water was applied with the mini-sprinkler system. *Lomatium triternatum* and *L. grayi* started emerging on March 29. Beginning on June 24, the field was irrigated with the drip irrigation system. A total of 3.73 inches of water was applied with the drip system from June 24 to July 7. The field was not irrigated further in 2005.

Plant stands for *L. triternatum* and *L. grayi* were uneven; *L. dissectum* did not emerge. None of the species flowered in 2005. In early October 2005, more seed was received from the Rocky Mountain Research Station for replanting. The entire row lengths were replanted using the planter on October 26, 2005. In spring 2006, the plant stands were excellent.

On November 25, 2009 seed of *L. nudicaule, L. suksdorfii,* and three selections of *L. dissectum* (LODI 38, LODI 41, and seed from near Riggins, ID) was planted in 30-inch rows using a custom-made small-plot grain drill with disc openers. All seed was planted on the soil surface at 20-30 seeds/ft of row. After planting, sawdust was applied in a narrow band over the seed row at 0.26 oz/ft of row (558 lb/acre). Following planting and sawdust application, the beds were covered with row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO), which covered four rows (two beds) and was applied with a mechanical plastic mulch layer. The field was irrigated for 24 hours on December 2, 2009, due to very dry soil conditions.

Irrigation for seed production

In April 2006 (April 2010 for the species and selections planted in 2009) each planted strip of each species was divided into plots 30 ft long. Each plot contained four rows of each species. The experimental design for each species was a randomized complete block with four replicates. The three treatments were a nonirrigated check, 1 inch of water applied per irrigation, and 2 inches of water applied per irrigation. Each treatment received 4 irrigations applied approximately every 2 weeks starting with flowering. The length of time necessary to deliver 1 or 2 inches through the drip system was calculated. Irrigations were regulated with a controller and solenoid valves. After each irrigation, the amount of water applied was read on a water meter and recorded to ensure correct water applications.

Irrigation dates are found in Table 2. Irrigations for all species were initiated on May 19 and terminated on June 30 in 2006. Irrigations for each species were initiated and terminated on different dates (Table 2).

In 2007, irrigation treatments were inadvertently continued after the fourth irrigation. Irrigation treatments for all species were continued until the last irrigation on June 24, 2007.

Flowering, harvesting, and seed cleaning

Flowering dates for each species were recorded (Table 2). Each year, the middle two rows of each plot were harvested manually when seed of each species was mature (Table 2). Seed was cleaned manually.

Cultural practices

Fertilization was modest and was the same for all plots of all species. On November 11, 2007, 100 lb nitrogen (N)/acre as urea was broadcast on the soil surface. Nitrogen was applied as URAN (urea ammonium nitrate) injected through the drip tape at 50 lb N/acre on April 9, 2009, May 3, 2011, and April 13, 2012. Nitrogen was applied as URAN at 20 lb N/acre, on March 29, 2013, April 2, 2014, April 15, 2015, and March 31, 2016.

Phosphorus (P) was applied through the drip tape at 50 lb P/acre on October 27, 2006, 10 lb P/acre on April 9, 2009 and April 13, 2012, 25 lb P/acre on March 29, 2013, April 2, 2014, April 15, 2015, and March 31, 2016.

Zinc (Zn) at 2 lb Zn/acre was injected through the drip tape on October 27, 2006.

Iron (Fe) as iron chelate was injected through the drip tape at 0.3 lb Fe/acre on April 13, 2012, March 29, 2013, April 2, 2014, April 15, 2015, March 31, 2016, April 4, 2017, and May 3, 2018.

The herbicides pendimethalin (Prowl®) and sethoxydim (Poast®) have been used for weed control. Prowl at 1 lb ai/acre was broadcast on the soil surface on November 17, 2006, November 9, 2007, April 15, 2008, March 18, 2009, December 4, 2009, November 17, 2010, November 9, 2011, November 7, 2012, April 3, 2013, February 26, 2014, March 13, 2015, November 6, 2015, October 27, 2016, March 28, 2017, October 19, 2017.

Poast at 0.38 lb ai/acre was broadcast on March 18, 2009, April 3, 2013, February 26, 2014, and March 28, 2017 for weed control. On November 6, 2015, Roundup® at 24 oz/acre was broadcast for weed control. In addition to herbicides, hand weeding was used as necessary to control weeds.

Statistical analysis

Seed yield means were compared by analysis of variance and by linear and quadratic regression. Seed yield (y) in response to irrigation or irrigation plus precipitation (x, inches/season) was estimated by the equation $y = a + b \cdot x + c \cdot x^2$. For the quadratic equations, the amount of irrigation (x') that resulted in maximum yield (y') was calculated using the formula $x' = -b/2c$, where a is the intercept, b is the linear parameter, and c is the quadratic parameter. For the linear regressions, the seed yield responses to irrigation were based on the actual amounts of water applied plus precipitation and the measured average seed yield.

For each species, seed yields for each year were regressed separately against 1) applied water; 2) applied water plus spring precipitation; 3) applied water plus winter and spring precipitation; and 4) applied water plus fall, winter, and spring precipitation. Winter and spring precipitation occurred in the same year that yield was determined; fall precipitation occurred the prior year.

Adding the seasonal precipitation to the irrigation response equation potentially could provide a closer estimate of the amount of water required for maximum seed yields of the *Lomatium* species. Regressions of seed yield each year were calculated on all the sequential seasonal amounts of precipitation and irrigation, but only some of the regressions are reported below. The period of precipitation plus applied water that had the lowest standard deviation for irrigation plus precipitation over the years was chosen as the most reliable independent variable for predicting seed yield. For species with few years where a yield response to irrigation existed, yield responses are reported as a function of water applied.

Results and Discussion

Spring precipitation in 2012, 2015, and 2016 was close to the average of 2.8 inches (Table 3). Spring precipitation in 2006, 2009-2011, and 2017 was higher, and spring precipitation in 2007, 2008, 2013, 2014, and 2018 was lower than average. The accumulated growing degree-days (50-86°F) from January through June in 2006, 2007, 2013-2016, and 2018 were higher than average (Table 3). The high accumulated growing degree-days in 2015 probably caused early harvest dates (Table 2).

Flowering and seed set

Lomatium grayi and *L. triternatum* started flowering and producing seed in 2007 (second year after fall planting in 2005, Tables 2 and 4). *Lomatium dissectum* started flowering and producing seed in 2009 (fourth year after fall planting in 2005). *Lomatium nudicaule* started flowering and produced seed in 2012 (third year after fall planting in 2009), and *L. suksdorfii* started flowering and produced seed in 2013 (fourth year after fall planting in 2009).

Seed yields

***Lomatium dissectum*, fernleaf biscuit root**

Lomatium dissectum had very little vegetative growth during 2006-2008, and produced very few flowers in 2008. All the *Lomatium* species tested were affected by *Alternaria* fungus, but the infection was greatest on the *L. dissectum* selection planted in this trial. This infection delayed *L. dissectum* plant development. In 2009, vegetative growth and flowering were improved.

Seed yields of *L. dissectum* showed a quadratic response to irrigation rate plus spring precipitation in 2009-2011, 2013-2015, 2017, and 2018 (Tables 4 and 6). In 2012, seed yields of *L. dissectum* did not respond to irrigation. In 2016, seed yield increased linearly with increasing irrigation rate plus spring precipitation. Averaged over the 10 years, seed yield showed a quadratic response to irrigation rate plus spring precipitation and was estimated to be maximized at 924 lb/acre/year by spring precipitation plus irrigation of 9.5 inches.

***Lomatium dissectum* Riggins selection**

The Riggins selection *L. dissectum* started flowering in 2013, but only in small amounts. Seed yields of this selection showed a quadratic response to irrigation rate plus spring precipitation in 2014, 2016, and 2018 (Tables 5 and 7). Seed yields were estimated to be maximized by 6.5, 7.5, and 7.8 inches of applied water plus spring precipitation in 2014, 2016, and 2018, respectively. Seed was inadvertently not harvested in 2015. In 2017, seed yields showed a linear positive response to irrigation plus spring precipitation and was estimated to be maximized by 12 inches of applied water plus spring precipitation. Over years, seed yields were estimated to be maximized by 7.8 inches of applied water plus spring precipitation.

***Lomatium dissectum* selections LODI 38 and LODI 41**

Lomatium dissectum 38 and 41started flowering in 2013, but only in small amounts. Seed yields of LODI 38 did not respond to irrigation in 2014-2017 (Tables 5 and 7). Seed yields of LODI 41 did not respond to irrigation in 2014 and 2016. In 2015 and 2017, seed yields of LODI 41 showed a quadratic response to irrigation rate (Tables 5 and 7). Seed yields of LODI 41 were estimated to be maximized by 8.1 inches of applied water plus spring precipitation in 2015 and by 10.4 inches of applied water plus spring precipitation in 2017. In 2018, seed yields of LODI 38 and LODI 41 showed a positive linear response to applied water plus spring precipitation. In 2018, seed yields of LODI 38 and LODI 41 were maximized by 9.9 inches of applied water plus spring precipitation. Over years, seed yields were estimated to be maximized by 7.6 inches of applied water plus spring precipitation.

Lomatium grayi, Gray’s biscuitroot

Seed yields of *L. grayi* showed a quadratic response to irrigation rate plus fall, winter, and spring precipitation in all years from 2007 through 2017, except in 2007, 2009, 2013, and 2017 (Tables 4 and 6). In 2007, 2009, and 2013, seed yield showed a positive linear response to water applied plus precipitation. In 2010, 2011, and 2017 seed yields did not respond to irrigation. In 2010, seed yield did not respond to irrigation, possibly because of the unusually wet spring of 2010. Rodent damage was a further complicating factor in 2010 that compromised seed yields. Extensive vole damage occurred over the 2009-2010 winter. The affected areas were transplanted with 3-year-old *L. grayi* plants from an adjacent area in the spring of 2010. To reduce the habitat attractiveness to voles, all of the *Lomatium* plants were mowed after becoming dormant in early fall of 2010 and in each subsequent year. In 2011 and 2017, seed yield again did not respond to irrigation. The spring of 2011 was unusually cool and wet and the winter and spring of 2017 had higher than average precipitation. On average, seed yields of *L. grayi* were maximized at 730 lb/acre by 14.3 inches of applied water plus fall, winter, and spring precipitation.

Lomatium triternatum, nineleaf biscuitroot

Seed yields of *L. triternatum* showed a quadratic response to irrigation plus spring precipitation from 2008 through 2013, and 2018 (Tables 4 and 6). In 2007 and 2014-2016, seed yield showed a positive linear response to water applied plus spring precipitation. In 2017, seed yields did not respond to irrigation, probably due to heavy winter and spring precipitation. On average, seed yields of *L. triternatum* were maximized at 1,113 lb/acre by 11.2 inches of applied water plus spring precipitation.

Lomatium nudicaule, barestem biscuitroot

Seed yields did not respond to irrigation from 2012 to 2016, and 2018 (Tables 4 and 6). In 2017, seed yields showed a quadratic response to irrigation rate. Seed yields in 2017 were 218 lb/acre with 9.9 inches of applied water.

Lomatium suksdorfii, Suksdorf's desert parsley

Lomatium suksdorfii started flowering in 2013, but only in small amounts. In the 5 years that seed was harvested, seed yields of *L. suksdorfii* responded to irrigation only in 2015 (Tables 5 and 7). In 2015, seed yield increased linearly with increasing water applied up to the highest amount of water applied, 8 inches.

Management applications

This report describes irrigation practices that can be immediately implemented by seed growers. Multi-year summaries of research findings are found in Tables 4-8.

Conclusions

The *Lomatium* species were relatively slow to produce ample seed. *Lomatium grayi* and *L. triternatum* had reasonable seed yields starting in the second year, *L. dissectum* and *L. nudicaule* were productive in their fourth year, while *L. suksdorfii* was only moderately productive in the fifth year after planting. The delayed maturity affects the cost of seed production, but these species have proven to be strong perennials, especially when protected from rodent damage.

Due to the arid environment, supplemental irrigation may often be required for successful flowering and seed set because soil water reserves may be exhausted before seed formation. The total irrigation requirements for these arid-land species were low and varied by species (Table 8). *Lomatium nudicaule* and *L. suksdorfii* did not respond to irrigation most years; natural rainfall was sufficient to maximize their seed production in the absence of weed competition. *Lomatium dissectum* required approximately 6 inches of irrigation; *L. grayi* and *L. triternatum* responded quadratically to irrigation with the optimum varying by year. Accounting for precipitation improved the accuracy in the estimates of irrigation necessary for optimal seed production for *L. grayi*, *L. triternatum,* and *L. dissectum.*

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Table 2. *Lomatium* flowering, irrigation, and seed harvest dates by species in 2006-2018, Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on next page.

		Flowering			Irrigation		
Species	Year	Start	Peak	End	Start	End	Harvest
Lomatium dissectum	2006	No flowering			19-May	30-Jun	
	2007	No flowering			5-Apr	24-Jun	
	2008	Very little flowering			10-Apr	29-May	
	2009	10-Apr		7-May	20-Apr	28-May	16-Jun
	2010	25-Apr		20-May	15-Apr	28-May	21-Jun
	2011	8-Apr	25-Apr	10-May	21-Apr	7-Jun	20-Jun
	2012	9-Apr	16-Apr	16-May	13-Apr	24-May	4-Jun
	2013	10-Apr		25-Apr	4-Apr	16-May	4-Jun
	2014	28-Mar		21-Apr	7-Apr	20-May	2-Jun
	2015	1-Apr		24-Apr	1-Apr	13-May	26-May (0 in), 1-Jun (4, 8 in)
	2016	25-Mar		24-Apr	31-Mar	9-May	26-May
	2017	7-Apr		8-May	19-Apr	6-Jun	6-Jun
	2018	1-Apr		1-May	18-Apr	30-May	31-May
Lomatium grayi	2006	No flowering			19-May	30-Jun	
	2007	5-Apr		10-May	5-Apr	24-Jun	30-May, 29-Jun
	2008	25-Mar		15-May	10-Apr	29-May	30-May, 19-Jun
	2009	10-Mar		7-May	20-Apr	28-May	16-Jun
	2010	15-Mar		15-May	15-Apr	28-May	22-Jun
	2011	1-Apr	25-Apr	13-May	21-Apr	7-Jun	22-Jun
	2012	15-Mar	25-Apr	16-May	13-Apr	24-May	14-Jun
	2013	15-Mar		30-Apr	4-Apr	16-May	10-Jun
	2014	28-Mar		2-May	7-Apr	20-May	10-Jun
	2015	1-Mar		28-Apr	1-Apr	13-May	1-Jun
	2016	7-Mar		29-Apr	31-Mar	9-May	1-Jun
	2017	15-Mar		12-May	19-Apr	6-Jun	8-Jun
	2018	15-Mar		3-May	18-Apr	30-May	5-Jun
Lomatium triternatum	2006	No flowering			19-May	30-Jun	
	2007	25-Apr		1-Jun	5-Apr	24-Jun	29-Jun, 16-Jul
	2008	25-Apr		5-Jun	10-Apr	29-May	3-Jul
	2009	10-Apr	7-May	1-Jun	20-Apr	28-May	26-Jun
	2010	25-Apr		15-Jun	15-Apr	28-May	22-Jul
	2011	30-Apr	23-May	15-Jun	21-Apr	7-Jun	26-Jul
	2012	12-Apr	17-May	6-Jun	13-Apr	24-May	21-Jun
	2013	18-Apr		10-May	4-Apr	16-May	4-Jun
	2014	7-Apr	29-Apr	2-May	7-Apr	20-May	4-Jun
	2015	10-Apr	28-Apr	20-May	1-Apr	13-May	7-Jun (0 in), 15-Jun (4, 8 in)
	2016	11-Apr	28-Apr	20-May	31-Mar	9-May	15-Jun
	2017	24-Apr	15-May	30-May	19-Apr	6-Jun	27-Jun
	2018	16-Apr	10-May	23-May	18-Apr	30-May	18-Jun

Table 2. (Continued.) *Lomatium* flowering, irrigation, and seed harvest dates by species in 2006-2018, Malheur Experiment Station, Oregon State University, Ontario, OR.

		Flowering			Irrigation		
Species	Year	Start	Peak	End	Start	End	Harvest
Lomatium nudicaule	2011		No flowering				
	2012	12-Apr	1-May	30-May	18-Apr	30-May	22-Jun
	2013	11-Apr		20-May	12-Apr	22-May	10-Jun
	2014	7-Apr		13-May	7-Apr	20-May	16-Jun
	2015	25-Mar		5-May	1-Apr	13-May	8-Jun
	2016	5-Apr		5-May	11-Apr	23-May	6-Jun
	2017	12-Apr		15-May	19-Apr	6-Jun	19-Jun
	2018	9-Apr	30-Apr	11-May	18-Apr	30-May	11-Jun
Lomatium suksdorfii	2013	18-Apr		23-May			
	2014	15-Apr		20-May	7-Apr	20-May	30-Jun
	2015	3-Apr	27-Apr	10-May	1-Apr	13-May	23-Jun
	2016	5-Apr	27-Apr	31-May	11-Apr	23-May	28-Jun
	2017	17-Apr		2-Jun	19-Apr	6-Jun	19-Jun
	2018	16-Apr	10-May	31-May	18-Apr	30-May	2-Jul

Table 3. Precipitation and growing degree-days at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2006-2018.

	Precipitation (inch)			Growing degree-days (50-86°F)
Year	Spring	spring + winter	spring + winter + fall	Jan–Jun
2006	3.4	10.1	14.5	1273
2007	1.9	3.8	6.2	1406
2008	1.4	3.2	6.7	1087
2009	4.1	6.7	8.9	1207
2010	4.3	8.4	11.7	971
2011	4.8	9.3	14.5	856
2012	2.6	6.1	8.4	1228
2013	0.9	2.4	5.3	1319
2014	1.7	5.1	8.1	1333
2015	3.2	5.9	10.4	1610
2016	2.2	5.0	10.1	1458
2017	4.0	9.7	12.7	1196
2018	1.9	4.9	5.8	1342
13-year average:	2.8	6.2	9.5	25-year average: 1207

Table 4. Seed yield response to irrigation rate (inches/season) for four *Lomatium* species in 2006 through 2018. Malheur Experiment Station, Oregon State University, Ontario, OR.

		Irrigation Rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
Lomatium dissectum		--------- lb/acre -----			
	2006	---- no flowering ----			
	2007	---- no flowering ----			
	2008	- very little flowering -			
	2009	50.6	320.5	327.8	196.4[a]
	2010	265.8	543.8	499.6	199.6
	2011	567.5	1342.8	1113.8	180.9
	2012	388.1	460.3	444.4	NS[b]
	2013	527.8	959.8	1166.7	282.4
	2014	353.4	978.9	1368.3	353.9
	2015	591.2	1094.7	1376.0	348.7
	2016	1039.4	1612.7	1745.4	564.2
	2017	488.2	713.1	674.4	220.5[b]
	2018	79.2	237.9	280.3	148
10-year average		435.1	850.9	899.7	133.6

		Irrigation Rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
Lomatium grayi		---------- lb/acre ----------			
	2006	---- no flowering ----			
	2007	36.1	88.3	131.9	77.7[b]
	2008	393.3	1287	1444.9	141.0
	2009	359.9	579.8	686.5	208.4
	2010	1035.7	1143.5	704.8	NS
	2011	570.3	572.7	347.6	NS
	2012	231.9	404.4	377.3	107.4
	2013	596.7	933.4	1036.3	NS
	2014	533.1	1418.1	1241.3	672.0
	2015	186.4	576.7	297.6	213.9
	2016	483.7	644.2	322.9	218.7
	2017	333.5	259.5	246.3	NS
11-year average		438.4	718.9	621.6	210.5

		Irrigation Rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
Lomatium nudicaule		---------- lb/acre ----------			
	2010	---- no flowering ----			
	2011	---- no flowering ----			
	2012	53.8	123.8	61.1	NS
	2013	357.6	499.1	544.0	NS
	2014	701.3	655.6	590.9	NS
	2015	430.6	406.1	309.3	NS
	2016	363.0	403.7	332.5	NS
	2017	53.7	159.7	212.0	49.7
	2018	17.1	41.3	28.7	NS
7-year average		282.5	327.0	296.9	NS

		Irrigation Rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
Lomatium triternatum		---------- lb/acre ----------			
	2006	---- no flowering ----			
	2007	2.3	17.5	26.7	16.9[b]
	2008	195.3	1060.9	1386.9	410.0
	2009	181.6	780.1	676.1	177.0
	2010	1637.2	2829.6	3194.6	309.4
	2011	1982.9	2624.5	2028.1	502.3[b]
	2012	238.7	603	733.2	323.9
	2013	153.7	734.4	1050.9	425.0
	2014	240.6	897.1	1496.7	157.0
	2015	403.2	440.8	954.9	446.6
	2016	395.0	475.7	638.4	175.7
	2017	932.8	948.9	1266.2	216.8
	2018	2.0	41.4	46.2	30.4
12-year average		530.4	954.5	1112.3	119.0

[a] LSD (0.10)

[b] not statistically significant

Table 5. Seed yield response to irrigation rate (inches/season) for two *Lomatium* species in 2014-2018. Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Year	Irrigation Rate 0 inches	 4 inches	 8 inches	LSD (0.05)
		---------- lb/acre ----------			
Lomatium dissectum 'Riggins'	2014	276.8	497.7	398.4	163.0
	2016	299.1	679.5	592.4	247.4
	2017	315.1	405.1	440.0	87.4
	2018	61.8	142.8	141.8	51.3
4-year average		238.2	431.3	393.1	98.5
Lomatium dissectum '38'	2014	281.9	356.4	227.1	NS
	2015	865.1	820.9	774.6	NS
	2016	474.8	634.5	620.0	70.3
	2017	398.8	575.0	553.2	NS
	2018	220.1	280.0	358.2	NS
5-year average		449.2	533.4	488.3	NS
Lomatium dissectum '41'	2014	222.2	262.4	149.8	NS
	2015	152.2	561.9	407.4	181.4
	2016	238.1	297.7	302.0	NS
	2017	214.9	363.0	377.5	71.0
	2018	53.7	71.4	97.6	NS
5-year average		176.2	311.3	266.9	100.1
Lomatium suksdorfii	2014	162.6	180.0	139.8	NS
	2015	829.6	1103.9	1832.0	750.2
	2016	692.6	898.8	467.5	NS
	2017	1315.5	1736.6	1315.5	NS
	2018	346.7	788.3	546.8	NS
5-year average		556.4	941.5	919.0	NS

Table 6. Regression analysis for native wildflower seed yield (y) in response to irrigation (x) (inches/season) using the equation $y = a + bx + cx^2$ in 2006-2018, and 10- to 12-year averages. For the quadratic equations, the amount of irrigation that resulted in maximum yield was calculated using the formula: -b/2c, where b is the linear parameter and c is the quadratic parameter. Malheur Exp. Station, Oregon State Univ., Ontario, OR.

Lomatium dissectum

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2009	-922.0	307.9	-16.9	0.60	0.05	478	9.1	4.1
2010	-178.3	128.3	-5.9	0.51	0.05	514	10.8	4.3
2011	-1669.6	618.7	-31.4	0.86	0.001	1380	9.9	4.8
2012	293.9	43.4	-2.8	0.07	NS			2.6
2013	407.0	148.1	-7.0	0.68	0.01	1186	10.5	0.9
2014	9.7	211.4	-7.4	0.83	0.001	1524	14.3	1.7
2015	24.5	198.4	-6.9	0.78	0.01	1441	14.3	3.2
2016	916.9	88.2		0.42	0.05	1623	10.2	2.2
2017	134.7	139.9	-8.2	0.40	0.10	730	8.5	4.0
2018	-36.2	68.0	-3.6	0.67	0.01	281	9.3	1.9
Average	-110.0	217.7	-11.5	0.90	0.001	924	9.5	2.9

Lomatium grayi

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring, winter, and fall precipitation for maximum yield	Spring, winter, fall precipitation
						lb/acre	inches/season	inch
2007	-36.6	12.0		0.26	0.10	59	14.2	6.19
2008	-2721.1	621.3	-23.0	0.93	0.001	1475	13.5	6.65
2009	17.8	40.8		0.38	0.05	344	16.8	8.8
2010	-2431.4	495.9	-17.1	0.22	NS			11.7
2011	-1335.1	234.7	-7.1	0.07	NS			14.5
2012	-778.8	172.8	-6.2	0.66	0.01	418	13.8	8.4
2013	344.3	55.0		0.25	0.10	1075	13.3	5.3
2014	-4502.3	890.8	-33.2	0.64	0.05	1477	13.4	8.1
2015	-3980.4	617.7	-20.9	0.71	0.01	579	14.8	10.4
2016	-2046.2	403.1	-15.1	0.66	0.01	651	13.4	9.1
2017	461.9	-10.9		0.22	NS			12.7
Average	-1690.8	337.9	-11.8	0.55	0.05	730	14.3	9.8

Lomatium triternatum

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2007	-2.6	3.1		0.52	0.01	28	9.9	1.92
2008	-245.1	332.1	-16.9	0.77	0.01	1390	9.8	1.43
2009	-1148.3	416.1	-22.0	0.83	0.001	824	9.5	4.1
2010	-586.2	625.4	-25.9	0.83	0.001	3196	12.1	4.3
2011	-400.3	684.1	-38.7	0.45	0.10	2623	8.8	4.8
2012	-123.6	158.4	-7.3	0.52	0.05	734	10.8	2.6
2013	-3.8	192.2	-8.3	0.68	0.01	1115	11.6	0.9
2014	-22.7	157.4		0.97	0.001	1509	9.7	1.7
2015	101.8	69.0		0.51	0.01	875	11.2	3.2
2016	313.9	30.4		0.29	0.10	624	10.2	2.2
2017	717.1	41.7		0.20	NS	1217	12.0	4.0
2018	-28.7	18.3	-1.1	0.52	0.05	48	8.4	1.9
Average	69.9	186.2	-8.3	0.81	0.001	1113	11.2	2.9

Table 7. Regression analysis for seed yield response to irrigation rate (inches/season) in 2012-2018 for *Lomatium nudicaule, L. suksdorfii*, and three selections of *L. dissectum* planted in 2009. For the quadratic equations, the amount of irrigation that resulted in maximum yield was calculated using the formula: -b/2c, where b is the linear parameter and c is the quadratic parameter. Malheur Exp. Station, Oregon State Univ., Ontario, OR.

Lomatium nudicaule							
Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2012	53.8	34.1	-4.1	0.18	NS		
2013	357.6	47.5	-3.0	0.11	NS		
2014	704.5	-13.8		0.08	NS		
2015	430.6	2.9	-2.3	0.15	NS		
2016	363.0	24.1	-3.5	0.07	NS		
2017	53.7	33.2	-1.7	0.75	0.01	218	9.9
2018	17.1	10.6	-1.1	0.26	NS		
Average	282.5	20.5	-2.3	0.07	NS		

Lomatium suksdorfii							
Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2014	162.6	11.5	-1.8	0.01	NS		
2015	753.9	125.3		0.43	0.05	1756	8.0
2016	692.6	131.2	-19.9	0.17	NS		
2017	750.7	422.4	-44.0	0.39	NS		
2018	346.7	195.8	-21.3	0.35	NS		
Average	556.4	147.2	-12.7	0.31	NS		

***Lomatium dissectum* 'Riggins'**								
Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2014	82.1	129.9	-10.0	0.57	0.05	503	6.5	1.7
2016	-113.8	218.4	-14.6	0.63	0.05	703	7.5	2.2
2017	262.3	15.6		0.37	0.05	387	8.0	4.0
2018	-4.9	40.1	-2.6	0.71	0.01	153	7.8	1.9
Average	5.5	112.6	-7.2	0.72	0.01	444	7.8	2.8

***Lomatium dissectum* '38'**								
Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2014	186.6	66.1	-6.4	0.11	NS			1.7
2015	901.8	-11.3		0.01	NS			3.2
2016	311.0	85.9	-5.4	0.32	NS			2.2
2017	28.2	117.9	-6.2	0.38	NS			4.0
2018	184.5	17.3		0.33	0.10	355	9.9	1.9
Average	302.9	61.2	-4.0	0.10	NS			2.8

***Lomatium dissectum* '41'**								
Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2014	222.2	29.1	-4.8	0.13	NS			1.7
2015	-587.4	286.5	-17.6	0.67	0.01	576	8.1	3.2
2016	181.3	29.4	-1.7	0.18	NS			2.2
2017	-64.2	86.9	-4.2	0.70	0.01	388	10.4	4.0
2018	41.9	5.5		0.34	0.05	86	8.0	1.9
Average	-8.3	85.4	-5.6	0.49	0.05	317	7.6	2.8

Table 8. Amount of irrigation water plus precipitation for maximum *Lomatium* seed yield, years to seed set, and life span. A summary of multi-year research findings, Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Optimum amount of irrigation plus precipitation	Critical precipitation period	Years to first seed set	Life span
	inches		from fall planting	years
Lomatium dissectum	7.7-9.5[a]	spring	4	14+
Lomatium grayi	14.3	fall, winter, and spring	2	14+
Lomatium nudicaule	no response in 6 out of 7 years 8 inches in 2017		3	9+
Lomatium triternatum	11.2	spring	2	14+
Lomatium suksdorfii	no response in 2014, 2016-2018 8 inches irrigation in 2015	undetermined	5	9+

[a] The amount of recommended irrigation plus precipitation varied with the *L. dissectum* seed source.

NATIVE *PENSTEMON* SPECIES SEED YIELD HAS LITTLE RESPONSE TO IRRIGATION

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Summary

Penstemon is an important wildflower genus in the Great Basin of the United States. Seed of *Penstemon* species is desired for rangeland restoration activities, but little cultural practice information is known for seed production of native penstemons. The seed yield response of five *Penstemon* species to four biweekly irrigations applying either 0, 1, or 2 inches of water (a total of 0, 4, or 8 inches of water/season) was evaluated over multiple years. *Penstemon acuminatus* (sharpleaf penstemon) seed yields were maximized by 4-8 inches of water applied per season in warmer, drier years and did not respond to irrigation in cooler, wetter years. In 8 years of testing, *P. cyaneus* (blue penstemon) responded to irrigation only in 2013 and 2018, years with lower than average precipitation, with 4 and 4.2 inches of water applied maximizing yields, respectively. In 8 years of testing, *P. pachyphyllus* (thickleaf beardtongue) seed yields responded to irrigation only in 2013 and 2018 with 8 and 3 inches of water applied maximizing yields, respectively. In 8 years of testing, seed yields of *P. deustus* (scabland penstemon) responded to irrigation only in 2015, with highest yields resulting from 5.4 inches of water applied. From 2006 to 2018, *P. speciosus* showed a quadratic response to irrigation plus spring precipitation in 8 out of the 12 years. *Penstemon speciosus* showed either no response or a negative response to irrigation in 3 years with higher than average spring precipitation and showed a linear positive response to irrigation in 2013, the year with the lowest precipitation. Averaged over the 12 years of testing, *P. speciosus* seed yields were maximized by 8.8 inches of water applied plus spring precipitation.

Introduction

Native wildflower seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native wildflower (forb) seed is stable and consistent seed productivity over years.

In native rangelands, the natural variation in spring rainfall and soil moisture results in highly unpredictable water stress at flowering, seed set, and seed development, which for other seed crops is known to compromise seed yield and quality.

Native wildflower plants are not well adapted to croplands; they often do not compete with crop weeds in cultivated fields, and this could limit wildflower seed production. Both sprinkler and furrow irrigation could provide supplemental water for seed production, but these irrigation systems risk further encouraging weeds. Also, sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. By burying drip tapes at 12-inch depth and avoiding wetting the soil surface, we designed experiments to assure flowering and seed set without undue encouragement of weeds or opportunistic diseases. The trials reported here tested the effects of three low rates of irrigation on the seed yield of five species of *Penstemon* native to the Intermountain West (Table 1).

Table 1. *Penstemon* species planted in the drip-irrigation trials at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Common names
Penstemon acuminatus	sharpleaf penstemon, sand-dune penstemon
Penstemon cyaneus	blue penstemon
Penstemon deustus	scabland penstemon, hotrock penstemon
Penstemon pachyphyllus	thickleaf beardtongue
Penstemon speciosus	royal penstemon, sagebrush penstemon

Materials and Methods

Penstemon acuminatus, P. deustus, and *P. speciosus*

Seed of *Penstemon acuminatus*, *P. deustus*, and *P. speciosus* was received in late November in 2004 from the Rocky Mountain Research Station (Boise, ID). The plan was to plant the seed in the fall of 2004, but due to excessive rainfall in October, the ground preparation was not completed and planting was postponed to early 2005. To try to ensure germination, the seed was submitted to cold stratification. The seed was soaked overnight in distilled water on January 26, 2005, after which the water was drained and the seed soaked for 20 min in a 10% by volume solution of 13% bleach in distilled water. The water was drained and the seed was placed in thin layers in plastic containers. The plastic containers had lids with holes drilled in them to allow air movement. These containers were placed in a cooler set at approximately 34°F. Every few days the seed was mixed and, if necessary, distilled water added to maintain seed moisture.

In late February 2005, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between two 30-inch rows of a Nyssa silt loam with a pH of 8.3 and 1.1% organic matter. The drip tape was buried in alternating inter-row spaces (5 ft apart). The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 psi with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour.

On March 3, the seed was planted in 30-inch rows using a custom-made small-plot grain drill with disc openers. All seed was planted at 20-30 seeds/ft of row. The seed was planted at 0.25-inch depth. The trial was irrigated with a minisprinkler system (R10 Turbo Rotator, Nelson Irrigation Corp., Walla Walla, WA) for even stand establishment from March 4 to April 29. Risers were spaced 25 ft apart along the flexible polyethylene hose laterals that were spaced 30 ft apart and the water application rate was 0.10 inch/hour. A total of 1.72 inches of water was applied with the minisprinkler system. Seed emerged by late April. Starting June 24, the field was irrigated with the drip system. A total of 3.73 inches of water was applied with the drip system from June 24 to July 7. The field was not irrigated further in 2005.

Plant stands were uneven. None of the species flowered in 2005. In early October 2005, more seed was received from the Rocky Mountain Research Station for replanting. The empty lengths of row were replanted by hand on October 26, 2005 and fall and winter moisture was allowed to germinate the seed. In the spring of 2006, the plant stands of the replanted species were excellent, except for *P. deustus*. On November 11, 2006, the *P. deustus* plots were replanted again at 30 seeds/ft of row.

Stands of *P. speciosus* have regenerated by natural reseeding, but replanting was required in 2015 due to die-off, especially in the plots with the highest irrigation rate. On November 2, 2015, seed of *P. speciosus* was planted on the soil surface at 30 seeds/ft of row. Stand of *P. speciosus* in the spring of 2016 was adequate after fall planting in 2015. Prowl® was not applied after 2011 to encourage natural reseeding. While natural reseeding might be advantageous for maintaining stands for irrigation research, it might be disadvantageous for seed production, because of changes in the genetic composition of the stand over time. Due to substantial stand loss after 2 years of seed production, all plots of *P. deustus* were disked out in 2008. Due to substantial stand loss, all plots of *P. acuminatus* were disked out in 2010.

Irrigations for each species were initiated and terminated on different dates (Table 2).

Weeds were controlled in the first year after fall planting by hand-weeding. In subsequent years, weeds were controlled by yearly applications of pendimethalin (Prowl, soil-active herbicide), grass herbicides sethoxydim (Poast®), and Clethodim (Select Max® and Volunteer®), and hand-weeding. All plots had Prowl at 1 lb ai/acre broadcast on the soil surface for weed control on November 17, 2006, November 9, 2007, April 15, 2008, March 18, 2009, December 4, 2009, November 17, 2010, November 9, 2011, October 27, 2016, and October 19, 2017. On March 18, 2009, Volunteer at 0.24 lb ai/acre was broadcast on all plots. On April 3, 2013, Select Max at 0.5 lb ai/acre was broadcast on all plots of *P. speciosus.* On March 2, 2016, Poast at 0.35 lb ai/acre was broadcast on all plots.

Penstemon acuminatus and *P. speciosus* were sprayed with Aza-Direct® at 0.0062 lb ai/acre on May 14 and 29, 2007, and Capture® 2EC at 0.1 lb ai/acre on May 20, 2008 for lygus bug control. On April 18, 2014 and April 20, 2015, Orthene® at 8 oz/acre was broadcast on all plots of *P. speciosus* for lygus bug control.

Fertilization was modest and was the same for all plots of all species. On October 27, 2006, 50 lb phosphorus (P)/acre and 2 lb zinc (Zn)/acre were injected through the drip tape to all plots of each species. On April 29, 2014, 5 lb iron (Fe)/acre was applied through the drip tape to all plots of *P. speciosus*.

Penstemon cyaneus, P. deustus, and *P. pachyphyllus*

On November 25, 2009 seed of *P. cyaneus, P. deustus,* and *P. pachyphyllus* was planted in 30-inch rows using a custom-made small-plot grain drill with disc openers. All seed was planted on the soil surface at 20-30 seeds/ft of row. After planting, sawdust was applied in a narrow band over the seed row at 0.26 oz/ft of row (558 lb/acre). Following planting and sawdust application, the beds were covered with row cover. The row cover (N-sulate) covered four rows (two beds) and was applied with a mechanical plastic mulch layer. The field was irrigated for 24 hours on December 2, 2009 due to very dry soil conditions.

After the newly planted wildflowers had emerged, the row cover was removed in April of 2010. The irrigation treatments were not applied to these wildflowers in 2010. Stands of *P. cyaneus* and *P. pachyphyllus* were not adequate for yield estimates.

Gaps in the rows were replanted by hand on November 5, 2010. The replanted seed was covered with a thin layer of 50% sawdust and 50% hydroseeding mulch (Hydrostraw LLC, Manteno, IL) by volume. The mulch mixture was sprayed with water using a backpack sprayer.

A substantial amount of plant death occurred in the *P. deustus* plots during the winter and spring of 2011-2012. For *P. deustus*, only the undamaged parts in each plot were harvested in 2012. Seed of all species was harvested and cleaned manually. On October 26, 2012, dead *P. deustus* plants were removed and the empty row lengths were replanted by hand at 20-30 seeds/ft of row. After planting, sawdust was applied in a narrow band over the seed row. Following planting and sawdust application, the beds were covered with row cover. The replanted *P. deustus* did not flower in 2013.

Stand of *P. deustus* was poor again at the end of 2015 due to die-off. On November 5, 2015, seed of *P. deustus* was planted on the soil surface at 30 seeds/ft of row. Following planting, the beds were covered with row cover. Stands of *P. cyaneus* and *P. pachyphyllus* are currently poor, but might regenerate from natural reseeding. While natural reseeding might be advantageous for maintaining stands for irrigation research, natural reseeding might be disadvantageous for seed production, because of changes in the genetic composition of the stand over time. Weeds were controlled each year by hand weeding.

Many areas of the wildflower seed production were suffering from severe iron deficiency early in the spring of 2012. On April 13, 2012, 50 lb nitrogen/acre, 10 lb P/acre, and 0.3 lb Fe/acre was applied to all plots as liquid fertilizer injected through the drip tape. On April 23, 2012, and April 29, 2014, 0.3 lb Fe/acre was applied to all plots as liquid fertilizer injected through the drip tape.

Prowl at 1 lb ai/acre was broadcast on all plots for weed control on October 27, 2016. On October 19, 2017, Prowl at 1 lb ai/acre was broadcast on all plots of *P. deustus* for weed control.

Irrigation for seed production

In April 2006 each planted strip of *P. acuminatus, P. deustus*, and *P. speciosus* was divided into plots 30 ft long. Each plot contained four rows of each species. The experimental designs were randomized complete blocks with four replicates. The three treatments were a nonirrigated check, 1 inch of water applied per irrigation, and 2 inches of water applied per irrigation. Each treatment received 4 irrigations that were applied approximately every 2 weeks starting with bud formation and flowering. The amount of water applied to each treatment was calculated by the length of time necessary to deliver 1 or 2 inches through the drip system. Irrigations were regulated with a controller and solenoid valves. After each irrigation, the amount of water applied was read on a water meter and recorded to ensure correct water applications.

In March of 2007, the drip-irrigation system was modified to allow separate irrigation of the species due to different timings of flowering. *Penstemon deustus* and *P. speciosus* were irrigated together, but separately from *P. acuminatus*.

Irrigation dates are found in Table 2. In 2007, irrigation treatments were inadvertently continued after the fourth irrigation. Irrigation treatments for all species were continued until the last irrigation on June 24, 2007.

Penstemon cyaneus, P. deustus (second planting), and *P. pachyphyllus* were irrigated together starting in 2011 using the same procedures as previously described.

Flowering, harvesting, and seed cleaning

Flowering dates for each species were recorded (Table 2). Each year, the middle two rows of each plot were harvested when seed of each species was mature (Table 2).

All species were harvested with a Wintersteiger small plot combine. *Penstemon deustus* seed pods were too hard to be opened in the combine; the unthreshed seed was precleaned in a small clipper seed cleaner and then seed pods were broken manually by rubbing the pods on a ribbed rubber mat. The seed was then cleaned again in the small clipper seed cleaner. The other species were threshed in the combine and the seed was further cleaned using a small clipper seed cleaner. Seed of *P. cyaneus, P. pachyphyllus,* and *P. speciosus* were harvested by hand when stands became too poor for combining.

Statistical analysis

Seed yield means were compared by analysis of variance and by linear and quadratic regression. Seed yield (y) in response to irrigation or irrigation plus precipitation (x, inches/season) was estimated by the equation $y = a + b \cdot x + c \cdot x^2$. For the quadratic equations, the amount of irrigation (x') that resulted in maximum yield (y') was calculated using the formula $x' = -b/2c$, where a is the intercept, b is the linear parameter, and c is the quadratic parameter. For the linear regressions, the seed yield responses to irrigation were based on the actual greatest amount of water applied plus precipitation and the measured average seed yield.

For *P. speciosus,* seed yields for each year were regressed separately against 1) applied water; 2) applied water plus spring precipitation; 3) applied water plus winter and spring precipitation; and 4) applied water plus fall, winter, and spring precipitation. Winter and spring precipitation occurred in the same year that yield was determined; fall precipitation occurred the prior year.

Adding the seasonal precipitation to the irrigation response equation could potentially provide a closer estimate of the amount of water required for maximum seed yields for *P. speciosus.* Regressions of seed yield each year were calculated on all the sequential seasonal amounts of precipitation and irrigation, but only some of the regressions are reported below. The period of precipitation plus applied water that had the lowest standard deviation for irrigation plus precipitation over the years was chosen as the most reliable independent variable for predicting seed yield. For the other species, there were few years where a yield response to irrigation existed, so yield responses only to water applied are reported.

Results and Discussion

Precipitation showed large year-to-year variation over the 13 years of irrigation trials (Table 3). The accumulated growing degree-days (50-86°F) from January through June in 2006, 2007, and 2013-2016 were higher than average (Table 3).

Flowering and seed set

Penstemon acuminatus and *P. speciosus* had poor seed set in 2007, partly due to a heavy lygus bug infestation that was not adequately controlled by the applied insecticides. In the Treasure Valley, the first hatch of lygus bugs occurs when 250 degree-days (52°F base) are accumulated. Data collected by an AgriMet weather station adjacent to the field indicated that the first lygus bug hatch occurred on May 14, 2006; May 1, 2007; May 18, 2008; May 19, 2009; and May 29, 2010. The average (1995-2010) lygus bug hatch date was May 18. *Penstemon acuminatus* and *P. speciosus* start flowering in early May (Table 2). The earlier lygus bug hatch in 2007 probably resulted in harmful levels of lygus bugs present during a larger part of the *Penstemon* spp. flowering period than normal. Poor seed set for *P. acuminatus* and *P. speciosus* in 2007 also was related to poor vegetative growth compared to 2006 and 2008. In 2009, all plots of *P. acuminatus* and *P. speciosus* again showed poor vegetative growth and seed set. Root rot affected all plots of *P. acuminatus* in 2009, killing all plants in two of the four plots of the wettest treatment (2 inches per irrigation). Root rot affected the wetter plots of *P. speciosus* in 2009, but the stand partially recovered due to natural reseeding.

Seed yields

Penstemon speciosus, royal penstemon

In 2006-2009, 2012, 2014, 2015, and 2018 seed yield of *P. speciosus* showed a quadratic response to irrigation rate plus spring precipitation (Tables 4 and 5). Seed yields were maximized by 7.7, 6.1, 6.4, 8.3, 6.5, 6.9, 8.2, and 7 inches of water applied plus spring precipitation in 2006-2009, 2012, 2014, 2015, and 2018, respectively. In 2011 and 2017 there was no difference in seed yield between treatments. In 2010, seed yields were highest with no irrigation and 4.3 inches of spring precipitation. In 2013, seed yield increased with increasing water application, up to 8.9 inches, the highest amount tested (includes 0.9 inches of spring precipitation). Seed yield was low in 2007 due to lygus bug damage, as discussed previously. Seed yield in 2009 was low due to stand loss from root rot. The plant stand recovered somewhat in 2010 and 2011, due in part to natural reseeding, especially in the nonirrigated plots. The replanting of *P. speciosus* in the fall of 2015 resulted in a good stand in 2016. The new stand of *P. speciosus* did not flower in 2016.

Penstemon acuminatus, sharpleaf penstemon

There was no significant difference in seed yield between irrigation treatments for *P. acuminatus* in 2006 (Tables 4 and 5). Precipitation from March through June was 6.4 inches in 2006. The 64-year-average precipitation from March through June is 3.6 inches. The wet weather in 2006 could have attenuated the effects of the irrigation treatments. In 2007, seed yield showed a quadratic response to irrigation rate. Seed yields were maximized by 4.0 inches of water applied in 2007. In 2008, seed yield showed a linear response to applied water. In 2009 seed yield showed a negative response to irrigation. The negative effects of irrigation in 2009 were exacerbated by root rot, which was more pronounced in the irrigated plots. By 2010, substantial lengths of row contained only dead plants. Measurements in each plot showed that plant death increased with increasing irrigation rate. The stand loss was 51.3, 63.9, and 88.5% for the 0-, 4-, and 8-inch irrigation treatments, respectively. The trial area was disked out in 2010. Following the 2005 planting, seed yields were substantial in 2006 and moderate in 2008. *Penstemon acuminatus* performed as a short-lived perennial.

***Penstemon cyaneus*, blue penstemon**

From 2011 to 2018, seed yields were responsive to irrigation only in 2013 and 2018 (Tables 4 and 5). Seed yields showed a quadratic response to irrigation with a maximum seed yield at 4 and 4.2 inches of water applied in 2013 and 2018, respectively.

***Penstemon deustus*, scabland penstemon**

Seed yields did not respond to irrigation in any year except 2011 and 2015. In 2011, seed yields were highest with no irrigation (Tables 4 and 5). In 2015, seed yield showed a quadratic response to irrigation with a maximum seed yield at 5.4 inches of water applied.

***Penstemon pachyphyllus*, thickleaf beardtongue**

From 2011 to 2018, seed yields responded to irrigation only in 2013 and 2018 (Tables 4 and 5). In 2013, seed yields increased with increasing irrigation up to the greatest level of 8 inches. In 2018, seed yields showed a quadratic response to irrigation with a maximum seed yield at 3 inches of water applied.

Conclusions

Subsurface drip-irrigation systems were tested for native seed production because they have two potential strategic advantages: a) low water use, and b) the buried drip tape provides water to the plants at depth, precluding most irrigation-induced stimulation of weed seed germination on the soil surface and keeping water away from native plant tissues that are not adapted to a wet environment.

Due to the semi-arid environment, supplemental irrigation was occasionally required for successful flowering and seed set. The total irrigation requirements for these semi-arid-land species were low and varied by species and years (Table 6). In 4 years of testing, *P. acuminatus* showed a quadratic response to irrigation in 2007 and 2008 and a negative response to irrigation in 2009. The years 2007 and 2008 had lower than average spring precipitation. From 2011 to 2017, *P. cyaneus* and *P. pachyphyllus* responded to irrigation only in 2013 and 2018, which had lower than average fall, winter, and spring precipitation. From 2006 to 2018, *P. speciosus* showed a quadratic response to irrigation in 8 out of the 11 years. Similar to *P. pachyphyllus* and *P. cyaneus, P. speciosus* showed a positive linear response to irrigation in 2013. *Penstemon speciosus* showed either no response or a negative response to irrigation in 3 years with higher than average spring precipitation.

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Table 2. *Penstemon* flowering, irrigation, and seed harvest dates by species in 2006-2018, Malheur Experiment Station, Oregon State University, Ontario, OR.

		Flowering dates			Irrigation dates		
Species	Year	Start	Peak	End	Start	End	Harvest
Penstemon acuminatus	2006	2-May	10-May	19-May	19-May	30-Jun	7-Jul
	2007	19-Apr		25-May	19-Apr	24-Jun	9-Jul
	2008	29-Apr		5-Jun	29-Apr	11-Jun	11-Jul
	2009	2-May		10-Jun	8-May	12-Jun	10-Jul
Penstemon cyaneus	2011	23-May	15-Jun	8-Jul	13-May	23-Jun	18-Jul
	2012	16-May	30-May	10-Jun	27-Apr	7-Jun	27-Jun
	2013	3-May	21-May	5-Jun	24-Apr	5-Jun	11-Jul
	2014	5-May	13-May	8-Jun	29-Apr	10-Jun	14-Jul
	2015	5-May		12-Jun	21-Apr	3-Jun	13-Jul
	2016	29-Apr		15-Jun	18-Apr	31-May	8-Jul
	2017	8-May	15-May	7-Jun	2-May	20-Jun	17-Jul
	2018	1-May	10-May	20-Jun	3-May	13-Jun	6-Jul
Penstemon deustus	2006	10-May	19-May	30-May	19-May	30-Jun	4-Aug
	2007	5-May	25-May	25-Jun	19-Apr	24-Jun	
	2008	5-May		20-Jun	18-Apr	31-May	
	2011	23-May	20-Jun	14-Jul	13-May	23-Jun	16-Aug
	2012	16-May	30-May	4-Jul	27-Apr	7-Jun	7-Aug
	2013	3-May	18-May	15-Jun	24-Apr	5-Jun	
	2014	10-May	20-May	19-Jun	29-Apr	10-Jun	21-Jul
	2015	1-May		10-Jun	21-Apr	3-Jun	23-Jul
	2016	no flowering			18-Apr	31-May	
	2017	15-May	7-Jun	30-Jun	2-May	20-Jun	1-Aug
	2018	3-May		20-Jun	3-May	13-Jun	26-Jul
Penstemon pachyphyllus	2011	10-May	30-May	20-Jun	13-May	23-Jun	15-Jul
	2012	23-Apr	2-May	10-Jun	27-Apr	7-Jun	26-Jun
	2013	26-Apr		21-May	24-Apr	5-Jun	8-Jul
	2014	22-Apr	5-May	4-Jun	29-Apr	10-Jun	13-Jul
	2015	24-Apr	5-May	26-May	21-Apr	3-Jun	10-Jul
	2016	18-Apr		13-May	18-Apr	31-May	22-Jun
	2017	1-May	15-May	7-Jun	2-May	20-Jun	29-Jun
	2018	30-Apr	10-May	10-Jun	3-May	13-Jun	26-Jun
Penstemon speciosus	2006	10-May	19-May	30-May	19-May	30-Jun	13-Jul
	2007	5-May	25-May	25-Jun	19-Apr	24-Jun	23-Jul
	2008	5-May		20-Jun	29-Apr	11-Jun	17-Jul
	2009	14-May		20-Jun	19-May	24-Jun	10-Jul
	2010	14-May		20-Jun	12-May	22-Jun	22-Jul
	2011	25-May	30-May	30-Jun	20-May	5-Jul	29-Jul
	2012	2-May	20-May	25-Jun	2-May	13-Jun	13-Jul
	2013	2-May	10-May	20-Jun	2-May	12-Jun	11-Jul
	2014	29-Apr	13-May	9-Jun	29-Apr	10-Jun	11-Jul
	2015	28-Apr	5-May	5-Jun	21-Apr	3-Jun	30-Jun
	2016	no flowering			3-May	13-Jun	6-Jul
	2017	8-May	15-May	7-Jun	2-May	20-Jun	17-Jul
	2018	2-May		13-Jun	3-May	13-Jun	6-Jul

Table 3. Early season precipitation and growing degree-days at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2006-2018.

Year	Precipitation (inch)			Growing degree-days (50-86°F)
	Spring	Winter + spring	Fall + winter + spring	Jan–Jun
2006	3.4	10.1	14.5	1273
2007	1.9	3.8	6.2	1406
2008	1.4	3.2	6.7	1087
2009	4.1	6.7	8.9	1207
2010	4.3	8.4	11.7	971
2011	4.8	9.3	14.5	856
2012	2.6	6.1	8.4	1228
2013	0.9	2.4	5.3	1319
2014	1.7	5.1	8.1	1333
2015	3.2	5.9	10.4	1610
2016	2.2	5.0	10.1	1458
2017	4.0	9.7	12.7	1196
2018	1.9	4.9	5.8	1342
13-year average:	2.9	6.3	9.8	25-year average: 1207

Table 4. Native wildflower seed yield in response to irrigation rate (inches/season) in 2006 through 2018. Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
		----------- lb/acre ----------			
Penstemon acuminatus[a]	2006	538.4	611.1	544	NS
	2007	19.3	50.1	19.1	25.5[b]
	2008	56.2	150.7	187.1	79
	2009	20.7	12.5	11.6	NS
	2010	-- Stand disked out --			
Penstemon cyaneus	2011	857.2	821.4	909.4	NS
	2012	343.3	474.6	581.1	NS
	2013	221.7	399.4	229.2	74.4
	2014	213.9	219.8	215.1	NS
	2015	148.4	122.5	216.8	NS
	2016	36.0	84.1	79.6	NS
	2017	117.7	196.6	173.1	NS
	2018	86.8	37.4	79.4	36.6
	Average	253.1	310.4	310.5	NS
Penstemon deustus[c]	2006	1246.4	1200.8	1068.6	NS
	2007	120.3	187.7	148.3	NS
	2008	-- Stand disked out --			
	2011	637.6	477.8	452.6	NS
	2012	308.7	291.8	299.7	NS
	2013	--- no flowering ---			
	2014	356.4	504.8	463.2	NS
	2015	20.0	76.9	67.0	43.7[b]
	2017	205.4	258.8	247.6	NS
	2018	110.7	85.3	94.7	NS
	Average	314.5	324.8	300.1	NS
Penstemon pachyphyllus	2011	569.9	337.6	482.2	NS
	2012	280.5	215	253.7	NS
	2013	159.4	196.8	249.7	83.6
	2014	291.7	238.6	282.1	NS
	2015	89.5	73.5	93.3	NS
	2016	142.7	186.3	169.7	NS
	2017	111.2	108.1	99.1	NS
	2018	152.5	119.9	221.0	85.0
	Average	224.7	184.5	231.4	NS
Penstemon speciosus[a]	2006	163.5	346.2	213.6	134.3
	2007	2.5	9.3	5.3	4.7[b]
	2008	94	367	276.5	179.6
	2009	6.8	16.1	9	6.0[b]
	2010	147.2	74.3	69.7	NS
	2011	371.1	328.2	348.6	NS
	2012	103.8	141.1	99.1	NS
	2013	8.7	80.7	138.6	63.7
	2014	76.9	265.6	215.1	76.7
	2015	105.4	207.3	173.7	50.3
	2016	--- no flowering ---			
	2017	88.6	117.1	82.3	NS
	2018	0.8	7.7	5.7	4.2
	Average	97.4	160.3	135.1	31.5

[a] Planted March, 2005, areas of low stand replanted by hand in October 2005.

[b] LSD (0.10).

[c] Planted March, 2005, areas of low stand replanted by hand in October 2005 and whole area replanted in October 2006. Yields in 2006 are based on small areas with adequate stand. Yields in 2007 are based on whole area of very poor and uneven stand.

Table 5. Regression analysis for native wildflower seed yield (y) in response to irrigation (x) (inches/season) using the equation $y = a + b•x + c•x^2$ in 2006-2018, and 4- to 13-year averages. For the quadratic equations, the amount of irrigation that resulted in maximum yield was calculated using the formula: -b/2c, where b is the linear parameter and c is the quadratic parameter. Malheur Experiment Station, Oregon State University, Ontario, OR. (Continued on next page.)

Penstemon acuminatus

Year	Intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2006	538.4	35.6	-4.4	0.03	NS[a]		
2007	19.3	15.4	-1.9	0.44	0.10	50.5	4.1
2008	56.2	30.9	-1.8	0.63	0.05	188.8	8.6
2009	20.5	-1.1		0.28	0.10	11.4	8.0
Average	165.6	17.1	-1.8	0.1	NS		

Penstemon cyaneus

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2011	836.6	6.5		0.01	NS		
2012	347.4	29.7		0.21	NS		
2013	221.7	87.9	-10.9	0.63	0.05	398.9	4
2014	215.7	0.1		0.01	NS		
2015	128.4	8.5		0.09	NS		
2016	36.0	18.6	-1.6	0.29	NS		
2017	117.7	32.5	-3.2	0.19	NS		
2018	86.8	-23.8	2.9	0.61	0.05	37.3	4.2
Average	253.1	21.5	-1.8	0.38	NS		

Penstemon deustus

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2006	1260.9	-22.2		0.05	NS		
2007	120.3	30.2	-3.3	0.19	NS		
2011	615.2	-23.1		0.35	0.05	615.2	0
2012	304.6	-1.1		0.01	NS		
2014	356.4	60.8	-5.9	0.26	NS		
2015	20.0	22.6	-2.1	0.42	0.10	81.0	5.4
2017	205.4	21.4	-2.0	0.08	NS		
2018	104.9	-2.0		0.06	NS		
Average	314.5	6.9	-1.1	0.02	NS		

[a] Not significant. There was no statistically significant trend in seed yield in response to the amount of irrigation.

Table 5. (Continued.) Regression analysis for native wildflower seed yield in response to irrigation rate (inches/season) in 2006-2018, and 4- to 13-year averages. Malheur Experiment Station, Oregon State University, Ontario, OR.

Penstemon pachyphyllus

Year	intercept	linear	quadratic	R^2	P	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2011	507.1	-11		0.04	NS		
2012	263.1	-3.3		0.01	NS		
2013	156.8	11.3		0.33	0.1	247.2	8.0
2014	275.6	-1.2		0.01	NS		
2015	83.6	0.5		0.01	NS		
2016	142.7	18.4	-1.9	0.07	NS		
2017	112.2	-1.5		0.02	NS		
2018	152.5	-24.9	4.2	0.54	0.05	115.5	3.0
Average	224.7	-20.9	2.7	0.28	NS		

Penstemon speciosus

Year	intercept	linear	quadratic	R^2	P	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2006	-238.2	151.9	-9.9	0.66	0.05	347.2	7.7	3.4
2007	-5.1	4.7	-0.4	0.48	0.10	9.3	6.1	1.9
2008	-91.7	146.1	-11.4	0.56	0.05	378.4	6.4	1.4
2009	-19.5	8.6	-0.5	0.54	0.05	16.2	8.3	4.1
2010	177.8	-9.7		0.28	0.10	135.8	4.3	4.3
2011	374.0	-2.8		0.01	NS			4.8
2012	6.5	46.7	-3.6	0.54	0.05	158.8	6.5	2.6
2013	-2.8	16.2		0.77	0.001	141.0	8.9	0.9
2014	-78.8	102.9	-7.5	0.62	0.05	275.5	6.9	1.7
2015	-75.1	69.7	-4.2	0.64	0.05	211.6	8.2	3.2
2017	-2.4	30.8	-2.0	0.27	NS			4.0
2018	-5.6	3.9	-0.3	0.62	0.05	8.1	7.0	1.9
Average	-56.6	53.0	-3.0	0.60	0.05	177.0	8.8	2.9

[a] Not significant. There was no statistically significant trend in seed yield in response to the amount of irrigation.

Table 6. Amount of irrigation water for maximum *Penstemon* seed yield, years to seed set, and life span. A summary of multi-year research findings, Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Optimum amount of irrigation for seed production	Year of first seed set	Approximate life span
	inches/season	from fall planting	years
P. acuminatus	0 in wetter years, 4 in warm, dry years	1	3
P. deustus	response to irrigation in 1 out of 8 years	2	3
P. cyaneus	no response in 6 out of 8 years, 4 inches in drier years	1	3
P. pachyphyllus	no response in 6 out of 8 years, 3 to 8 inches in drier years	1-2	3
P. speciosus	0 in cool, wet years, 4-8 in warm, dry years	1-2	3

2018 POTATO VARIETY TRIALS

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Introduction

New potato varieties were evaluated in 2018 for their productivity and their suitability for fresh market and processing. Potatoes in Malheur County, Oregon, are grown under contract for processors to make frozen potato products for the food service industry and grocery chain stores. There is very little production for fresh pack or open market, and very few growers store potatoes on their farms. There is also no local production of varieties for making potato chips.

The varieties grown for processing in Malheur County are mainly ‘Ranger Russet’, ‘Shepody’, and ‘Russet Burbank’. Harvest begins in July and potatoes arrive at processing plants for storage or processing directly from the field.

Prolonged vine health supports increased potato yield, but the “early die” syndrome can limit tuber bulking later than mid-August. Early die causes early senescence of the vines of susceptible varieties such as Shepody and Russet Burbank. A complex of soil pathogens, including bacteria, nematodes, and fungi, particularly Verticillium wilt, causes early die in Malheur County. Early die is worse when the crop rotation between potato crops is shorter.

Small acreages of new varieties or advanced selections are sometimes grown under contract to study the feasibility of expanding their use. To replace an existing processing variety, a new potato variety must have numerous outstanding characteristics. The yield should be at least as high as the yield of the currently contracted varieties. The tubers need to have low reducing sugars for light fry color, and high specific gravity. A new variety should be resistant to tuber defects or deformities caused by disease, water stress, or heat. It should begin tuber bulking early and grow rapidly for early harvest. Late-harvested varieties resistant to early die can continue bulking into September.

Potato variety development trials at the Malheur Experiment Station in 2018 included the Tristate Russet Trial with 14 entries, the Oregon Statewide Russet Trial with 31 entries, the Preliminary Yield Russet Trial with 123 entries, the National Fry Processing Trial (NFPT) with 44 entries, the Oregon Statewide Specialty Trial of 6 colored skin and/or flesh potato varieties, the Western Region Specialty Trial of 13 colored skin and/or flesh potato varieties, the Preliminary Yield Specialty Trial of 24 colored skin and/or flesh potato varieties, the Oregon Statewide Chip Trial with 10 entries, and the Preliminary Yield Chip Trial with 33 entries. Through these trials and active cooperation with other scientists in Oregon, Idaho, and

Washington, promising new lines are bred and evaluated. Eventually, the lines may be released as new varieties.

Materials and Methods

The potato variety trials were grown in 2018 on Greenleaf silt loam, following winter wheat using sprinkler irrigation. Based on a soil test, 15 lb phosphorus (P)/acre, 85 lb potassium (K)/acre, 160 lb sulfur (S)/acre, 9 lb manganese (Mn)/acre, 1 lb copper (Cu)/acre, and 4 lb boron (B)/acre were broadcast in the fall of 2017. The field was fumigated with 20 gal/acre of Telone® II and bedded on 36-inch row spacing in the fall of 2017. On April 2, 2018, 100 lb nitrogen (N)/acre and 20 oz/acre of Admire® (Imidacloprid) at 7 oz/acre (0.25 lb ai/acre) were shanked in the bed center.

Seed of all varieties was cut by hand into 2.5-oz seed pieces, treated with Maxim® MZ (fludioxonil, mancozeb) dust, and stored briefly to suberize. Potato seed pieces were planted using a 2-row assist-feed planter with 9-inch seed spacing in 36-inch rows. Red potatoes were planted at the end of each plot as markers to separate the potato plots at harvest, except in the specialty trials where russeted potatoes were used as markers.

The TriState Russet Early Trial was planted on April 3. The State Russet Trial was planted on April 6. The Russet Preliminary Yield Trial was planted on April 10. The Regional Specialty Trial and the NFPT trial were planted on April 11. The Chip Preliminary Yield Trial was planted on April 12. The State Specialty Trial, State Chip Trial, and the Specialty Preliminary Yield Trial were planted on April 13.

All trials, except the preliminary yield trials and the NFPT trial, had plots that were a single bed wide with 30 seed pieces (23 ft long) replicated 4 times. The preliminary yield trials had unreplicated plots that were two beds with 20 seed pieces (15 ft long). The NFPT trial had plots that were a single bed wide with 15 seed pieces (11 ft long) replicated once for tier one clones, twice for tier two clones, and 3 times for tier three clones.

After planting, hills were re-formed over the rows with a Lilliston rolling cultivator. The herbicides Prowl® H_2O (pendimethalin) at 0.95 lb ai/acre, Dual Magnum® (metolachlor) at 1.27 lb ai/acre, and Roundup® at 2 pt/acre were applied as a tank mix for weed control on April 24. The herbicides were incorporated by sprinkler irrigation with approximately 0.5 inch of water. The herbicide Shadow® (clethodim) at 10 oz/acre was broadcast on May 15. Matrix® (rimsulfuron) at 0.25 oz ai/acre was applied on May 21 through the sprinkler system. On June 12 and June 27, Bravo® (chlorothalonil) at 1 pt/acre (0.75 lb ai/acre) was broadcast aerially. On July 28 and August 20, Movento® (Spirotetramat) at 5 oz/acre and Agri-Mek® (abamectin) at 3.5 oz/acre were broadcast aerially. On August 27, Zing! ® fungicide (Zoxamide, chlorothalonil) at 34 oz/acre was broadcast aerially.

Emergence for the Tristate Russet trial started on May 5. Emergence for the other trials started on May 7. Irrigation scheduling was based on a soil water tension criterion of 50-60 cb. Soil water tension was measured at seed piece depth (8-inch depth) using 8 Watermark soil moisture sensors (Model 200SS, Irrometer Co., Inc., Riverside, CA) connected to a datalogger. Irrigations were managed to maintain the soil water tension below 60 cb. Irrigation decisions were based on the average of all 8 sensors. Irrigations started on May 21 and ended on September 6, totaling 19 irrigations.

Fertilization during plant growth was based on petiole and soil solution tests taken on June 8, June 22, June 29, July 9, July 23, August 3, and August 10. Based on the tissue and soil tests, a total of 15 lb N/acre, 75 lb K/acre, 14 lb magnesium (Mg)/acre and 0.5 lb Mn/acre were applied during the growing season. Fertilizer was injected into the sprinkler system during irrigation.

The vines in the Tristate Russet trial were flailed on August 8 and on August 14 the potatoes were harvested. For the other trials, the vines were flailed on September 14. The harvest dates for the other trials were September 24 for the NFPT trial, September 25 for the Preliminary Yield Russet trial, September 26 for the Preliminary Yield Chip and Preliminary Yield Specialty trials, September 27 for the Regional Specialty trial, October 1 for the State Russet and State Specialty trials, and October 2 for the State Chip trial.

At harvest, potatoes in each plot were lifted with a two-row digger that laid the tubers back onto the soil in each row. At harvest, visual evaluations were made that included observations of desirable traits (i.e., high yield of large, smooth, uniformly shaped and sized, oblong to long, attractively russeted tubers, with shallow eyes evenly distributed over the tuber length). Observations were also taken of the external tuber defects including growth cracks, knobs, thumbnail cracks, curved or irregularly shaped tubers, pointed ends, stem-end decay, attached stolons, heat sprouts, chain tubers, folded bud ends, scab, rough skin due to excessive russeting, and pigmented eyes. A note was made for each plot to keep or discard the clone based on the overall appearance of the tubers.

Tubers were placed into burlap sacks and placed in a barn where they were kept under tarps until grading. Tubers were graded by market class (U.S. No. 1 and U.S. No. 2) and weight (<4 oz, 4-6 oz, 6-12 oz, and >12 oz). Tubers were graded as U.S. No. 2 if any of the following conditions occurred: growth cracks, bottleneck shape, abnormally curved shape, or two or more knobs. Marketable tubers are U.S. No. 1 and U.S. No. 2 larger than 4 oz. A 20-tuber sample from each plot was placed into storage. The storage temperature was gradually reduced to 45°F.

After 6 weeks in storage, a 10-tuber sample from each plot of the Tristate Russet Trial, Oregon Statewide Russet Trial, the Preliminary Yield Russet Trial, the Oregon Statewide Chip Trial, and the Preliminary Yield Chip Trial was evaluated for tuber quality traits for processing. Ten tubers per plot of the Tristate Russet Trial, Oregon Statewide Russet trial, and the Preliminary Yield Russet Trial were cut lengthwise and the 10 center slices were fried for 2.5 min in 375°F soybean oil. For the Oregon Statewide Chip Trial, 10 tubers per plot were cut into 0.06-inch slices and fried for 2.5 min in 375°F soybean oil. Percent light reflectance was measured on the stem and bud ends of each slice for the russet varieties and in the slice center for the chip varieties. Percent light reflectance was measured using a Photovolt Reflectance Meter model 577A (Photovolt Instruments, Inc., Minneapolis, MN), with a green tristimulus filter, calibrated to read 0% light reflectance on the black standard cup and 77.1% light reflectance on the white porcelain standard plate. Specific gravity of all varieties was measured from a 10-tuber sample from each plot using the weight-in-air, weight-in-water method. All varieties were evaluated for internal tuber defects from a 10-tuber sample from each plot.

Data from all trials were analyzed with the General Linear Models analysis of variance procedure in NCSS (Number Cruncher Statistical Systems, Kaysville, UT). Means comparisons were made using Fisher's protected LSD (least significant difference) at the 95% confidence level.

Results and Discussion

In 2018, the potatoes were planted close to the ideal planting date of April 7. Irrigations were adequate to maintain the soil water tension below the critical level of 50 to 60 cb (Fig. 1). Both petiole nitrate and soil solution N levels remained above the critical level during the season, despite the low amount of N applied (100 lb N/acre preplant plus 15 lb N/acre sprinkler applied, Figs. 2 and 3). The adequate N supply to the crop is reflected in the ample amounts of soil available N during the season (Fig. 4).

Tristate Russet Trial

The clones Ranger Russet, OR12133-10, A07705-4, POR12NCK50-1, and AOR08540-1 were among those with the highest total yields (Table 1). The clones Ranger Russet, POR12NCK50-1, OR12133-10, A07547-4adg, and AOR10204-3 were among the clones with the highest U.S. No. 1 yields.

A08510-1LB, AOR08540-1, and POR12NCK50-1were among the clones with the highest specific gravity (measure of tuber solids) in this trial (Table 1). The tuber internal defects encountered were internal brown spot and black spot bruise (Table 2). Observations on visual appearance at harvest can be found in Table 3.

Oregon Statewide Russet Trial

The clones AOR10633-1, AOR12347-5, AOR11847-2, AOR12344-21, and AOR13066-1 were among those with the highest total yields (Table 4). AOR12347-5, AOR12344-21, AOR10633-1, AOR13066-1, and AOR12386-5 were among the clones with the highest U.S. No. 1 yields.

AOR13064-2, AOR12344-21, AOR12342-2, AOR13066-1, and AOR11217-3 were among the clones with the lightest tuber fry color in this trial (Table 4). The tuber internal defects encountered for each clone are listed in Table 5. Observations on visual appearance at harvest can be found in Table 6.

Preliminary Yield Russet Trial

Some of the varieties had significantly higher yield and grade and better processing quality than the three commercial varieties in the trial (Table 7). Of the 123 clones tested, 40 were selected for further testing based on visual observations at harvest (Table 8). Some of the clones had better visual appearance at harvest than ‘Russet Norkotah’, Ranger Russet, and Russet Burbank. Tuber internal defects for the clones are listed in Table 9.

National Fry Processing Trial (NFPT)

Some varieties had higher yield and processing quality than the commercial varieties (Tables 10 and 11). Of the six commercial varieties in the trial, Ranger Russet, ‘Clearwater Russet’, and ‘Dakota Russet’ were among the highest in total yield (Table 11).

Colored Flesh Potato Trials

Potato tubers with red to yellow carotenoid or red, blue, and purple anthocyanin pigments are of interest because of the anti-oxidant properties of these pigments in human nutrition. Three trials tested specialty potato varieties in 2018: Oregon Statewide Specialty, Preliminary Yield Specialty, and Western Region Specialty.

Oregon Statewide Specialty Trial

The clones ‘Chieftain’ and POR15PG014-8 were among those with the highest total yield (Table 12). Chieftain and ‘Yukon Gold’ had the highest yield of tubers over 14 oz, an undesirable trait. POR15PG014-8 and POR15PG034-1 had the highest yield of tubers under 4 oz. POR15PG015-3 and POR15PG036-3 had the highest yield of cull tubers, due to sprouting. Tuber internal defects for the clones are listed in Table 13. Chieftain had the highest percentage of tubers with internal brown spot. Observations on visual appearance at harvest can be found in Table 14.

Preliminary Yield Specialty Trial

The varieties Yukon Gold, Chieftain, OR13SP198-2, and OR13SP198-4 were among those with the highest yield of tubers over 14 oz (Table 15). ‘Purple Majesty’, POR16PG7-3, and OR14H004-3 had high yields of cull tubers due to sprouting at harvest (Table 15). Yukon Gold Chieftain, and POR16PG42-4 had internal brown spot (Table 16). Clones POR16PG42-4 and OR13SP198-4 has vascular discoloration and hollow heart. Exterior appearance observations can be found in Table 17.

Western Region Specialty Trial

The varieties ‘Red LaSoda’ and Chieftain were among those with the highest total yield (Table 18). Red LaSoda had the highest yield of tubers over 14 oz, an undesirable trait. Clones COTX04193S-2R/Y and CO08037-2P were among those with the highest yield of tubers under 4 oz. Clones CO09128-3W/Y and CO09128-5W/Y had high yields of cull tubers due to sprouting at harvest.

Chieftain had the highest percentage of tubers with the internal defect internal brown spot (Table 19). Exterior appearance observations can be found in Table 20.

Oregon Statewide Chip Trial

Several varieties had total yields over 700 cwt/acre, with clone AOR12197-4 among the highest yielding (Table 21). Several varieties had yield of tubers over 10 oz (an undesirable trait) greater than 200 cwt/acre. Clone AOR13125-9 and ‘Atlantic’ were among those with the highest specific gravity. Tuber internal defects for the clones are listed in Table 22.

Preliminary Yield Chip Trial

Clones ‘Snowden’ and NYORQ2-10 were among those with the highest total yield (Table 23). Clones NYORQ2-10, Snowden, and NYORQ6-3 were among those with the highest yield of tubers more than 10 oz. Clones NYORQ6-6 and NYORQ6-8 were among the clones with the lightest fry color. Tuber internal defects for the clones are listed in Table 24. Exterior appearance observations can be found in Table 25.

Acknowledgements

This project was funded by the USDA/ARS, Oregon Potato Commission, Oregon State University, Malheur County Education Service District, and was supported by Formula Grant nos. 2018-31100-06041 and 2018-31200-06041 from the USDA National Institute of Food and Agriculture.

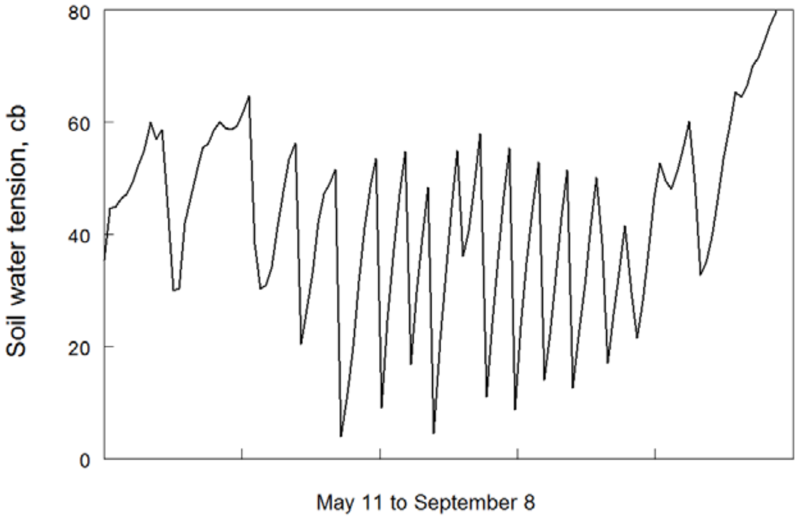


Figure 1. Soil water tension at 8-inch depth over time. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

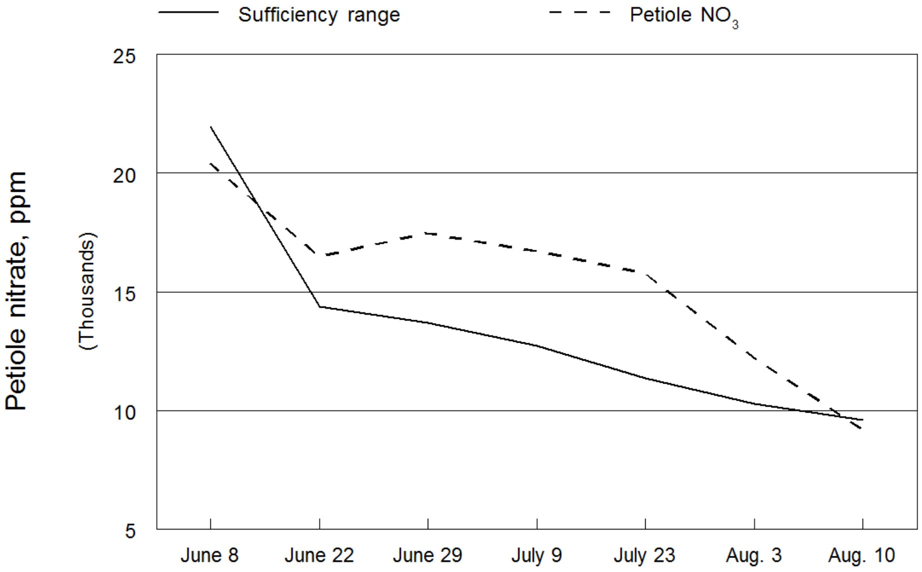


Figure 2. Petiole nitrate over time. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

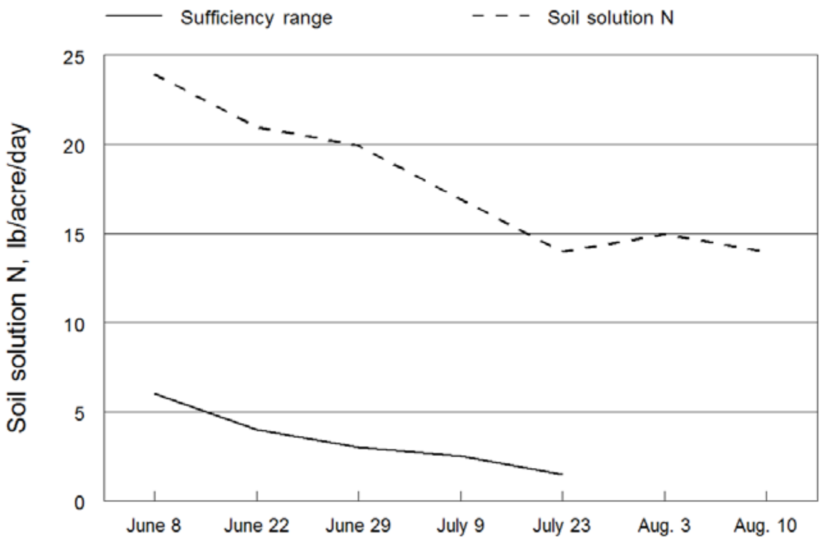


Figure 3. Soil solution nitrogen over time. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

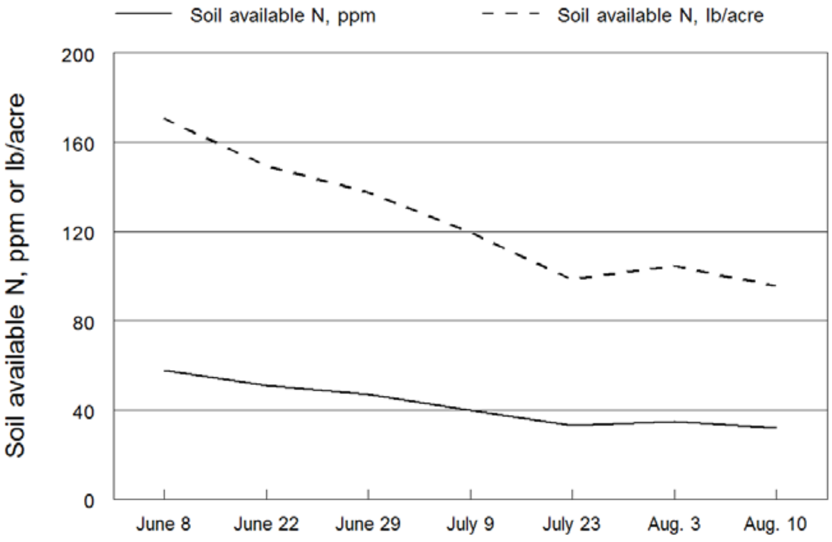


Figure 4. Soil available N (NO_3-N + NH_4-N) in parts per million and lb/acre over time. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Table 1. Tristate Russet Trial potato yield, grade, and processing quality, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

			U.S. No. 1														
Variety	Percent No. 1	Total yield	Total	>20 oz	10 to 20 oz	6 to 10 oz	4 to 6 oz	U.S. No. 2	Marketable	<4 oz	Cull	Average tuber weight	No. of tubers /plant	Length/width	Specific gravity	Average fry color, light reflectance	Sugar ends
	%	cwt/acre										oz		ratio	g cm^{-3}	%	
Ranger Russet	79.0	727.0	574.6	10.9	319.7	186.1	57.8	76.0	650.6	45.4	31.0	7.0	8.7	2.2	1.079	40.9	0.0
Russet Burbank	43.7	624.8	273.0	2.3	101.2	118.9	50.6	217.8	490.8	51.7	82.3	5.9	8.8	2.1	1.072	34.6	10.0
Russet Norkotah	80.5	539.4	434.1	17.1	167.5	183.4	66.0	24.5	458.6	54.1	26.7	5.1	8.9	2.0	1.068	36.7	5.0
Shepody	81.2	608.9	494.2	58.1	270.2	123.0	42.9	71.3	565.5	38.0	5.5	5.9	8.5	1.9	1.072	41.8	0.0
A07098-4	84.5	582.3	492.2	4.2	140.0	231.1	116.9	12.1	504.2	69.8	8.3	5.2	9.2	1.7	1.073	33.8	0.0
A07547-4adg	93.9	567.3	532.6	25.9	245.4	199.5	61.9	1.0	533.6	28.0	5.6	5.5	8.6	1.4	1.078	47.3	0.0
A07705-4	78.9	639.2	504.6	0.0	78.0	280.7	145.9	4.4	509.0	120.1	10.1	6.1	8.7	1.4	1.069	36.5	0.0
A08422-4VRsto	86.2	523.7	451.6	4.2	202.3	189.7	55.4	31.0	482.5	33.2	8.0	4.8	9.1	1.6	1.079	40.0	0.0
A08510-1LB	83.2	624.9	520.2	4.5	161.9	244.7	109.2	4.4	524.6	86.5	13.8	5.7	9.1	1.4	1.085	44.0	0.0
A09022-4	77.3	433.1	334.6	0.0	67.1	149.5	118.0	8.4	343.0	80.5	9.6	4.1	8.8	1.5	1.077	47.3	0.0
AOR08540-1	80.6	634.6	511.5	36.8	300.0	135.5	39.2	66.6	578.1	31.7	24.8	5.9	9.0	2.1	1.085	40.1	2.5
AOR10204-3	83.5	624.8	521.7	4.9	186.1	222.8	108.0	32.7	554.4	60.2	10.2	5.7	9.1	2.1	1.073	37.5	10.0
OR12133-10	82.9	661.2	548.2	14.2	234.9	215.4	83.7	20.5	568.8	66.9	25.6	6.4	8.6	1.9	1.077	35.2	12.5
POR12NCK50-1	87.1	636.9	554.9	7.2	194.2	237.9	115.6	6.3	561.2	66.6	9.1	5.7	9.3	1.7	1.085	49.1	0.0
Mean	80.2	602.0	482.0	13.6	190.6	194.2	83.6	41.2	523.2	59.5	19.3	5.6	8.9	1.8	1.076	40.3	2.9
LSD (0.05)	6.0	95.0	96.4	24.7	80.1	47.6	24.3	39.6	106.5	22.7	35.6	1.1	NS	0.2	0.005	5.2	NS

Table 2. Tristate Russet Trial tuber internal defects, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety	Vascular discoloration	Hollow heart	Internal brown spot	Black spot bruise
	--	--------- % ---------	--	
Ranger Russet	0.0	0.0	0.0	0.0
Russet Burbank	0.0	0.0	7.5	0.0
Russet Norkotah	0.0	0.0	0.0	0.0
Shepody	0.0	0.0	0.0	0.0
A07098-4	0.0	0.0	0.0	0.0
A07547-4adg	0.0	0.0	0.0	0.0
A07705-4	0.0	0.0	5.0	0.0
A08422-4VRsto	0.0	0.0	2.5	0.0
A08510-1LB	0.0	0.0	0.0	0.0
A09022-4	0.0	0.0	0.0	0.0
AOR08540-1	0.0	0.0	0.0	2.5
AOR10204-3	0.0	0.0	0.0	0.0
OR12133-10	0.0	0.0	2.5	0.0
POR12NCK50-1	0.0	0.0	0.0	0.0
Mean	0.0	0.0	1.3	0.2
LSD (0.05)	NS	NS	NS	NS

Table 3. Tristate Russet Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Tuber defect observations are from four plots for each clone. K = clone should be saved, D = clone should be discarded. Capital letters denote a higher intensity of an observation compared to lower case letters. Since there were four replicates, a clone could be scored for the same attribute up to four times.

Variety	K or D	Description
Ranger Russet	2k, D, d	water rot, 2 curved, 2 Curved, pointed, irregular shape, Irregular shape, 2 heart shape, 2 growth cracks
Russet Burbank	4D	water rot, Water Rot, growth cracks, 2 pointed, 2 Pointed, 3 curved, Curved, 3 knobs, Knobs, irr. shape, Irr. Shape, lumpy, jelly end rot, 2 Bottle Neck
Russet Norkotah	4k	curved, growth cracks, water rot
Shepody	d, 3D	Lumpy, 2 heart shape, growth cracks, 3 Irregular Shape, 2 curved, 2 pointed, knobs, Bottle Neck
A07098-4	4D	4 Sprouts, extensive sprouting, irregular shape, pointed, heart shape, swollen lenticels
A07547-4adg	k, 3d	3 chipper?, 2 round, Round, too round, nice
A07705-4	4D	sprouts, 3 Sprouts, 2 Rounds, too small, pointed, Pointed
A08422-4VRsto	k, 2d, D	3 growth cracks, low yield, 3 irregular shape, curved, odd shape, inconsistent shape, lumpy
A08510-1LB	2k, 2d	flat, 2 heart shape, 3 too round
A09022-4	2d, 2D	small, round, too round, 2 Round, low yield, Sprouts, growth cracks
AOR08540-1	2K, 2d	2 Nice, 2 irregular shape, 2 curved, Curved, pointed, Pointed, swollen lenticels, heart shape
AOR10204-3	3d, D	pointed, 3 Pointed, curved, knobs, irregular shape, heart shape
OR12133-10	k, 2d, D	2 irregular shape, 2 sprouts, water rot, curved, Pointed, inconsistent shape, swollen lenticels
POR12NCK50-1	k, 2K, d	nice, Nice, 2 irregular shape, sprouts, chain

Table 4. Oregon Statewide Russet Trial potato yield, grade, and processing quality, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

			U.S. No. 1														
Variety	Percent No. 1	Total yield	Total	>20 oz	10 to 20 oz	6 to 10 oz	4 to 6 oz	U.S. No. 2	Marketable	<4 oz	Cull	Average tuber weight	No. of tubers /plant	Length/width	Specific gravity	Average fry color, light reflectance	Sugar ends
	%						cwt/acre					oz		ratio	g cm^{-3}	------- % --------	
Ranger Russet	68.7	756.7	520.2	24.2	281.6	171.0	67.6	162.0	706.4	48.1	2.2	5.8	11.1	1.9	1.086	41.2	0.0
Russet Burbank	53.0	668.9	354.8	7.3	138.0	157.0	59.8	246.7	608.7	57.6	2.6	5.1	11.0	2.1	1.073	33.0	37.5
Russet Norkotah	79.5	562.5	447.5	6.7	171.4	193.7	82.3	34.4	488.6	73.0	0.9	4.0	11.9	1.7	1.075	36.4	10.0
AOR11217-3	85.4	753.7	643.4	0.0	169.5	317.4	156.5	16.9	660.4	91.4	1.9	6.0	10.4	1.7	1.091	44.6	0.0
AOR10633-1	75.7	892.7	676.1	40.1	402.5	218.9	54.8	130.8	847.1	44.2	1.5	6.4	11.7	1.7	1.088	42.3	10.0
AOR12145-3	83.9	598.6	502.0	2.2	161.4	240.9	99.7	25.8	529.9	60.3	8.4	4.8	10.3	1.5	1.094	38.5	7.5
AOR12149-1	70.4	776.2	546.1	48.8	351.6	142.1	52.4	141.5	736.4	39.8	0.0	5.2	12.4	1.9	1.081	43.0	5.0
AOR12176-4	42.9	790.2	338.7	17.9	164.6	120.3	53.7	301.6	658.2	109.8	22.2	5.6	11.7	1.6	1.069	37.6	15.0
AOR12342-2	78.9	629.0	496.0	4.8	195.7	221.0	79.3	63.7	564.4	63.2	1.3	4.9	10.7	1.7	1.091	45.7	0.0
AOR12344-21	83.5	817.8	683.1	9.8	227.9	316.3	138.9	30.0	723.0	93.7	1.1	6.2	10.9	1.6	1.093	46.5	0.0
AOR12347-5	81.2	872.0	708.0	33.6	359.3	262.8	85.8	33.8	775.5	95.0	1.5	6.1	11.9	1.6	1.087	32.3	25.0
AOR12350-5	84.2	637.7	536.9	17.9	287.0	190.9	59.0	44.7	599.5	38.2	0.0	4.5	11.9	1.7	1.077	43.9	0.0
AOR12386-5	80.8	797.3	644.3	0.0	167.5	313.2	163.6	7.1	651.4	143.1	2.8	5.8	11.6	1.7	1.097	41.9	5.0
AOR13011-1	84.2	686.6	578.3	25.1	328.4	183.6	66.2	33.2	636.5	45.8	4.3	5.3	10.9	1.8	1.083	40.2	0.0
AOR13011-2	85.1	657.8	559.5	27.4	298.8	197.2	63.5	23.5	610.4	46.2	1.2	5.0	11.0	1.8	1.082	42.1	2.5
AOR13018-5	72.4	573.0	415.0	69.3	265.2	121.5	28.4	61.1	545.5	27.4	0.2	4.1	11.7	1.6	1.070	41.9	0.0
AOR13038-1	65.9	745.0	491.2	50.3	315.5	146.4	29.2	172.2	713.7	25.5	5.8	5.6	11.1	2.1	1.081	43.1	2.5
AOR13058-9	81.3	511.5	416.0	8.7	159.5	163.7	92.8	26.9	451.6	58.7	1.2	3.5	12.2	1.6	1.081	38.2	5.0
AOR13061-20	73.3	735.9	539.5	47.3	248.2	202.3	89.0	67.5	654.3	80.2	1.5	5.1	12.1	1.7	1.097	41.7	2.5
AOR13063-3	80.8	656.2	530.3	66.8	320.2	146.8	63.2	14.6	611.7	44.5	0.0	4.8	11.5	1.7	1.086	40.7	0.0
AOR13082-6	84.3	577.4	486.9	11.1	159.9	232.3	94.7	4.2	502.2	75.2	0.0	4.3	11.2	1.7	1.089	37.8	2.5
AOR13107-2	71.5	683.6	488.8	124.2	339.1	119.3	30.4	32.3	645.4	35.9	2.3	5.1	11.2	1.7	1.092	44.6	0.0
AOR11847-2	71.7	838.4	601.2	52.4	311.5	219.1	70.7	108.4	762.0	66.0	10.5	5.9	11.9	1.6	1.094	37.0	5.0
POR15NCYK022-1	74.0	463.3	343.0	4.5	92.6	163.0	87.4	36.6	384.0	78.7	0.6	3.3	11.7	1.7	1.080	41.1	2.5
OR13SPC101-8	80.5	791.9	637.5	8.8	237.4	296.3	103.9	55.3	701.7	89.4	0.8	5.6	11.9	1.4	1.095	40.3	0.0
AOR13066-1	83.5	811.2	677.0	26.9	329.1	259.6	88.2	36.0	739.9	68.4	2.9	5.7	11.9	1.7	1.101	45.6	0.0
AOR12327-3	75.2	487.6	366.8	0.0	74.4	206.1	86.4	62.8	429.6	56.4	1.6	3.7	11.0	1.7	1.079	37.7	0.0
AOR13343-16	71.5	687.0	490.9	1.4	144.8	230.0	116.1	15.7	508.1	177.3	1.5	5.3	10.9	1.5	1.090	38.3	7.5
OR14SP016-3	80.1	636.7	509.8	4.8	186.9	246.4	76.6	57.5	572.1	61.7	3.0	4.5	11.6	1.9	1.080	38.2	12.5
AOR13075-10	67.0	535.5	359.0	69.2	190.2	123.5	45.2	63.6	491.8	43.8	0.0	3.8	11.8	1.5	1.070	34.1	10.0
AOR13064-2	84.8	632.8	536.4	9.5	206.3	237.4	92.7	18.1	564.0	68.3	0.5	4.5	11.8	1.8	1.093	47.9	0.0
Mean	76.0	686.0	520.1	26.5	235.0	205.2	79.9	68.7	615.3	68.0	2.7	5.0	11.5	1.7	1.0854	40.6	5.4
LSD (0.05)	8.6	106.5	98.2	30.5	84.6	52	26.9	57.5	10.8	26.1	NS	1.1	NS	0.2	0.001	3.4	12.3

Table 5. Oregon Statewide Russet Trial tuber internal defects, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety	Vascular discoloration	Hollow heart	Internal brown spot	Black spot bruise
	---------------------- % --------------------			
Ranger Russet	0.0	0.0	0.0	2.5
Russet Burbank	0.0	0.0	7.5	0.0
Russet Norkotah	0.0	0.0	7.5	0.0
AOR11217-3	0.0	0.0	15.0	0.0
AOR10633-1	0.0	0.0	17.5	5.0
AOR12145-3	0.0	0.0	27.5	5.0
AOR12149-1	0.0	0.0	0.0	5.0
AOR12176-4	0.0	0.0	0.0	0.0
AOR12342-2	0.0	0.0	5.0	15.0
AOR12344-21	0.0	0.0	2.5	0.0
AOR12347-5	0.0	0.0	2.5	2.5
AOR12350-5	0.0	0.0	0.0	5.0
AOR12386-5	0.0	0.0	0.0	2.5
AOR13011-1	0.0	0.0	0.0	0.0
AOR13011-2	0.0	0.0	0.0	0.0
AOR13018-5	0.0	0.0	0.0	7.5
AOR13038-1	0.0	0.0	5.0	7.5
AOR13058-9	0.0	0.0	5.0	10.0
AOR13061-20	0.0	0.0	0.0	2.5
AOR13063-3	0.0	0.0	0.0	0.0
AOR13082-6	0.0	0.0	0.0	2.5
AOR13107-2	0.0	0.0	0.0	0.0
AOR11847-2	0.0	0.0	0.0	0.0
POR15NCYK022-1	0.0	0.0	0.0	0.0
OR13SPC101-8	0.0	0.0	42.5	5.0
AOR13066-1	0.0	0.0	17.5	7.5
AOR12327-3	0.0	0.0	2.5	0.0
AOR13343-16	0.0	0.0	7.5	0.0
OR14SP016-3	0.0	0.0	5.0	2.5
AOR13075-10	0.0	0.0	0.0	0.0
AOR13064-2	0.0	0.0	0.0	0.0
Average	0.0	0.0	5.5	2.8
LSD (0.05)	NS	NS	14.4	NS

Table 6. Oregon Statewide Russet Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Tuber defect observations are from four plots for each clone. K = clone should be saved, D = clone should be discarded. Capital letters denote a higher intensity of an observation compared to lower case letters. Since there were four replicates, a clone could be scored for the same attribute up to four times.

Variety	K or D	Description
Ranger Russet	2D, d, k	Growth Cracks, 3 growth cracks, 2 Irregular shape, irregular shape, Bottleneck, 3 bottleneck, 2 dumbell, 2 pointed, Curved, 3 curved
Russet Burbank	4D	Curved, 3 curv., Pointed, 3 point., dumbell, Jelly End, jelly end, water rot, heart shape, Irr. Shape, irr. shape, bottleneck, growth cracks, knobs
Russet Norkotah	D,2d,k	Pointed, 3 pointed, heart shape, dumbell, 2 low yield, sprouted, knobs, growth cracks
AOR11217-3	D,k,2K	2 pointed, Sprouted, sprouted, small, irregular shape
AOR10633-1	D,d,K,k	4 pointed, Growth Cracks, 3 growth cracks, sprouted, 2 curved, heart shaped
AOR12145-3	K,3k	2 dumbell, 2 growth cracks, pointed, inconsistent shape, round, small
AOR12149-1	2D,d,k	4 growth cracks, 2 curved, Bottleneck, 3 bottleneck, 2 knobs, pointed, lumpy, Irregular Shape,
AOR12176-4	4D	3 Growth Cracks, Dumbell, dumbell, Curved, 2 curved, 2 Pointed, 2 pointed, 2 Irregular Shape, knobs, Bottleneck, 2 bottleneck, Sprouted
AOR12342-2	2D,d,k	2 Alligator Hide, dumbell, 3 curved, 2 sprouted, 2 bottleneck, pointed, knobs, heart shape
AOR12344-21	K,3k	3 growth cracks, sprouted, one sprouted, curved, bottleneck
AOR12347-5	3D, k	Pointed, 2 pointed, 3 Sprouted, sprouted, 2 growth cracks
AOR12350-5	K,3k	4 pointed, 2 sprouted, 3 bottleneck, 2 growth cracks
AOR12386-5	3d,k	3 sprouted, curved, 3 pointed, small, some small, skin cracks, growth cracks
AOR13011-1	d,3k	rough, 2 deep eyes, dumbell, 2 Pointed, pointed
AOR13011-2	D,d,2K	Pointed, 3 pointed, 2 heart shape, bottleneck
AOR13018-5	2D,d,K	Irregular Shape, irregular shape, 2 pointed, 2 knobs, lumpy, rough skin
AOR13038-1	3D,d	2 growth cracks, 3 curved, 3 Pointed, pointed, Irregular Shape
AOR13058-9	D,K,2k	2 sprouted, folded bud end, bottleneck, 2 growth cracks, heart shaped
AOR13061-20	D,2d,K	3 growth cracks, bottleneck, 4 pointed, Sprouted, 2 sprouted, round, knobs
AOR13063-3	D,2d,K	Irregular Shape, 2 irregular shape, 2 pointed, growth cracks, curved, inconsistent shape
AOR13082-6	2K,2k	growth cracks, small
AOR13107-2	2K,2k	flat, 2 sprouted, 2 curved
AOR11847-2	2D,d,k	2 Pointed, 2 pointed, Irregular Shape, 2 irregular shape, 2 sprouted, curved, bottleneck, knobs, greening
POR15NCYK022-1	2D,d,K	3 sprouted, rough skin, pointed, 2 bottleneck, 2 knobs, 2 low yield, 2 heart shape, (may contain a better variety, 1 hill)
OR13SPC101-8	D,3d	Sprouted, 2 sprouted, 3 growth cracks, knobs, 3 round, pointed, Irregular Shape
AOR13066-1	2D,d,K	4 pointed, Sprouted, 2 sprouted, dumbell, curved, heart shape, growth cracks, 2 bottleneck, 2 knobs
AOR12327-3	D,2d,k	Bottleneck, 2 bottleneck, 2 growth cracks, 3 curved, 3 pointed, dumbell, low yield
AOR13343-16	3D,d	4 Sprouted, small, chain
OR14SP016-3	D,3d	2 sprouted, Pointed, 3 pointed, 3 bottleneck, curved, growth cracks
AOR13075-10	D,3d	3 irregular shape, round, 2 bottleneck, 2 growth cracks, inconsistent (one better hill, lighter skin), Sprouted, irregular shape
AOR13064-2	2d,2k	Pointed, 3 pointed

Table 7. Preliminary Yield Russet Trial yield, grade, and processing quality for selected varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety	Percent No. 1	Total yield	U.S. No. 1					U.S. No. 2	Marketable	<4 oz	Cull	Average tuber weight	No. of tubers /plant	Length/width	Specific gravity	Average fry color, light reflectance	Sugar ends
			Total	>20 oz	10 to 20 oz	6 to 10 oz	4 to 6 oz										
	%	----------------	----------------	----------------	----------------	cwt/acre	----------------	----------------	----------------	----------------	----------------	oz		ratio	g/cm^{-3}	-------- %	---------
Ranger Russet	65.5	773.2	506.3	24.0	276.3	157.8	72.2	177.9	708.1	65.1	0.0	7.7	8.3	1.67	1.0901	38.3	0.0
Russet Burbank	61.7	590.5	364.4	62.5	125.8	182.4	56.2	123.9	550.8	39.7	0.0	22.1	6.7	2.04	1.0722	30.9	50.0
Russet Norkotah	81.4	399.7	325.4	0.0	90.3	131.6	103.5	14.8	340.2	59.5	0.0	19.2	6.2	1.88	1.0717	36.9	0.0
AOR10067-5	80.2	517.9	415.2	69.8	271.7	103.2	40.3	14.3	499.3	18.6	0.0	24.6	4.4	1.47	1.0670	36.6	0.0
AOR10067-6	79.5	453.6	360.6	22.8	227.8	84.7	48.2	39.5	423.0	30.6	0.0	22.6	4.7	1.92	1.0596	36.5	0.0
AOR10067-15	80.8	561.6	453.8	28.2	278.5	106.8	68.4	22.3	504.2	51.3	6.1	22.3	5.8	1.50	1.0773	42.9	0.0
AOR10067-20	86.2	494.7	426.5	0.0	182.7	172.9	71.0	21.3	447.8	46.9	0.0	21.2	6.0	1.74	1.0821	40.7	0.0
AOR10067-28	68.5	379.1	259.5	76.5	169.5	65.0	25.0	22.7	358.7	17.8	2.6	24.2	3.4	1.76	1.0666	45.3	0.0
AOR10129-1	86.9	783.9	681.5	6.4	343.1	246.9	91.5	21.6	709.5	74.4	0.0	21.2	9.8	1.71	1.0902	48.6	0.0
AOR10129-3	77.4	648.7	502.1	0.0	107.0	294.6	100.4	54.6	556.7	87.5	4.5	20.0	9.5	2.17	1.0760	36.7	20.0
AOR10150-1	71.9	803.9	577.7	116.0	370.8	152.2	54.7	42.1	735.7	66.3	1.9	22.8	8.3	1.33	1.0924	46.3	0.0
AOR10222-2	83.5	529.2	441.8	13.3	151.2	202.4	88.3	3.7	458.9	70.3	0.0	20.1	7.4	1.45	1.0992	46.2	0.0
AOR11027-4	89.2	621.1	554.1	19.7	334.6	176.2	43.2	5.9	579.7	41.4	0.0	22.5	6.8	1.82	1.0921	45.5	0.0
AOR12082-7	85.9	732.1	628.7	32.5	333.5	204.7	90.5	21.2	682.4	49.8	0.0	7.8	7.8	1.59	1.0884	42.9	0.0
AOR14015-5	85.9	520.2	447.0	0.0	115.6	221.0	110.4	1.3	448.3	71.9	0.0	6.0	7.2	1.52	1.0880	44.6	0.0
AOR14015-7	85.7	540.1	462.9	6.1	217.3	179.9	65.7	31.9	500.8	39.3	0.0	7.0	6.4	2.00	1.0852	42.2	0.0
AOR14016-8	86.6	647.1	560.5	6.2	173.7	263.3	123.4	8.9	575.6	71.5	0.0	6.0	8.9	1.55	1.0885	40.0	0.0
AOR14032-12	90.0	706.1	635.7	0.0	249.1	275.0	111.7	9.7	645.4	60.6	0.0	6.7	8.8	1.71	1.0917	42.9	0.0
AOR14033-1	53.8	670.3	360.7	217.7	260.5	81.7	18.5	76.0	654.4	15.9	0.0	12.0	4.6	1.70	1.0835	43.5	0.0
AOR14051-3	77.1	668.5	515.2	103.0	253.6	186.3	75.3	8.3	626.5	42.1	0.0	8.6	6.5	1.47	1.0948	43.7	0.0
OR13SP175-6	83.5	673.8	562.9	64.4	353.7	160.3	48.9	21.6	648.9	24.9	0.0	9.3	6.0	1.48	1.0813	40.6	0.0
AOR10603-5	68.4	672.6	460.0	108.0	278.9	147.8	33.3	52.5	620.5	52.1	0.0	8.0	7.0	1.69	1.0938	39.9	0.0
AOR10648-5	83.4	663.4	553.3	57.2	315.8	183.5	54.0	2.3	612.7	50.6	0.0	7.2	7.6	1.25	1.0916	41.5	0.0
AOR10654-11	83.2	897.9	747.3	51.5	379.2	273.7	94.4	26.3	825.2	72.7	0.0	7.4	10.0	1.64	1.0967	43.0	0.0
AOR10673-14	73.4	617.8	453.6	138.9	332.8	102.1	18.6	0.0	592.5	25.3	0.0	10.7	4.8	1.66	1.0706	40.2	0.0
AOR10673-25	72.2	448.1	323.4	96.7	229.7	77.2	16.4	11.5	431.5	16.6	0.0	10.4	3.6	1.79	1.0683	42.3	0.0
AOR10786-1	76.8	823.2	632.6	7.4	247.4	261.6	123.6	66.2	706.2	106.1	10.9	6.6	10.3	1.85	1.0844	39.9	0.0
AOR11902-1	76.3	762.0	581.5	67.0	369.1	163.7	48.6	74.8	723.2	38.7	0.0	9.1	7.0	1.82	1.0824	33.4	20.0
AOR11847-6	84.8	591.9	501.8	13.3	221.4	167.0	113.4	18.9	534.0	57.9	0.0	6.6	7.4	1.60	1.0985	47.7	0.0
AOR11847-15	81.9	728.9	597.1	13.2	239.1	267.1	90.8	27.5	637.8	91.1	0.0	6.2	9.7	1.59	1.0902	45.1	0.0
AOR13113-1	76.2	688.6	524.4	28.2	240.4	209.1	75.0	47.4	600.0	88.6	0.0	6.3	9.1	1.71	1.0785	37.2	0.0
AOR12312-1	79.1	714.3	564.8	90.9	366.4	143.2	55.3	8.6	664.3	49.9	0.0	8.0	7.4	1.52	1.0850	38.8	0.0
AOR12312-6	81.6	777.9	634.6	63.7	332.9	216.6	85.0	38.0	736.4	40.4	1.2	8.2	7.8	1.79	1.0802	39.2	0.0
AOR12321-18	85.7	815.2	698.5	6.9	238.5	358.9	101.1	35.0	740.4	74.9	0.0	6.2	10.9	1.63	1.0960	41.0	0.0
AOR13088-2	70.5	676.2	476.9	130.8	275.9	160.7	40.3	12.6	620.2	52.3	3.7	7.7	7.3	1.47	1.0773	35.7	0.0
OR13SP142-2	84.7	634.6	537.8	21.4	200.2	210.6	127.1	1.2	560.4	74.2	0.0	6.6	8.0	1.56	1.0904	41.7	0.0
POR16V2-3	83.2	618.0	514.3	0.0	100.3	253.3	160.7	2.0	516.3	101.6	0.0	5.3	9.7	1.37	1.0826	38.8	0.0
AOR13338-2	80.9	598.6	484.4	56.1	286.2	135.2	62.9	18.9	559.4	39.3	0.0	9.1	5.4	1.54	1.0780	40.4	0.0
OR13SP115-1	79.0	458.3	362.2	0.0	114.8	158.3	89.1	15.7	377.9	80.4	0.0	5.5	6.9	1.71	1.0803	39.5	0.0
A10508-2KF	86.5	690.3	596.8	38.1	351.4	168.4	77.1	19.3	654.2	36.1	0.0	8.3	6.9	1.45	1.0906	40.5	0.0

Table 8. Preliminary Yield Russet Trial tuber visual observations at harvest for selected varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. K = clone should be saved, D = clone should be discarded. Capital letters denote a higher intensity of an observation compared to lower case letters.

Variety	K or D	Description
Ranger Russet	k/d	Curved, knobs, Irregular shape
Russet Burbank	d	Irregular shape, dumbell, knobs
Russet Norkotah	D	sprouted, chain
AOR10067-5	K	irregular shape
AOR10067-6	d/k	sprouted, alligator hide, water rot
AOR10067-15	k	heart shaped, Irregular shape, misshapen
AOR10067-20	k	heart shaped, Irregular shape, misshapen
AOR10067-28	k	heart shaped, Irregular shape, misshapen
AOR10129-1	K	pointed, irregular shape, dumbell, swollen lenticels
AOR10129-3	d/k	growth cracks, small
AOR10150-1	k	sprouted, Round, growth cracks
AOR10222-2	k	small, sprouted
AOR11027-4	K	sprouted, irregular shape
AOR12082-7	k	irregular shape
AOR14015-5	k	small
AOR14015-7	k	sprouted, growth cracks, pointed
AOR14016-8	k	bottleneck, irregular shape
AOR14032-12	k	Pointed, growth cracks
AOR14033-1	k	knobs, deep eyes, pointed, jelly end
AOR14051-3	K	
OR13SP175-6	K	round
AOR10603-5	k	growth cracks, sprouted, knobs, heart shaped, curved
AOR10648-5	k	pointed, sprouted
AOR10654-11	K	
AOR10673-14	K	irregular shape, skin cracks, a winner
AOR10673-25	k	knobs, growth cracks, irregular shape
AOR10786-1	k	greening, (one mixed seed piece with radical Knobs)
AOR11902-1	k	heart shape, bottleneck, pointed
AOR11847-6	k	growth cracks, small
AOR11847-15	K	chain
AOR13113-1	k	growth cracks
AOR12312-1	k	pointed, sprouted
AOR12312-6	K	pointed
AOR12321-18	k	undersized tubes
AOR13088-2	k	water rot, pointed, sprouted
OR13SP142-2	K	nice, a bit small
POR16V2-3	k	small, nice shape, beats Norkotah?
AOR13338-2	k	sprouted, growth cracks
OR13SP115-1	k	irregular shape, growth cracks, pointed
A10508-2KF	K	irregular shape, growth cracks

Table 9. Preliminary Yield Russet Trial tuber internal defects, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety	Vascular discoloration	Hollow heart	Internal brown spot	Brown center	Black spot bruise
		---------------------------	%	---------------------------	
Ranger Russet	0.0	0.0	0.0	0.0	0.0
Russet Burbank	0.0	0.0	0.0	0.0	0.0
Russet Norkotah	0.0	0.0	0.0	0.0	0.0
AOR10067-5	0.0	0.0	0.0	20.0	0.0
AOR10067-6	0.0	0.0	0.0	0.0	0.0
AOR10067-15	0.0	0.0	0.0	0.0	0.0
AOR10067-20	0.0	0.0	0.0	0.0	0.0
AOR10067-28	0.0	0.0	0.0	0.0	0.0
AOR10129-1	0.0	0.0	0.0	0.0	0.0
AOR10129-3	0.0	0.0	0.0	0.0	0.0
AOR10150-1	0.0	0.0	0.0	0.0	0.0
AOR10222-2	0.0	0.0	0.0	0.0	0.0
AOR11027-4	0.0	0.0	0.0	0.0	0.0
AOR12082-7	0.0	0.0	0.0	0.0	0.0
AOR14015-5	0.0	0.0	0.0	0.0	0.0
AOR14015-7	0.0	0.0	0.0	0.0	0.0
AOR14016-8	0.0	0.0	0.0	30.0	0.0
AOR14032-12	0.0	0.0	0.0	0.0	0.0
AOR14033-1	0.0	0.0	0.0	0.0	0.0
AOR14051-3	0.0	0.0	0.0	10.0	0.0
OR13SP175-6	0.0	0.0	0.0	30.0	0.0
AOR10603-5	0.0	0.0	0.0	0.0	0.0
AOR10648-5	0.0	0.0	0.0	0.0	0.0
AOR10654-11	0.0	0.0	0.0	0.0	0.0
AOR10673-14	0.0	0.0	0.0	0.0	0.0
AOR10673-25	0.0	0.0	0.0	0.0	0.0
AOR10786-1	0.0	0.0	0.0	0.0	0.0
AOR11902-1	0.0	0.0	0.0	10.0	0.0
AOR11847-6	0.0	0.0	0.0	0.0	0.0
AOR11847-15	0.0	0.0	0.0	0.0	0.0
AOR13113-1	0.0	0.0	0.0	0.0	0.0
AOR12312-1	0.0	0.0	0.0	0.0	0.0
AOR12312-6	0.0	0.0	0.0	0.0	0.0
AOR12321-18	0.0	0.0	0.0	0.0	0.0
AOR13088-2	0.0	0.0	20.0	0.0	0.0
OR13SP142-2	0.0	0.0	0.0	0.0	0.0
POR16V2-3	0.0	0.0	10.0	0.0	0.0
AOR13338-2	0.0	0.0	0.0	0.0	0.0
OR13SP115-1	0.0	0.0	0.0	0.0	0.0
A10508-2KF	0.0	0.0	0.0	0.0	0.0

Table 10. National Fry Processing Trial yield, grade, and processing quality for Tier 1 varieties (one replicate), Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

				U.S. No. 1								
Tier	Variety	Percent No. 1	Total yield	Total	>10 oz	6 to 10 oz	4 to 6 oz	U.S. No. 2	Marketable	<4 oz	Cull	Specific gravity
		%	cwt/acre									g/cm^{-3}
1	A10594-4sto	100.0	608.9	608.9	316.6	150.6	97.3	0.0	608.9	44.4	0.0	1.086
	A10595-13sto	79.1	664.3	525.3	276.9	153.2	35.9	139.0	525.3	59.4	0.0	1.080
	A10947-3CSR	94.4	367.5	346.9	192.2	39.5	28.3	20.5	346.9	87.0	0.0	1.098
	A11188-1	100.0	760.6	760.6	414.1	221.5	71.2	0.0	760.6	53.8	0.0	1.082
	A11226-1	94.5	755.4	713.9	410.2	166.1	67.2	41.6	713.9	70.3	0.0	1.082
	A11737-1LB	98.8	444.3	438.7	37.7	100.4	177.7	5.6	438.7	122.9	0.0	1.093
	AF5494-3	95.9	356.5	342.0	63.0	127.8	75.6	14.5	342.0	75.6	0.0	1.083
	AF5628-2	94.3	518.3	488.9	219.9	147.8	71.4	25.3	488.9	49.8	4.1	1.083
	AF5644-8	92.4	711.7	657.7	36.9	154.4	190.8	54.0	657.7	275.7	0.0	1.104
	AF5661-13	100.0	634.2	634.2	82.6	253.6	151.8	0.0	634.2	146.2	0.0	1.087
	AOR10633-1	98.5	635.9	626.5	125.6	285.2	135.8	9.4	626.5	79.9	0.0	1.095
	CO10087-4RU	98.9	530.9	525.2	59.4	209.6	165.3	5.7	525.2	90.9	0.0	1.096
	CO10091-1RU	98.8	556.5	550.1	85.4	237.6	111.4	6.5	550.1	115.6	0.0	1.075
	COAF11149-5	97.8	547.6	535.4	86.6	256.7	103.5	12.3	535.4	88.5	0.0	1.119
	ND12241YB-2Russ	97.8	473.0	462.6	72.2	228.2	98.2	8.4	462.6	64.0	2.1	1.107
	NDAF113476CB-3	78.7	466.3	367.1	37.3	167.8	73.7	99.3	367.1	88.3	0.0	1.091
	TX13590-9Ru	100.0	431.7	431.7	160.8	129.1	54.0	0.0	431.7	87.9	0.0	1.082
	W13012-18rus	98.0	785.2	769.9	193.2	231.3	172.3	15.4	769.9	173.1	0.0	1.105
	W13A11229-1rus	98.2	738.9	725.7	136.7	297.0	163.0	13.2	725.7	129.1	0.0	1.108
	A10594-8VR	94.8	863.3	818.7	341.5	268.7	103.8	37.2	818.7	104.7	7.5	1.104

Table 11. National Fry Processing Trial yield, grade, and processing quality for Tier 2 (2 replicates) and Tier 3 (3 replicates) varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

				U.S. No. 1								
Tier	Variety	Percent No. 1	Total yield	Total	>10 oz	6 to 10 oz	4 to 6 oz	U.S. No. 2	Marketable	<4 oz	Cull	Specific gravity
		%		---------------------------------- cwt/acre --------------------------------------								g/cm^{-3}
2	A07098-4	97.4	680.1	663.1	114.7	293.3	137.1	15.7	663.1	118.0	1.2	1.069
	A07705-4	98.9	803.6	794.7	197.3	296.5	171.0	8.9	794.7	130.0	0.0	1.084
	A07769-4	100.0	779.0	779.0	363.8	240.9	86.9	0.0	779.0	87.4	0.0	1.094
	AAF10237-4	98.4	721.2	708.7	120.9	293.5	145.7	12.5	708.7	148.6	0.0	1.093
	AAF10615-1	96.2	503.2	484.7	218.8	173.7	41.0	16.1	484.7	51.2	2.5	1.090
	AF5492-6	100.0	619.3	619.3	39.0	237.4	178.2	0.0	619.3	164.7	0.0	1.092
	AOR08540-1	90.9	900.8	820.3	377.0	225.1	148.3	76.4	820.3	69.9	4.1	1.090
	OR12133-10	97.0	940.7	911.5	453.0	310.7	77.0	29.2	911.5	70.8	0.0	1.079
	Average	97.3	743.5	722.7	235.6	258.9	123.2	19.9	722.7	105.1	1.0	1.086
	LSD (0.05)	NS	154.7	177.5	119.1	74.1	63.3	NS	177.5	37.1	NS	NS
3	A07061-6	97.6	791.1	772.5	132.3	275.5	179.5	15.7	772.5	185.2	3.0	1.092
	A071012-4BF	95.3	834.9	795.3	496.6	186.7	62.0	39.7	795.3	49.9	0.0	1.105
	A08433-4sto	93.9	743.9	698.6	207.2	237.6	113.4	45.3	698.6	140.5	0.0	1.097
	AAF07521-1	99.2	569.9	564.9	219.3	190.9	87.2	5.0	564.9	67.5	0.0	1.085
	AF5071-2	91.4	611.9	560.4	188.8	193.0	99.3	43.4	560.4	79.3	8.1	1.095
	AF5406-7	93.7	581.2	545.0	160.6	247.3	81.8	32.3	545.0	55.3	3.9	1.084
	AO02183-2	93.6	881.9	824.0	393.4	234.0	94.4	56.3	824.0	102.3	1.6	1.087
	AOR06576-1	94.7	795.6	752.6	260.2	289.9	98.2	43.0	752.6	104.3	0.0	1.094
	CO09036-2RU	75.2	503.2	377.2	96.6	84.1	84.6	126.0	377.2	111.9	0.0	1.079
	ND050032-4Russ	96.1	790.4	750.7	271.2	284.4	108.3	39.7	750.7	86.8	0.0	1.095
	Russet Burbank	51.4	672.7	335.4	124.9	114.8	50.9	312.0	335.4	44.7	25.4	1.074
	Ranger Russet	85.4	882.9	749.5	360.0	250.0	71.1	127.7	749.5	68.4	5.7	1.088
	Clearwater Russet	96.4	751.3	724.3	223.7	261.1	136.9	27.0	648.7	102.6	0.0	1.094
	Payette Russet	99.0	555.5	550.2	71.2	131.5	154.6	4.4	361.7	192.9	0.9	1.103
	Dakota Russet	99.1	710.6	704.7	307.1	266.0	78.2	5.2	656.6	53.3	0.7	1.091
	Shepody	81.7	501.1	409.2	101.3	165.9	70.9	91.9	430.0	71.1	0.0	1.073
	Average	94.0	649.5	611.4	200.0	209.6	106.3	37.8	605.1	97.9	1.6	1.090
	LSD (0.05)	12.9	188.6	174.5	148.9	70.6	43.8	99.0	176.3	45.1	NS	0.012

Table 12. Oregon Statewide Specialty Trial yield and grade of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

			U.S. No. 1										
Clone/Variety	Total yield	<1¾ inch	<4 oz	4 to 6 oz	6 to 10 oz	10 to 14 oz	>14 oz	U.S. No. 2	Cull	Average tuber weight	No. of tubers/plant	Length/ width	Specific gravity
	cwt/acre									oz		ratio	g cm^{-3}
Yukon Gold	475.8	7.1	45.8	60.6	171.5	123.5	57.0	57.0	17.5	6.4	6.1	1.3	1.084
Chieftain	704.8	15.3	99.5	138.8	248.4	130.5	71.1	71.1	16.6	5.4	10.8	1.1	1.088
POR15PG014-8	619.3	47.0	304.7	178.5	100.3	11.0	0.0	0.0	24.7	2.8	18.5	1.0	1.083
POR15PG034-1	577.8	46.2	270.2	165.7	94.9	14.5	0.0	0.0	32.5	2.8	17.1	1.3	1.094
POR15PG036-3	547.6	40.9	225.6	14.6	0.4	0.0	0.0	0.0	307.0	1.5	29.8	2.0	1.080
POR15PG015-3	577.9	32.9	121.6	15.5	34.8	11.1	0.0	0.0	394.9	1.7	22.2	0.9	1.066
Mean	583.8	31.6	177.9	95.6	108.4	48.4	21.3	21.3	132.2	3.4	17.4	1.2	1.082
LSD (0.05)	132.8	11.5	43.9	25.9	58.6	37.1	28.5	28.5	60.1	0.6	3.1	0.3	NS

Table 13. Oregon Statewide Specialty Trial tuber internal defects of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Clone/Variety	Vascular discoloration	Hollow heart	Internal brown spot	Brown center	Black spot bruise
		-------------------------	%	-------------------------	
Yukon Gold	0.0	0.0	2.5	2.5	10.0
Chieftain	2.5	0.0	42.5	2.5	10.0
POR15PG014-8	0.0	0.0	0.0	0.0	7.5
POR15PG034-1	0.0	2.5	0.0	5.0	2.5
POR15PG036-3	0.0	0.0	0.0	0.0	0.0
POR15PG015-3	0.0	0.0	12.5	0.0	0.0
Mean	0.4	0.4	9.6	1.7	5.0
LSD (0.05)	NS	NS	15.9	NS	NS

Table 14. Oregon Statewide Specialty Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Tuber defect observations are from four plots for each clone. K = clone should be saved, D = clone should be discarded. Capital letters denote a higher intensity of an observation compared to lower case letters. Since there were four replicates, a clone could be scored for the same attribute up to four times.

Clone/Variety	K or D	Description
Yukon Gold	D,3k	silver scurf, greening, water rot, too much rot, growth cracks, too big
Chieftain	4k	dull red, too dull, sprouted
POR15PG014-8	3K,k	2 sprouted
POR15PG034-1	4k	4 sprouted, greening
POR15PG036-3	4D	4 Sprouted
POR15PG015-3	4D	4 Sprouted

Table 15. Preliminary Yield Specialty Trial yield and grade of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

		U.S. No. 1												
Variety/Clone	Total yield	<1.75	<4 oz	4 to 6 oz	6 to10 oz	10 to 14 oz	>14 oz	U.S. No. 2	Cull	Twos + culls	Average tuber weight	No. of tubers /plant	Length/ width	Specific gravity
	-- cwt/acre --										oz		ratio	g/cm^{-3}
Yukon Gold	447.7	7.2	50.0	84.1	195.0	66.5	48.2	0.0	4.0	4.0	6.0	6.2	1.03	1.082
Chieftain	643.2	9.8	93.8	126.8	273.3	123.2	23.5	0.0	2.6	2.6	5.6	9.5	1.03	1.075
Purple Majesty	599.0	49.4	269.0	87.7	30.4	3.0	0.0	0.0	208.8	208.8	2.8	17.8	1.29	1.072
POR16PG7-3	441.7	47.0	250.4	39.8	2.7	0.0	0.0	0.0	148.9	148.9	2.0	18.4	1.14	1.065
POR16PG17-2	618.9	26.2	179.7	167.5	219.1	47.1	0.0	0.0	5.5	5.5	4.3	12.0	1.19	1.071
POR16PG25-2	670.2	38.4	232.4	242.2	155.1	33.3	0.0	0.0	7.2	7.2	3.7	14.9	1.43	1.084
POR16PG34-1	486.2	47.7	307.0	143.8	30.2	0.0	0.0	0.0	5.3	5.3	2.6	15.6	1.12	1.077
POR16PG42-4	511.2	102.0	431.6	65.7	11.9	0.0	0.0	0.0	2.0	2.0	1.9	22.1	1.21	1.082
NDOR13293B-1	539.3	34.8	257.5	179.4	86.3	6.6	0.0	0.0	9.5	9.5	2.9	15.3	1.08	1.063
OR11157-1	436.6	95.4	367.6	28.4	26.5	9.8	0.0	0.0	4.3	4.3	1.5	24.0	2.44	1.066
OR11157-10	297.1	37.6	215.3	58.9	21.4	0.0	0.0	0.0	1.5	1.5	2.0	12.5	3.00	1.065
OR13SP198-2	708.1	19.7	113.5	119.2	234.3	173.2	65.4	0.0	2.4	2.4	5.4	10.8	1.45	1.089
OR13SP198-4	551.6	4.8	79.9	106.5	197.2	126.8	25.0	0.0	16.2	16.2	5.8	7.8	1.56	1.070
OR13SP207-1	536.2	122.0	406.7	46.2	15.0	0.0	0.0	0.0	68.2	68.2	1.2	36.8	1.68	1.075
OR14H004-3	626.9	59.1	245.2	72.8	4.2	0.0	0.0	0.0	304.7	304.7	1.5	35.1	2.53	1.081
Mean	540.9	46.8	233.3	104.6	100.2	39.3	10.8	0.0	52.7	52.7	3.3	17.2	1.55	1.075

Table 16. Preliminary Yield Specialty Trial tuber internal defects of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety/Clone	Vascular discoloration	Hollow heart	Internal brown spot	Brown center	Black spot bruise
		----------------	% ----------------		
Yukon Gold	0.0	0.0	30.0	0.0	0.0
Chieftain	0.0	0.0	80.0	10.0	0.0
Purple Majesty	0.0	0.0	0.0	0.0	0.0
POR16PG7-3	0.0	0.0	0.0	0.0	0.0
POR16PG17-2	0.0	0.0	0.0	0.0	10.0
POR16PG25-2	0.0	0.0	0.0	0.0	20.0
POR16PG34-1	0.0	0.0	0.0	0.0	0.0
POR16PG42-4	40.0	40.0	40.0	0.0	20.0
NDOR13293B-1	0.0	0.0	0.0	0.0	10.0
OR11157-1	0.0	0.0	0.0	0.0	0.0
OR11157-10	0.0	0.0	0.0	0.0	0.0
OR13SP198-2	0.0	0.0	0.0	0.0	0.0
OR13SP198-4	90.0	90.0	0.0	0.0	0.0
OR13SP207-1	0.0	0.0	0.0	0.0	0.0
OR14H004-3	0.0	0.0	10.0	0.0	0.0
Mean	8.7	8.7	10.7	0.7	4.0

Table 17. Preliminary Yield Specialty Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. K = clone should be saved, D = clone should be discarded. Capital letters denote a higher intensity of an observation compared to lower case letters.

Clone	K or D	Description
Yukon Gold	K	
Chieftain	K	
Purple Majesty	d	pointed, sprouted, heavy skin
POR16PG7-3	K	sprouted
POR16PG17-2	K	scab, smooth
POR16PG25-2	K	nice, smooth
POR16PG34-1	K	chain
POR16PG42-4	K	sprouted
NDOR13293B-1	K	sprouted, pretty
OR11157-1	k	Sprouted, distinctive
OR11157-10	k	
OR13SP198-2	k	good replacement for Chieftain
OR13SP198-4	k	
OR13SP207-1	k	Sprouted
OR14H004-3	k	sticky stolon

Table 18. Western Region Specialty Trial yield and grade of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

			U.S. No. 1										
Clone/Variety	Total yield	<1¾ inch	<4 oz	4 to 6 oz	6 to 10 oz	10 to 14 oz	>14 oz	U.S. No. 2	Cull	Average tuber weight	No. of tubers /plant	Length/ width	Specific gravity
		cwt/acre								oz		ratio	g cm^{-3}
Chieftain	693.5	8.1	89.6	132.6	279.3	154.5	25.1	0.0	12.4	5.7	10.1	1.1	1.073
Red LaSoda	787.4	10.2	56.3	79.8	194.3	206.8	228.9	3.5	17.9	7.5	8.8	1.1	1.076
ATTX05175S-1R/Y	608.3	33.6	246.6	138.3	39.0	9.7	1.6	2.1	87.8	2.4	21.3	1.2	1.075
COTX04193S-2R/Y	486.1	49.8	354.7	148.1	98.8	2.2	0.0	3.6	70.5	3.4	11.9	1.1	1.078
CO09079-5PW/Y	420.0	16.6	213.4	46.4	10.0	9.3	3.0	0.8	12.7	1.8	19.1	1.0	1.071
Purple Majesty	560.9	16.9	139.6	117.0	96.2	5.6	0.0	0.0	7.1	2.9	16.0	1.2	1.084
CO08037-2P/P	305.2	61.5	346.4	90.6	62.2	0.0	0.0	0.5	16.6	3.1	8.1	1.2	1.062
Yukon Gold	494.8	4.4	59.2	78.3	165.8	127.8	46.6	1.0	16.0	5.9	6.9	1.1	1.080
CO09128-3W/Y	389.8	63.4	249.8	12.6	1.3	0.0	0.0	0.0	126.2	1.5	21.9	1.3	1.060
CO09128-5W/Y	512.5	58.1	310.2	61.2	12.9	5.0	0.0	0.0	123.2	1.9	22.6	1.0	1.078
CO09218-4W/Y	523.4	34.9	279.9	139.4	83.0	5.5	0.0	0.0	15.6	2.6	16.7	1.2	1.078
LaRatte	358.8	58.5	313.7	11.5	1.6	0.0	0.0	0.0	32.1	0.8	35.5	2.5	1.072
POR11PG62-3	349.4	36.3	296.3	41.1	3.5	0.0	0.0	0.0	8.5	1.7	17.1	2.3	1.078
Mean	499.3	34.8	227.4	84.4	80.6	40.5	23.5	0.9	42.1	3.2	16.6	1.3	1.074
LSD (0.05)	100.0	11.8	57.7	34.3	34.8	30.3	28.5	NS	36.3	0.6	3.7	0.20	NS

Table 19. Western Region Specialty Trial tuber internal defects of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Clone/Variety	Vascular discoloration	Hollow heart	Internal brown spot	Brown center	Black spot bruise
	--------------------	----------	%	----------	--------------------
Chieftain	0.0	0.0	45.0	2.5	2.5
Red LaSoda	2.5	2.5	0.0	0.0	5.0
ATTX05175S-1R/Y	0.0	0.0	0.0	0.0	2.5
COTX04193S-2R/Y	0.0	0.0	0.0	0.0	0.0
CO09079-5PW/Y	7.5	0.0	2.5	0.0	2.5
Purple Majesty	0.0	0.0	0.0	0.0	2.5
CO08037-2P/P	0.0	0.0	2.5	0.0	0.0
Yukon Gold	0.0	0.0	2.5	0.0	0.0
CO09128-3W/Y	0.0	0.0	0.0	0.0	0.0
CO09128-5W/Y	0.0	0.0	5.0	0.0	5.0
CO09218-4W/Y	0.0	0.0	5.0	0.0	2.5
LaRatte	0.0	0.0	5.0	0.0	0.0
POR11PG62-3	0.0	0.0	0.0	0.0	0.0
Mean	0.8	0.2	5.2	0.2	1.7
LSD (0.05)	NS	NS	7.1	NS	NS

Table 20. Western Region Specialty Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. Tuber defect observations are from four plots for each clone. K = clone should be saved, D = clone should be discarded. Capital letters denote a higher intensity of an observation compared to lower case letters. Since there were four replicates, a clone could be scored for the same attribute up to four times.

Clone/Variety	K or D	Description
Chieftain	3d, k	3 dull, too big, poor color
Red LaSoda	4D	2 Irr. Shape, sprouted, 3 lumpy, 2 too big, poor color, 2 dull color, 2 large, misshapen tubers
ATTX05175S-1R/Y	4d	russet skin, 2 sprouted, dull purple, ugly skin, rough skin
COTX04193S-2R/Y	3k, K	dull red, colorful
CO09079-5PW/Y	3k, K	dull red, good color
Purple Majesty	2k, 2d	low yield, low yield vs. Purple Majesty, skin is nice
CO08037-2P/P	k, 3d	russeted purple, ugly, dull, dull color, sprouted
Yukon Gold	3k, d	greening, irregular shape, 2 too big, sprouted, skin crack
CO09128-3W/Y	2d, 2D	4 chain, 2 sprouted, Sprouted, Sticky Stem
CO09128-5W/Y	k, d, 2D	4 Sprouted, growth cracks, Chain
CO09218-4W/Y	2d, 2k	Chain, 3 chain, 3 sprouted, knobs
LaRatte	2d, 2D	2 sprouted, 2 Sprouted, chain
POR11PG62-3	4k	knobs, colorful

Table 21. Oregon Statewide Chip Trial yield and grade, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

		U.S. No. 1												
Variety	Total yield	>10 oz	6 to 10 oz	4 to 6 oz	<4 oz	>4 inch	U.S. No. 2	cull	Average tuber weight	No. of tubers /plant	Length/width	Specific gravity	Average fry color, light reflectance	Sugar end
	------------------------- cwt/acre -------------------------								oz		ratio	g/cm^{-3}	------- % ------	
Atlantic	639.0	234.2	236.8	85.2	66.6	17.1	0.4	15.9	6.6	8.0	1.05	1.0927	32.9	10.0
Snowden	738.3	245.7	275.7	119.3	78.8	29.4	4.8	14.0	6.5	9.4	1.01	1.0885	32.1	2.5
AOR12197-4	791.4	236.0	300.9	123.3	119.4	31.0	4.5	7.3	5.3	12.3	0.88	1.0886	32.4	5.0
AOR13125-2	510.6	50.2	214.8	147.0	88.1	0.0	0.0	10.4	5.0	8.4	1.03	1.0814	34.7	7.5
AOR13125-9	666.5	212.6	248.7	96.7	90.6	2.1	0.0	18.0	6.9	8.7	0.93	1.1004	32.8	5.0
NYOR14Q9-5	709.6	386.3	189.1	62.1	56.7	70.1	0.0	15.4	7.6	7.7	0.94	1.0909	36.3	0.0
NYOR14Q9-9	749.7	266.3	255.4	118.3	80.7	25.2	3.5	25.5	6.3	9.8	1.02	1.0895	34.1	5.0
NYOR14Q12-1	761.1	195.7	265.1	132.5	142.8	8.7	3.4	21.6	4.7	13.4	1.01	1.0872	32.0	7.5
COOR13270-2	647.7	148.6	289.0	126.8	77.7	5.7	0.0	5.5	5.9	9.1	1.00	1.0881	32.9	5.0
COOR13428-1	607.2	121.8	221.3	109.8	97.5	4.1	1.7	55.1	5.9	8.7	1.01	1.0865	35.1	0.0
Mean	682.1	209.7	249.7	112.1	89.9	19.3	1.8	18.9	6.1	9.5	0.99	1.0894	33.5	4.8
LSD (0.05)	125.8	94.4	NS	30.6	30.1	21.1	NS	NS	1.4	2.1	0.09	0.0084	NS	NS

Table 22. Oregon Statewide Chip Trial tuber internal defects for selected clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety	Vascular discoloration	Hollow heart	Internal brown spot	Brown center	Black spot bruise
		------------------------ % --------------------------			
Atlantic	0.0	0.0	7.5	0.0	0.0
Snowden	2.5	0.0	0.0	2.5	0.0
AOR12197-4	0.0	0.0	0.0	0.0	0.0
AOR13125-2	0.0	0.0	0.0	0.0	5.0
AOR13125-9	0.0	0.0	0.0	0.0	5.0
NYOR14Q9-5	0.0	0.0	5.0	0.0	5.0
NYOR14Q9-9	2.5	0.0	5.0	0.0	2.5
NYOR14Q12-1	0.0	0.0	0.0	0.0	5.0
COOR13270-2	0.0	0.0	0.0	0.0	5.0
COOR13428-1	0.0	0.0	0.0	0.0	0.0
Mean	0.5	0.0	1.8	0.3	2.8
LSD (0.05)	NS	NS	NS	NS	NS

Table 23. Preliminary Yield Chip Trial yield and grade, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety	Total yield	U.S. No. 1					U.S. No. 2	Culls	Average tuber weight	No. of tubers /plant	Length/ width	Specific gravity	Average fry color, light reflectance	Sugar end
		>10 oz	6 to 10 oz	4 to 6 oz	<4 oz	>4 inch								
	------------ cwt/acre ------------								oz		ratio	g/cm^{-3}	-------- % --------	
Atlantic	651.2	212.1	257.6	110.5	65.9	12.4	5.1	0.0	6.6	8.2	1.03	1.096	30.1	0.0
Snowden	834.1	359.8	255.6	137.3	75.1	20.4	0.0	6.2	6.8	10.1	1.03	1.088	34.3	0.0
NYORQ2-2	460.5	96.9	203.4	92.1	65.2	11.0	0.0	2.9	5.7	6.6	1.10	1.083	32.1	0.0
NYORQ2-3	529.0	207.9	181.5	87.1	48.7	25.6	0.0	3.7	6.9	6.3	1.06	1.080	34.2	0.0
NYORQ2-9	503.9	142.5	191.6	84.7	85.1	0.0	0.0	0.0	5.4	7.7	1.16	1.098	34.5	0.0
NYORQ2-10	816.5	414.7	275.4	65.0	59.2	66.5	2.1	0.0	6.7	10.0	1.13	1.099	35.5	0.0
NYORQ6-1	729.7	246.8	265.6	118.6	93.4	22.1	0.0	5.3	6.0	10.0	1.15	1.088	35.5	0.0
NYORQ6-3	590.6	354.1	142.6	55.8	36.5	102.9	0.0	1.5	8.8	5.6	1.03	1.079	36.5	0.0
NYORQ6-6	520.7	154.4	178.8	99.7	87.7	0.0	0.0	0.0	5.9	7.3	1.11	1.093	42.9	0.0
NYORN6-8	696.2	106.7	274.5	174.8	140.3	0.0	0.0	0.0	4.9	11.7	1.06	1.077	40.0	0.0
NYORN18-1	376.5	146.3	133.8	55.6	36.5	18.2	2.8	1.5	6.9	4.5	1.03	1.072	38.0	0.0
OR13SP225-8	682.2	110.3	260.3	155.9	148.1	5.9	0.0	7.7	4.8	11.7	1.00	1.083	32.9	0.0
OR13SP225-9	363.8	3.1	101.8	142.2	108.9	0.0	0.0	7.8	4.0	7.6	1.11	1.074	36.6	0.0
OR13SP225-12	600.0	168.3	249.6	100.1	74.5	6.8	7.6	0.0	6.0	8.3	1.07	1.085	33.9	0.0
AOR13175-13	455.7	225.5	145.3	59.8	25.1	103.1	0.0	0.0	6.9	5.4	1.07	1.077	27.7	40.0
Mean	587.4	196.6	207.8	102.6	76.7	26.3	1.2	2.4	6.2	8.1	1.08	1.085	35.0	2.7

Table 24. Preliminary Yield Chip Trial tuber internal defects for selected clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

Variety	Vascular discoloration	Hollow heart	Internal brown spot	Brown center	Black spot bruise
		-----------------------	%	--------------------------	
Atlantic	0.0	0.0	0.0	0.0	0.0
Snowden	0.0	0.0	0.0	0.0	0.0
NYORQ2-2	0.0	0.0	0.0	0.0	10.0
NYORQ2-3	0.0	0.0	0.0	0.0	0.0
NYORQ2-9	0.0	0.0	0.0	0.0	10.0
NYORQ2-10	0.0	0.0	0.0	0.0	0.0
NYORQ6-1	0.0	0.0	0.0	0.0	0.0
NYORQ6-3	0.0	0.0	0.0	0.0	20.0
NYORQ6-6	0.0	0.0	0.0	0.0	10.0
NYORN6-8	0.0	0.0	0.0	0.0	0.0
NYORN18-1	0.0	0.0	0.0	0.0	0.0
OR13SP225-8	0.0	0.0	60.0	0.0	10.0
OR13SP225-9	0.0	0.0	20.0	0.0	0.0
OR13SP225-12	0.0	0.0	0.0	0.0	0.0
AOR13175-13	0.0	0.0	0.0	40.0	0.0
Mean	0.0	0.0	5.3	2.7	4.0

Table 25. Preliminary Yield Chip Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. K = clone should be saved, D = clone should be discarded. Capital letters denote a higher intensity of an observation compared to lower case letters.

Variety	K or D	Description
Atlantic	k	folded bud end
Snowden	d	Folded Bud End
NYORQ2-2	k	sprouted
NYORQ2-3	k	
NYORQ2-9	k	
NYORQ2-10	k	
NYORQ6-1	k	
NYORQ6-3	k	
NYORQ6-6	k	
NYORN6-8	k	
NYORN18-1	k	folded bud end, scab
OR13SP225-8	k	
OR13SP225-9	k	
OR13SP225-12	k	
AOR13175-13	k	irregular shape

DEVELOPING REDUCED-RISK MANAGEMENT STRATEGIES FOR LYGUS IN POTATO CROPPING SYSTEMS

Stuart Reitz, Ian Trenkel, Kyle Wieland, Erik Feibert, Alicia Rivera, and Clint Shock, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018

Introduction

A number of insect pests negatively affect yield and quality of potatoes throughout the Pacific Northwest (PNW). However, their distribution, intensity of infestations, and yield-limiting damage vary by location and year. Unfortunately, Lygus has become a pest of importance in the region due to its direct feeding damage. Work by Schreiber's Agricultural Development Group (Alan Schreiber, personal communication) in 2016 demonstrated that moderate and high levels of Lygus can reduce sugars and specific gravity in tubers in 'Umatilla' potato. The loss of key products such as Monitor® and Temik® has made management of potato insects such Lygus increasingly complicated. Thus, there is a need to develop a comprehensive Lygus management strategy. It is critical to determine the effect of Lygus pressure on yield quality, and what insecticides would be most suitable for Lygus management including best time of application. Preliminary work by Rondon (unpublished) under cage studies suggests that there are variety-specific numerical effects of Lygus on yield. Responses have yet to be assessed in commercial fields. This information will enable growers to make informed choices regarding insecticide selection and timing, if needed, and will aid in developing appropriate insecticide resistance management programs. Our proposed work includes different, complementary trials in southern Idaho, Oregon (Hermiston and Ontario), and the Columbia Basin of Washington using standardized experimental designs and methods. This unified approach will enable us to comprehensively assess Lygus effects across the PNW's differing growing conditions. Although our treatment list focuses on products with activity against Lygus, we will be able to assess their efficacy across the PNW against other insect pests as well as beneficial insects.

Hypothesis and Objectives

General objective: Is Lygus an economic pest?

1. Hypothesis: Lygus is an economic pest. Objective: Evaluation and demonstration of reduced-risk chemistries that reduce Lygus infestations while protecting yield and tuber quality plus conserving key natural enemies.
2. Hypothesis: Coordinated delivery of research-based information on Lygus management is needed. Objective: Develop a coordinated extension program that includes on-farm demonstration and stakeholder-engaged research, organized outreach activities training for growers around a theme of Lygus suppression through improved field practices.

Procedures

Insecticide Efficacy Trial

Potato plots (‘Ranger Russet’) were planted in a randomized complete block design on 16 April 2018 at the Malheur Experiment Station, Ontario, Oregon. The flat-topped beds were on 72-inch centers. The two rows of potatoes within the bed were spaced 6 inches apart. Seed was planted at a 6-inch depth. Plants were irrigated by drip irrigation. A drip line was placed approximately 6 inches from each row of potatoes and shanked in the soil to about a 3-inch depth. Soil moisture was monitored with Watermark sensors and irrigation was initiated when the soil water tension (SWT) reached 30 cb. Other cultural practices followed standard practices for commercial production in the Treasure Valley.

Each experimental plot was 4 rows wide (12 ft) and 25 ft long. There was a 5-ft buffer between the ends of each plot. There were four replications for each of the 9 treatments for a total of 36 plots (Table 1). Insecticides were applied with a CO_2-powered backpack sprayer operating at 20 gal/acre and 30 PSI.

Sampling

Although the insecticide trial was intended to focus on efficacy against Lygus, other pest and beneficial insects and mites were monitored throughout the study. Therefore, two sampling procedures were used. The first sampling procedure involved vacuum sampling and targeted Lygus and other relatively large, mobile insects, including adult potato psyllids, adult beet leafhoppers, winged aphids, and beneficial predators (big-eyed bugs, lady beetles, lacewing adults, pirate bugs). An inverted leaf-blower was run along the border rows of each plot for 2 minutes. A mesh screen inside the leaf blower nozzle collected insects. At the end of the sampling interval for each plot, insects were transferred into Ziploc bags and returned to the lab for analysis.

The second sampling method involved collecting 10 potato leaves from the mid-canopy throughout the interior rows of each plot. Leaves were placed in Ziploc bags and returned to the lab for analysis. This sampling targeted small, soft-bodied arthropods, including spider mites, thrips, whitefly nymphs and eggs, potato psyllid nymphs and eggs, and wingless aphids.

Data were analyzed with the Agricultural Research Management (ARM) software.

Results

Sampling was conducted from early June through the middle of August. Lygus began to appear in appreciable numbers in July and the first insecticide application was made on July 10. Relatively few nymphs were collected through the season, suggesting that potato may not be a significant reproductive host and adults are transient in potato (Figs. 1 and 2). None of the insecticides significantly reduced Lygus abundance relative to the control. Except for July 20 in the control treatment, an average of fewer than 2 adults were collected per week in any of the treatments. Fewer than 1 lygus nymph was collected on average per plot each week.

Thrips collected from foliage samples were almost exclusively western flower thrips. Adult thrips abundance declined significantly for all insecticide treatments following the first insecticide application on July 10 (Figs. 3 and 4). Subsequently, adult and larval thrips numbers remained significantly higher in the Brigade® (bifenthrin) treatment than all other treatments, including the control. The other insecticides significantly reduced thrips abundance relative to the control. Agri-Mek® (abamectin) showed good activity, as evidenced by the treatment where Agri-Mek was applied in combination with Brigade (Figs. 3 and 4).

An opposite pattern was observed for whiteflies. Whitefly nymph and egg numbers were significantly lower in treatments with Brigade than with other insecticides compared with the control (Figs. 5 and 6). Agri-Mek by itself did not suppress whitefly numbers. Beleaf® was the only other insecticide to suppress whitefly nymphs or eggs.

Spider mite populations were low until the end of the sampling period (Fig. 7). Brigade by itself increased spider mite abundance following the final insecticide application (August 10). Agri-Mek, by itself and in combination with Brigade, significantly reduced spider mite abundance.

Insecticides had variable effects on natural enemies. Transform® and Brigade were the most detrimental to big-eyed bug populations (Figs. 8 and 9). Aza-Direct®, Beleaf. Radiant® and Torac® tended to be the least disruptive. Pirate bug populations did not develop until late in the season. Aza-Direct was the least disruptive insecticide to pirate bug populations. Interestingly, there were significantly more pirate bugs in the Brigade treatment than in the control after the second and third applications. This result likely reflects the increased availability of prey in the Brigade treatment compared with the control at this time. Pirate bug populations increased significantly once the insecticide applications had ceased (see the August 17 sample date, which was 10 days after the final application).

There were too few potato psyllids, leafhoppers, or aphids at the experimental site to make meaningful comparisons.

Acknowledgments

We appreciate the technical assistance of Hannah Rose, Kelsey Alexander, Brooke Bezona, Allison Simmons, and Mary Phipps. Funding for this project was provided by the Northwest Potato Research Consortium.

Table 1. Insecticides used in trial at the Malheur Experiment Station, 2018. Application dates were: A = July 10; B = July 24; C = August 7.

Trt No.	Type	Treatment^{a} Name	Rate	Rate Unit	Application Code	Application pH
1	CHECK	Untreated Check				
2	INSECTICIDE	RADIANT	8	fl oz/a	ABC	pH 7.0
	ADJUVANT	DYNE-AMIC	0.7	pt/a	ABC	
3	INSECTICIDE	TRANSFORM	2.25	fl oz/a	ABC	pH 7.0
4	INSECTICIDE	AZA-DIRECT	2	pt/a	ABC	
5	INSECTICIDE	BELEAF	2.8	oz wt/a	ABC	pH 6.0
	ADJUVANT	NIS	0.25	% v/v	ABC	
6	INSECTICIDE	BRIGADE	6.4	fl oz/a	ABC	pH 6.5
	ADJUVANT	NIS	0.25	% v/v	ABC	
7	INSECTICIDE	TORAC	21	fl oz/a	ABC	pH 7.0
	ADJUVANT	NIS	0.25	% v/v	ABC	
8	INSECTICIDE	BRIGADE	6.4	fl oz/a	ABC	pH 6.5
	INSECTICIDE	AGRI-MEK	3.5	fl oz/a	ABC	
	ADJUVANT	NIS	0.25	% v/v	ABC	
9	INSECTICIDE	AGRI-MEK	3.5	fl oz/a	ABC	pH 6.5
	ADJUVANT	NIS	0.25	% v/v	ABC	

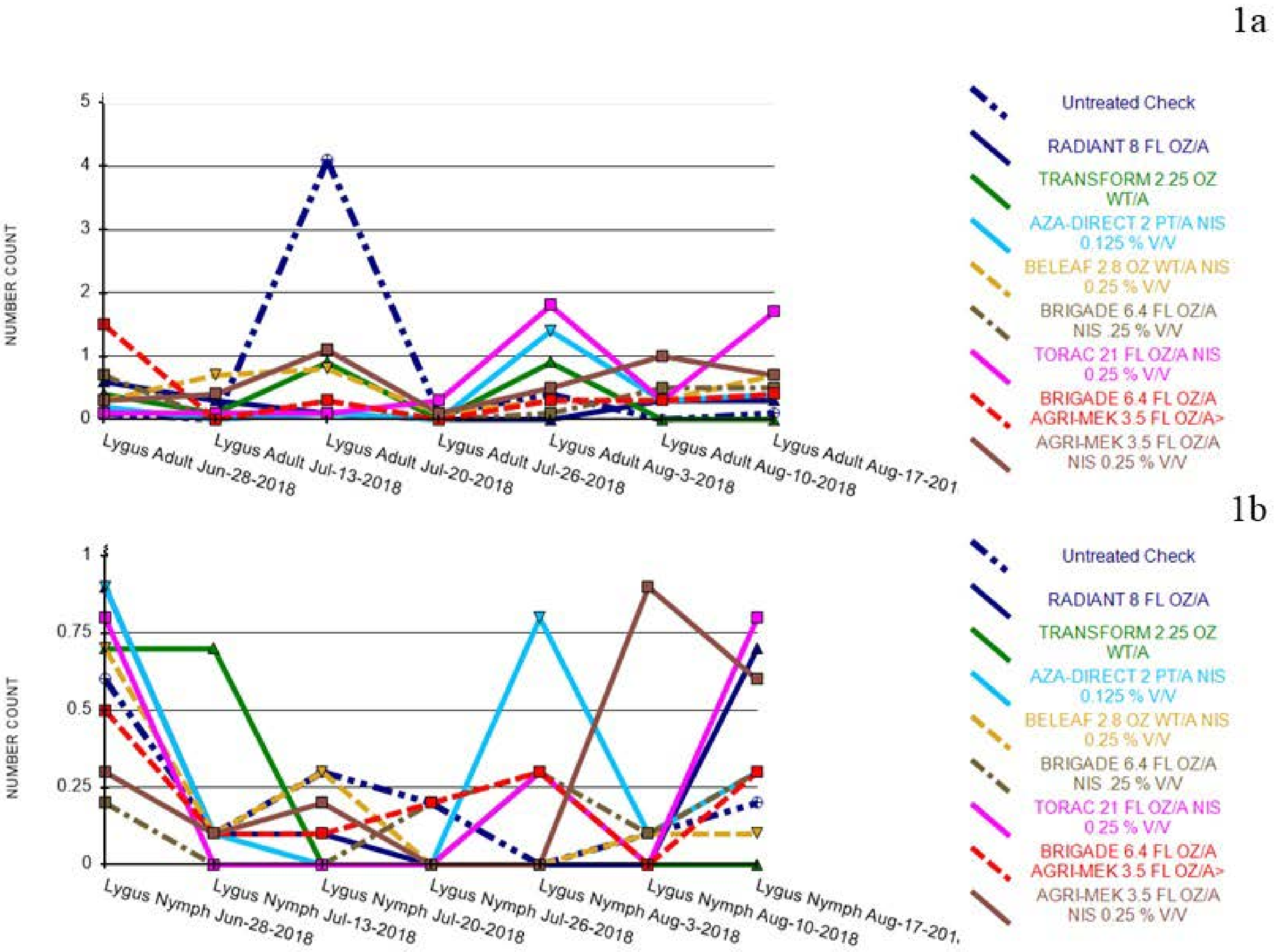
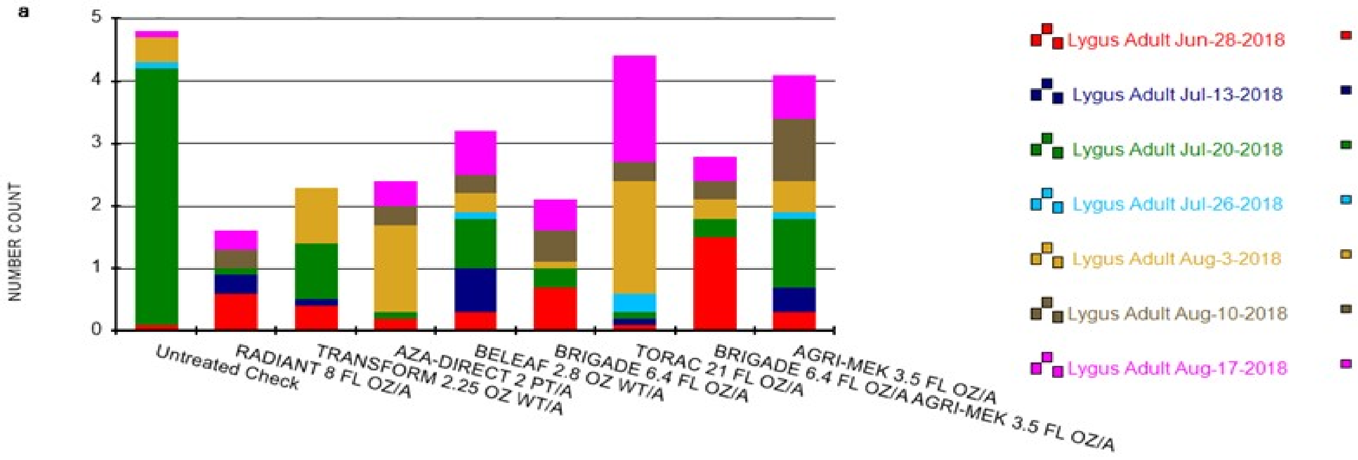


Figure 1. Seasonal trends in Lygus abundance for adults (1a) and nymphs (1b) by treatment. Insecticide applications were made July 10, July 24, and August 7. Malheur Experiment Station, 2018.

2a



2b

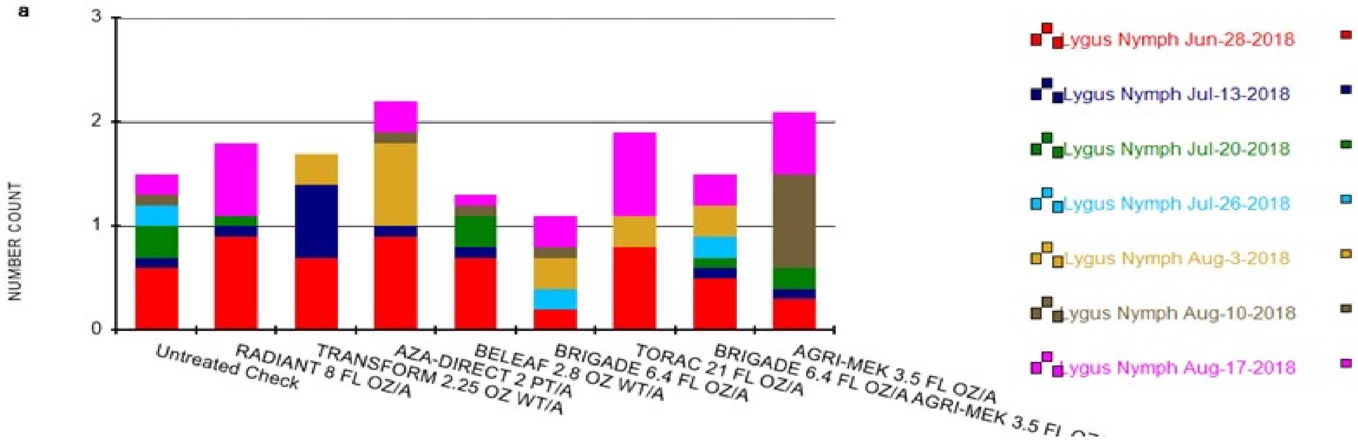


Figure 2. Seasonal trends in Lygus abundance for adults (2a) and nymphs (2b) by treatment. Insecticide applications were made July 10, July 24, and August 7. Bars represent seasonal totals for each treatment, with each sample date shown as a different color pattern. Malheur Experiment Station, 2018.

3a

3b

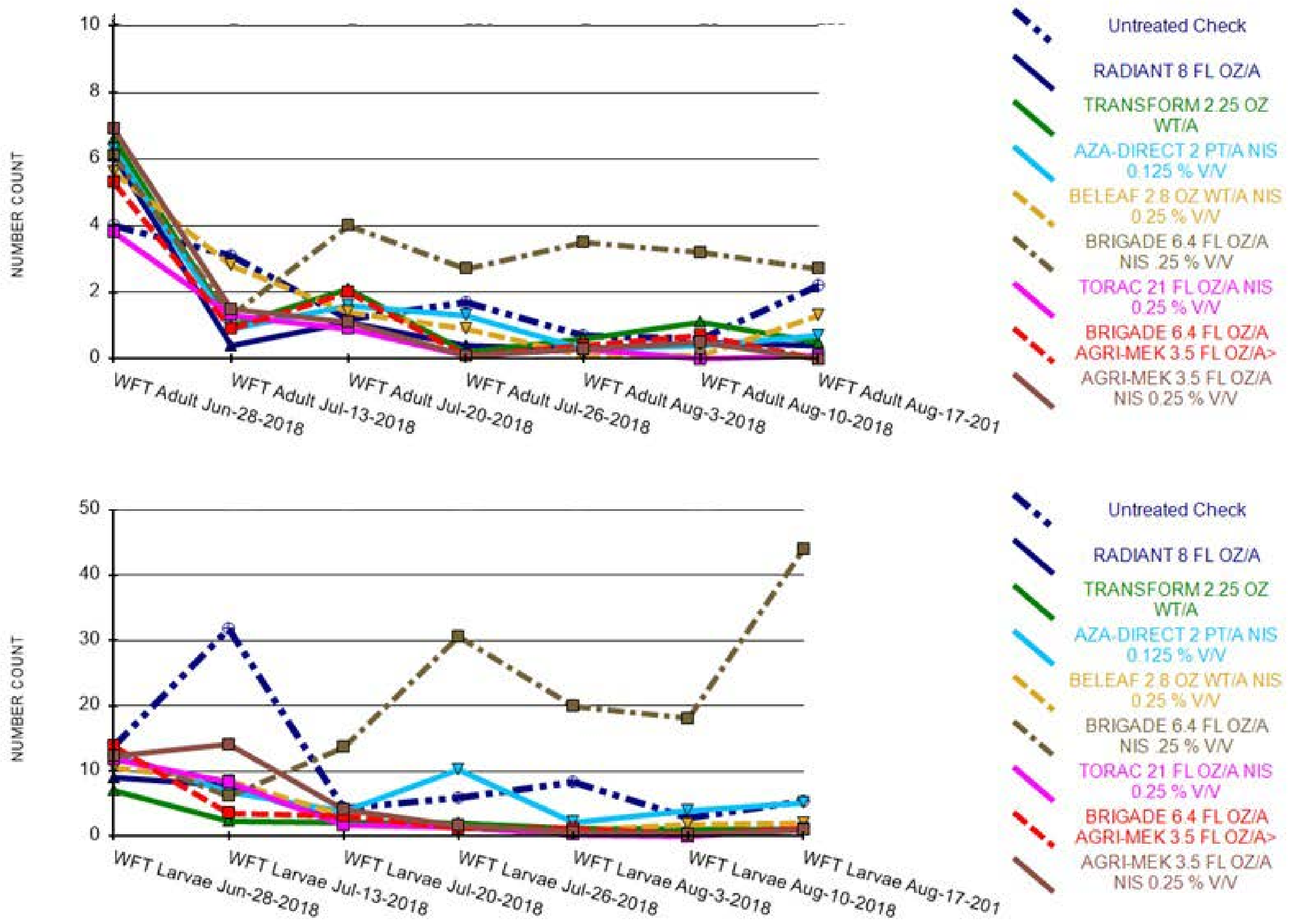


Figure 3. Seasonal trends in western flower thrips (WFT) abundance for adults (3a) and larvae (3b) by treatment. Insecticide applications were made July 10, July 24, and August 7. Malheur Experiment Station, 2018.

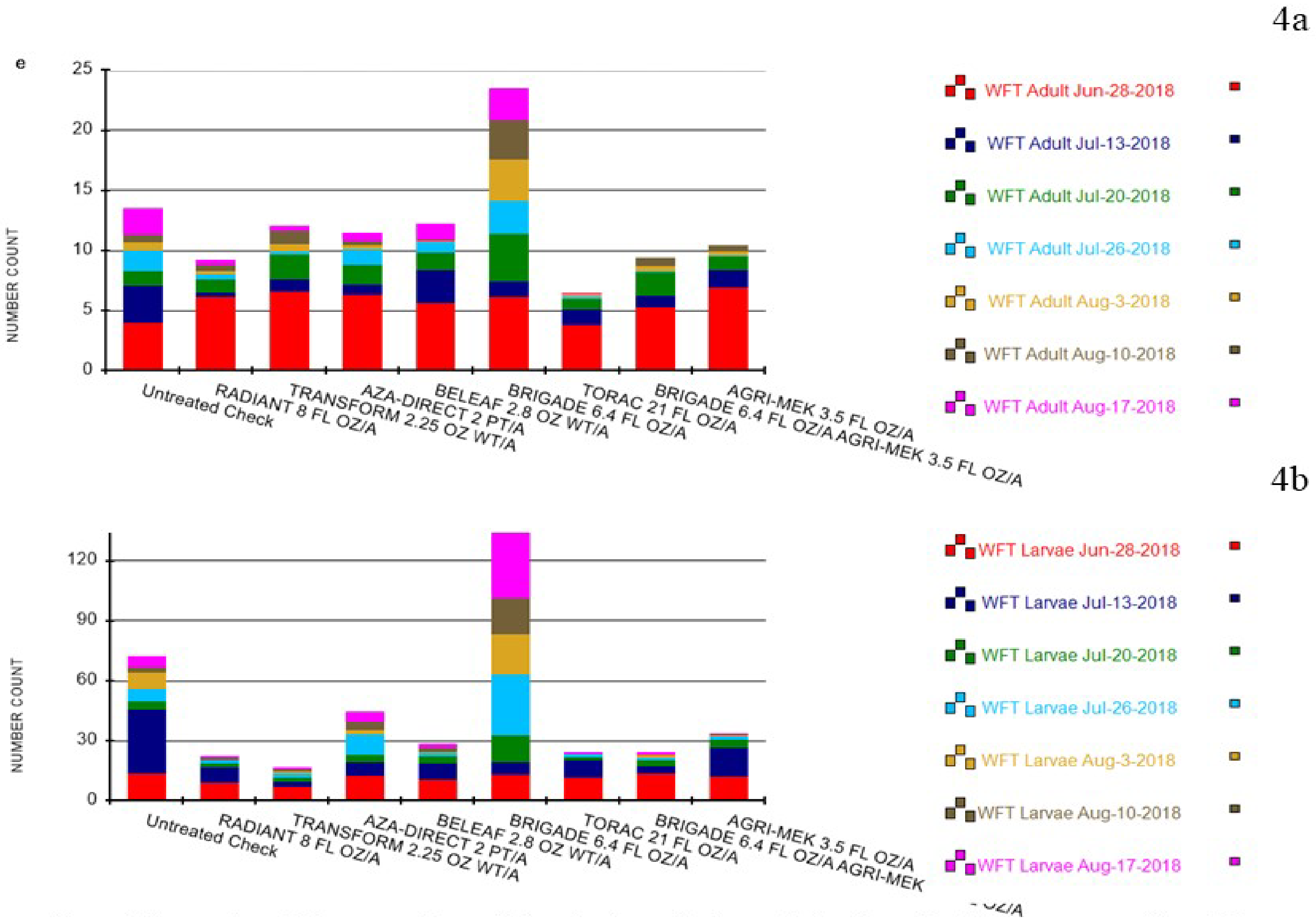


Figure 4. Seasonal trends in western flower thrips (WFT) abundance for adults (4a) and larvae (4b) by treatment. Insecticide applications were made July 10, July 24, and August 7. Bars represent seasonal totals for each treatment, with each sample date shown as a different color pattern. Malheur Experiment Station, 2018.

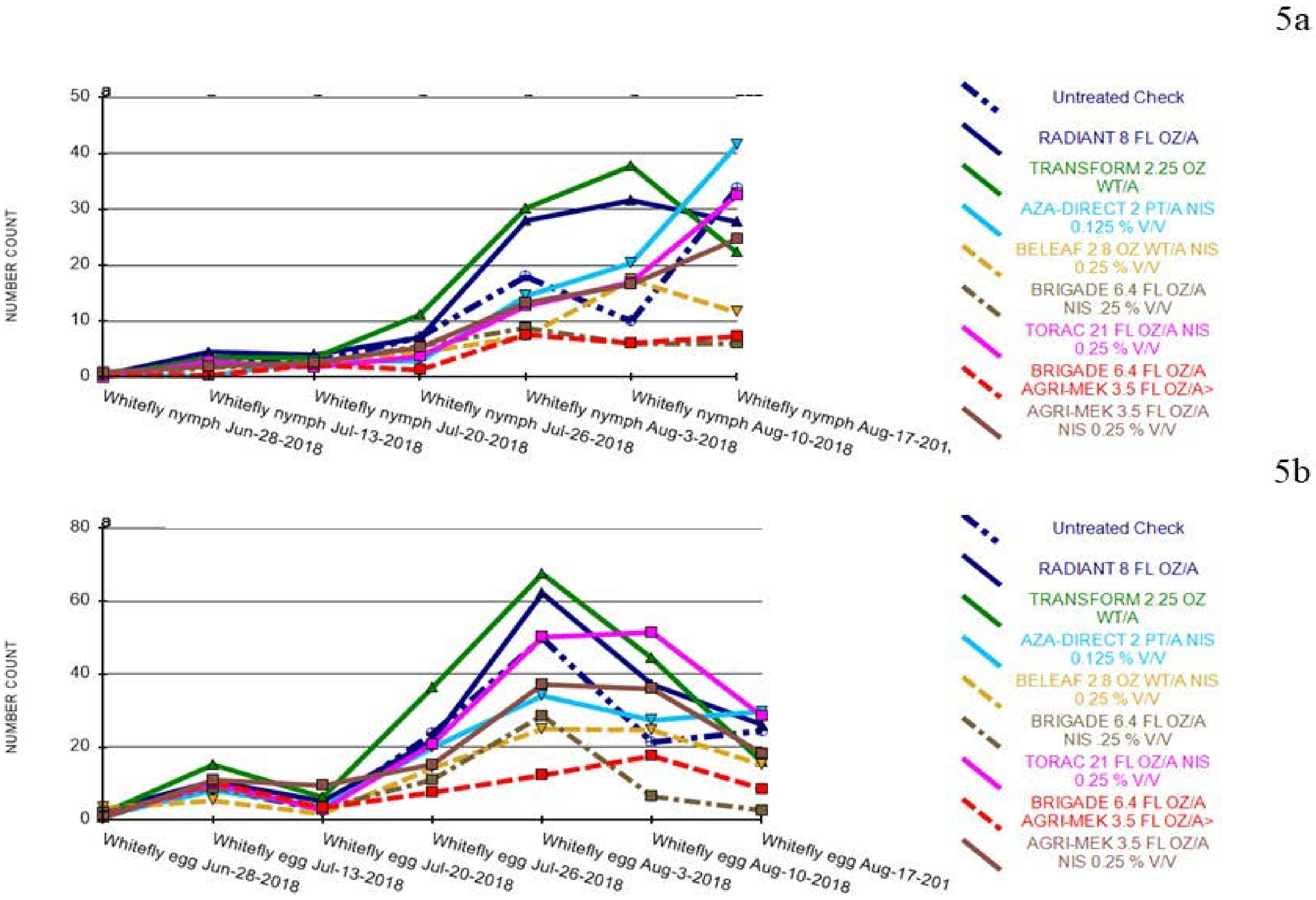


Figure 5. Seasonal trends in whitefly abundance for nymphs (5a) and eggs (5b) by treatment. Insecticide applications were made July 10, July 24, and August 7. Malheur Experiment Station, 2018.

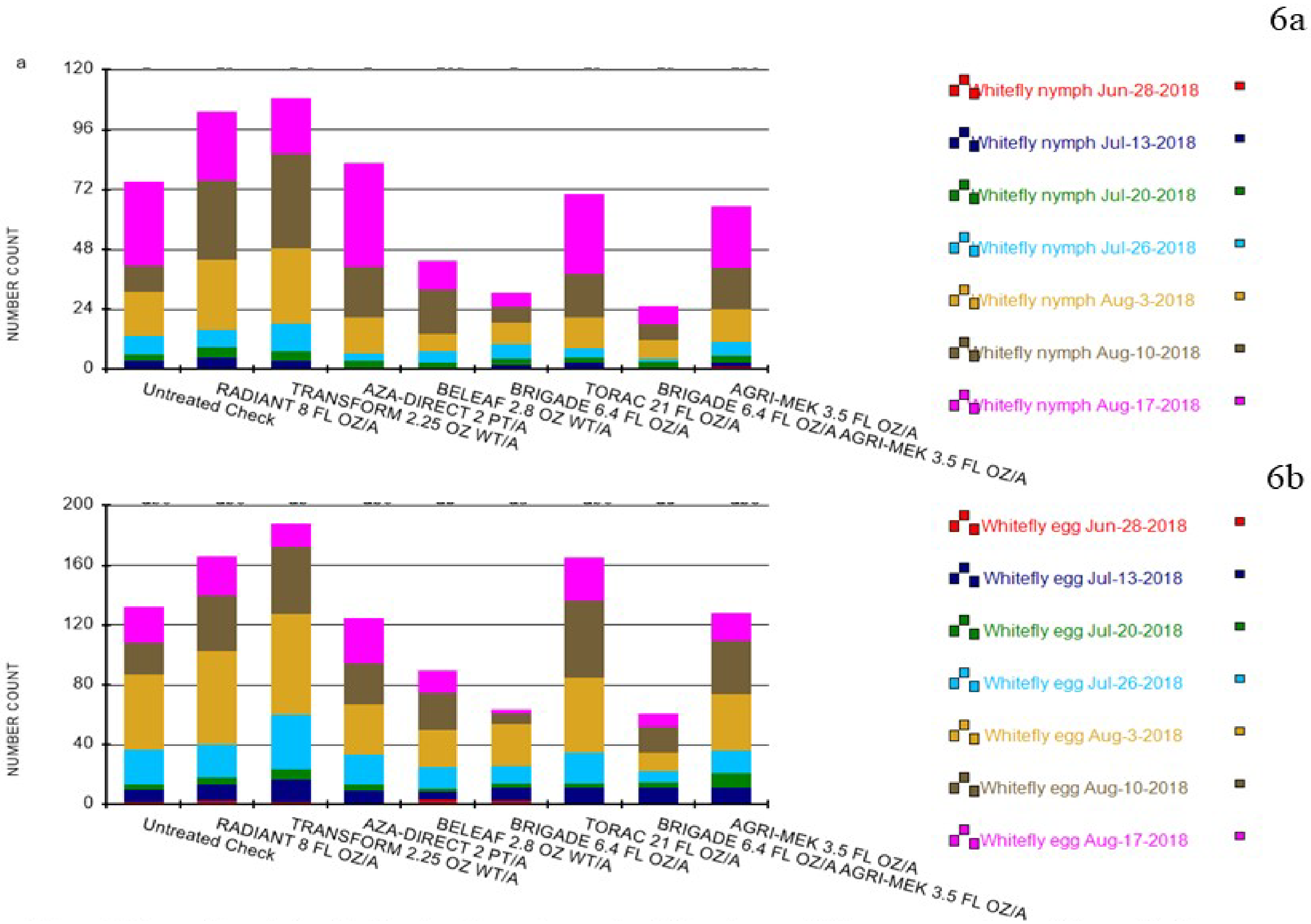


Figure 6. Seasonal trends in whitefly abundance for nymphs (6a) and eggs (6b) by treatment. Insecticide applications were made July 10, July 24, and August 7. Bars represent seasonal totals for each treatment, with each sample date shown as a different color pattern. Malheur Experiment Station, 2018.

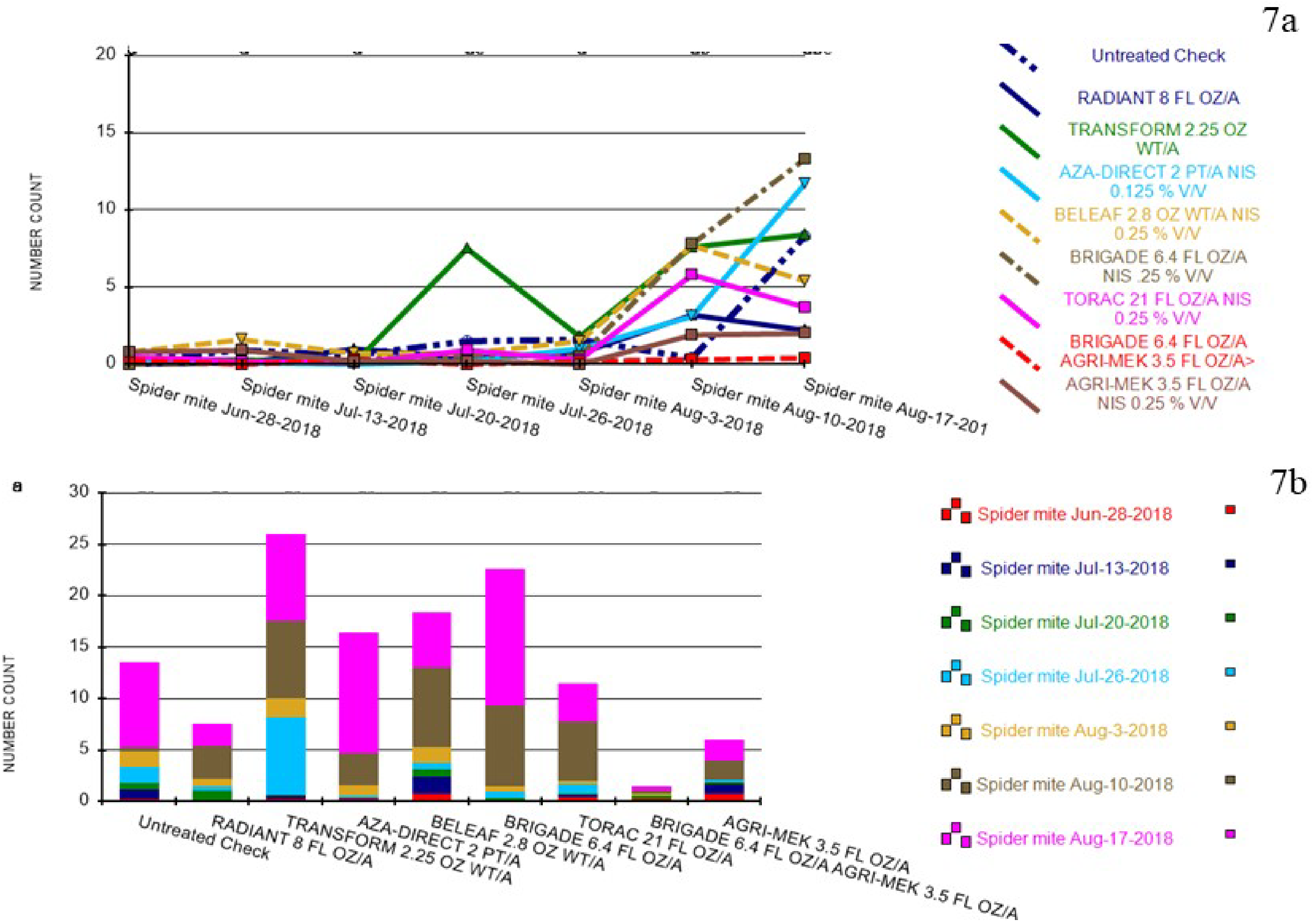
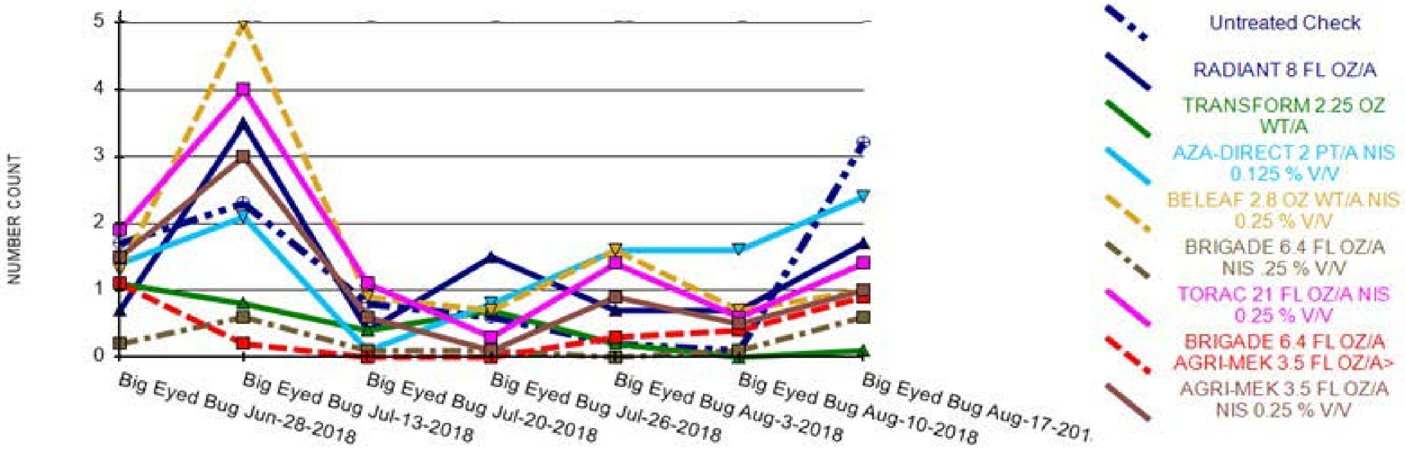


Figure 7. Seasonal trends in spider mite abundance by treatment. Insecticide applications were made July 10, July 24, and August 7. Bars in (7b) represent seasonal totals for each treatment, with each sample date shown as a different color pattern. Malheur Experiment Station, 2018.

8a



8b

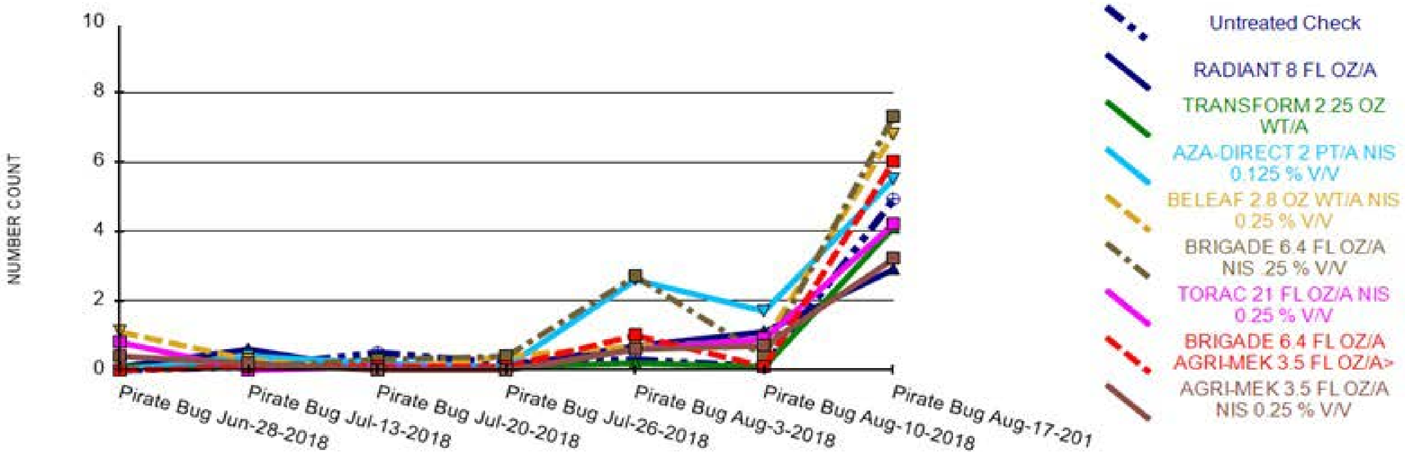


Figure 8. Seasonal trends in adult abundance of predatory big-eyed bugs (8a) and pirate bugs (8b) by treatment. Insecticide applications were made July 10, July 24, and August 7. Malheur Experiment Station, 2018.

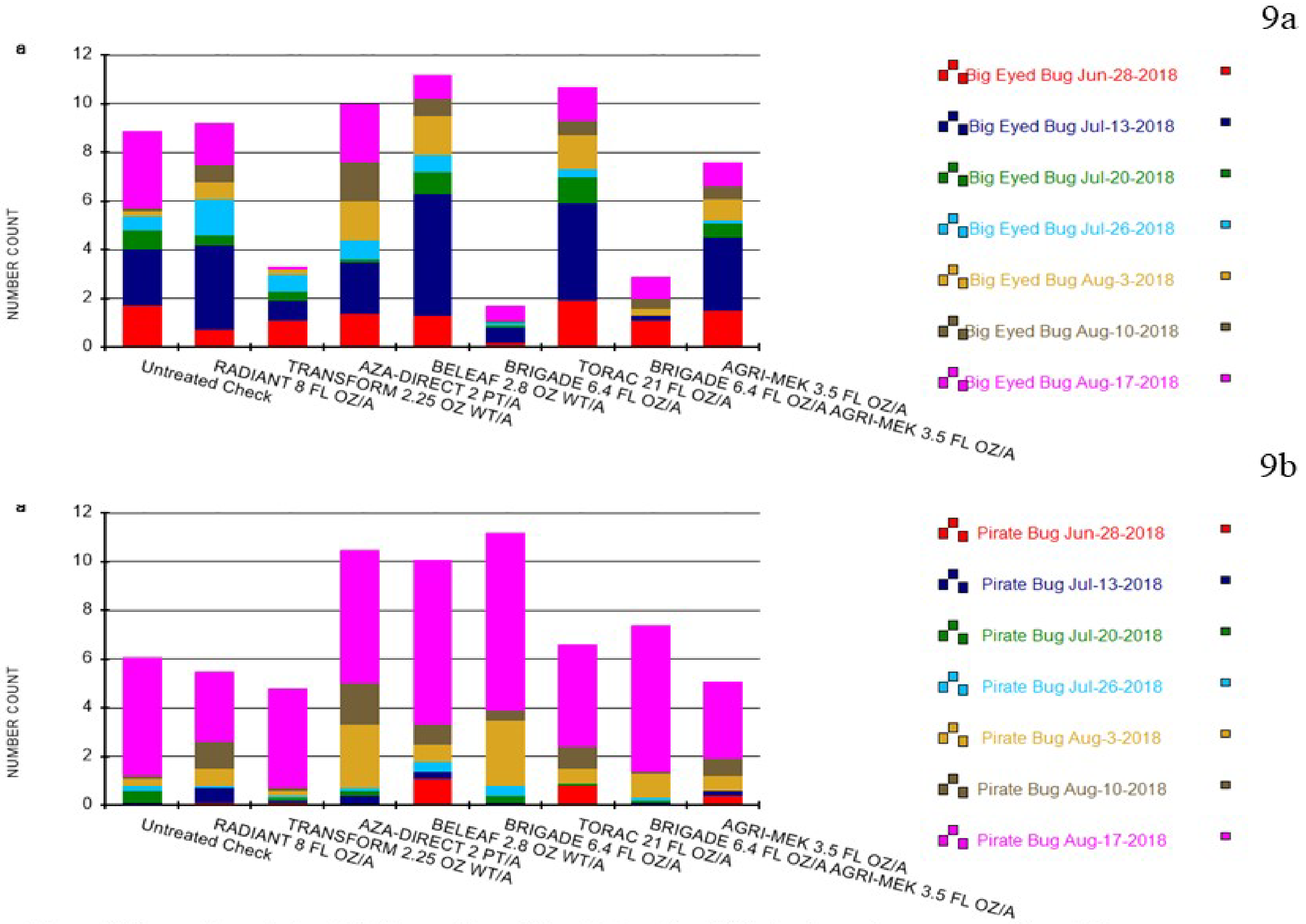


Figure 9. Seasonal trends in adults of predatory big-eyed bugs (9a) and pirate bugs (9b) by treatment. Insecticide applications were made July 10, July 24, and August 7. Malheur Experiment Station, 2018. Bars represent seasonal totals for each treatment, with each sample date shown as a different color pattern.

MALHEUR COUNTY EXTENSION POTATO PEST MONITORING PROGRAM ─ 2018

Stuart Reitz, Malheur Experiment Station, Oregon State University, Ontario, OR

Abstract

Twenty-eight commercial potato fields throughout Malheur County were monitored for pest and beneficial insects. Traps were monitored weekly from May through the end of July when harvest began. Results were reported via email to growers and their crop advisors. Significant findings were also reported on the Pacific Northwest Pest Alert network (http://www.pnwpestalert.net/).

Potato psyllids were found from July 7 through the end of the season. One psyllid tested positive for the Zebra chip bacterium, which is the first detection of an infected psyllid for Malheur County. However, no Zebra chip infected plants were found in scouting of fields.

Beet leafhoppers were present throughout the growing season, and their numbers did not decline over the summer as usual. No plants infected with purple top disease (transmitted by leafhoppers) were found during this year's monitoring program.

The pest status of thrips and Lygus in the Treasure Valley is still uncertain. Lygus populations were present throughout the season, peaking from late June through July. High numbers of thrips were recorded in June and July.

The relatively large numbers of beneficial insects probably helped suppress pest populations. Large numbers of ladybird beetles and lacewings probably helped to suppress aphid populations.

OSU Extension also helped to keep growers and crop advisors up to date on other pest problems. The monitoring project provided up-to-date information that allowed growers to make more informed pest management decisions and reduce their pesticide applications in 2018.

Objectives

- Monitor populations of key potato pests across Malheur County and deliver that information on a weekly basis to potato growers, crop advisors, and other interested people in the county. Pests that were monitored included 1) potato psyllids, 2) aphids, 3) beet leafhoppers, 4) potato tuberworm moths, 5) thrips, 6) Lygus (a potential pest), 7) Colorado potato beetle, and other pests. Associated beneficial parasites, predators, and pathogens were monitored to assess levels of naturally occurring biological control.
- Assist growers in scouting for other pests and diseases during the growing season.
- Assist growers with identifying and addressing other crop management issues.
- Relay information to growers and crop advisors directly through email and phone contact and publish pest monitoring data in the Treasure Valley Pest Alert Network.

Procedures

Trapping stations were set at 30 potato fields in Malheur County and were monitored from June until mid-August when fields were harvested. Trapping techniques specific for the different pests were used for monitoring.

Potato Psyllid Monitoring – To aid growers in managing potato psyllids and zebra chip, yellow sticky cards were placed in potatoes fields, with four traps per field. Traps were collected and replaced weekly. Aphid and leafhopper traps were also examined for the presence of psyllids. Foliage samples were inspected for psyllid nymphs and eggs.

Beet Leafhopper Monitoring – Yellow sticky traps were placed along borders of fields to monitor beet leafhoppers, which can transmit the pathogen that causes purple top disease. Traps were collected and replaced weekly, and the numbers of leafhoppers recorded. Fields were also inspected for plants infected with purple top.

Aphids – Aphids were also monitored with yellow sticky traps.

Potato Tuberworm Monitoring – To monitor tuberworm moth populations, pheromone traps were placed along field borders. Traps were collected and replaced weekly. Pheromone lures were replaced every 3 weeks, or as needed.

Colorado Potato Beetle – Yellow sticky traps were also inspected for adult Colorado potato beetles and plants were examined for the presence of beetle larvae and egg masses.

Beneficial insects – Yellow sticky traps used for pest monitoring were also inspected for beneficial insects, in particular predatory insects, including minute pirate bugs, big-eyed bugs, lacewings, and ladybird beetles. These counts were used as an indication of the overall activity of natural enemies in a field.

Diagnostics – Psyllids were tested by Kylie Swisher's lab (USDA-ARS Prosser/Wapato, WA) for the Zebra chip bacterium.

Other Pest and Disease Monitoring – Assistance was provided to growers and crop advisors in identifying other pest and diseases problems that they encountered.

Accomplishments

- Traps were monitored over a 12-week period from May 11 until July 28 when fields were near harvest.
- Growers and crop advisors received up-to-date weekly reports within 1 day after traps were collected. Psyllids were first found during the week of July 1–7. Populations did increase through the remainder of the season, as has been typical.
- One psyllid, caught the week of July 18, tested positive for the Zebra chip bacterium, but no Zebra chip infected plants were found (Fig. 1). The grower and crop advisor for that field were notified of the find, and all other growers and crop advisors were informed that a positive psyllid was detected in the county. A notice was also posted to the PNW Pest Alert website. Testing was conducted by Dr. Kylie Swisher, USDA-ARS, Prosser/Wapato, Washington.
- Beet leafhoppers were present throughout the growing season, with abundance highest during June, as is typical. However, we found no evidence of plants infected with potato

purple top disease (Fig. 1).

- Aphids were among the most common pests recorded and were abundant, especially from late June into July. Significant numbers of potato aphids were found during the season (4–11 per field per week), but relatively few green peach aphids were found (<2 per field per week) (Fig. 2).
- No potato tuberworm moths were found in 2018. This was the fourth consecutive year that no tuberworm moths were collected.
- The pest status of thrips and Lygus in the Treasure Valley remains uncertain. Lygus are one of the most commonly encountered insects in potato fields, with populations present throughout the season. However, area growers have not yet considered Lygus to be economically important. Thrips were predominately western flower thrips. Some onion thrips were also present because of the proximity of potato fields to the areas onion fields. High numbers of thrips were recorded in June and July (Fig. 3).
- The relatively large numbers of beneficial insects probably helped suppress pest populations. Large numbers of big-eyed bugs, pirate bugs, ladybird beetles, and lacewings probably helped to suppress psyllid, aphid, and thrips populations, in particular. All of the predators that were monitored are known to feed on these pests. They likely help suppress but do not completely control pest populations (Figs. 3 and 4).
- Growers were advised of other pest and disease issues reported in other parts of the PNW.

Impacts

Malheur County potato growers have been strong supporters of integrated pest management and continue to utilize information from this monitoring program. Their use of pest alert information reflects their commitment to providing consumers with safe, nutritious food. Growers were provided the latest recommendations and advice on potato psyllid management, which facilitated their pest management decisions and to better time and target pesticide applications.

Inclusion of many different pests and natural enemies in the monitoring program provides growers with information to assess their individual pest management programs and to know when insecticide applications may or may not be necessary.

Relation to Other Research

Monitoring results were shared with other research/extension personnel in Oregon and Idaho. Psyllid and other pest data have been included in the MAP-PSILDS-PNW project led by Bill Snyder, Washington State University. This project is assessing how field location and characteristics affect the risk of psyllid infestations and zebra chip outbreaks.

Acknowledgments

I appreciate the technical assistance of Ian Trenkel, Hannah Rose, Kelsey Alexander, Brooke Bezona, Allison Simmons, and Mary Phipps. Funding for this project came from the Oregon Potato Commission.

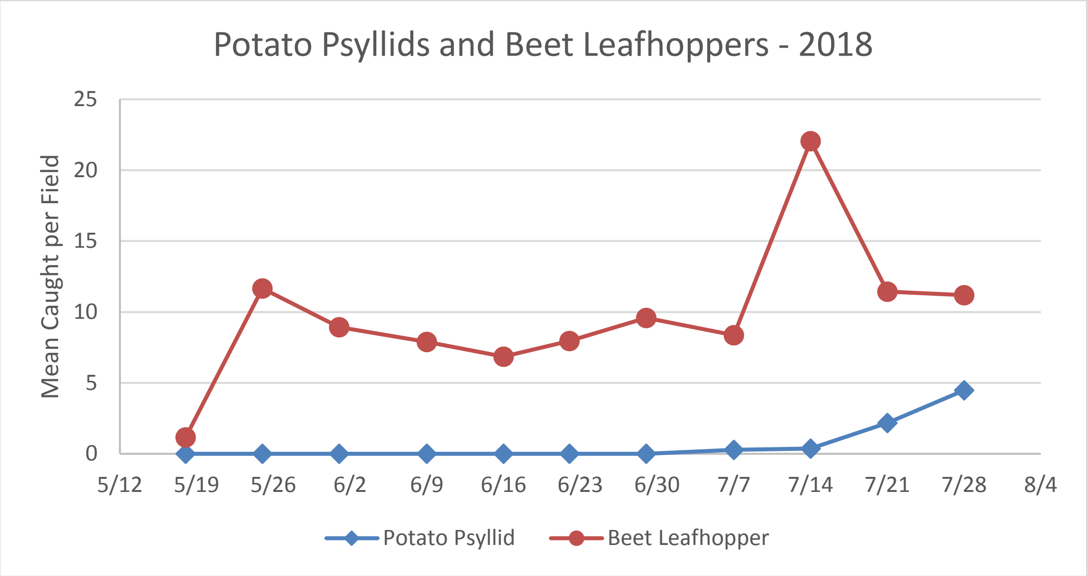


Figure 1. Seasonal dynamics of potato psyllids and beet leafhoppers in commercial potato fields in Malheur County, Oregon during 2018. Numbers are the mean per field per week for 28 fields.

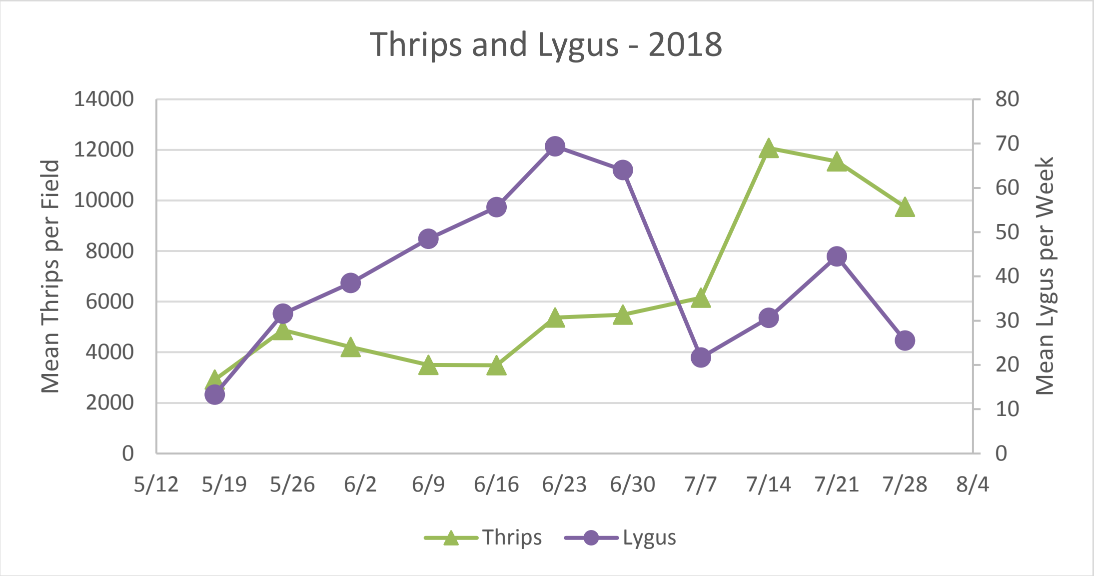


Figure 2. Seasonal dynamics of Lygus bugs and thrips in commercial potato fields in Malheur County, Oregon during 2018. Numbers are the mean per field per week for 28 commercial fields. Note the different axis scale for thrips and Lygus bugs.

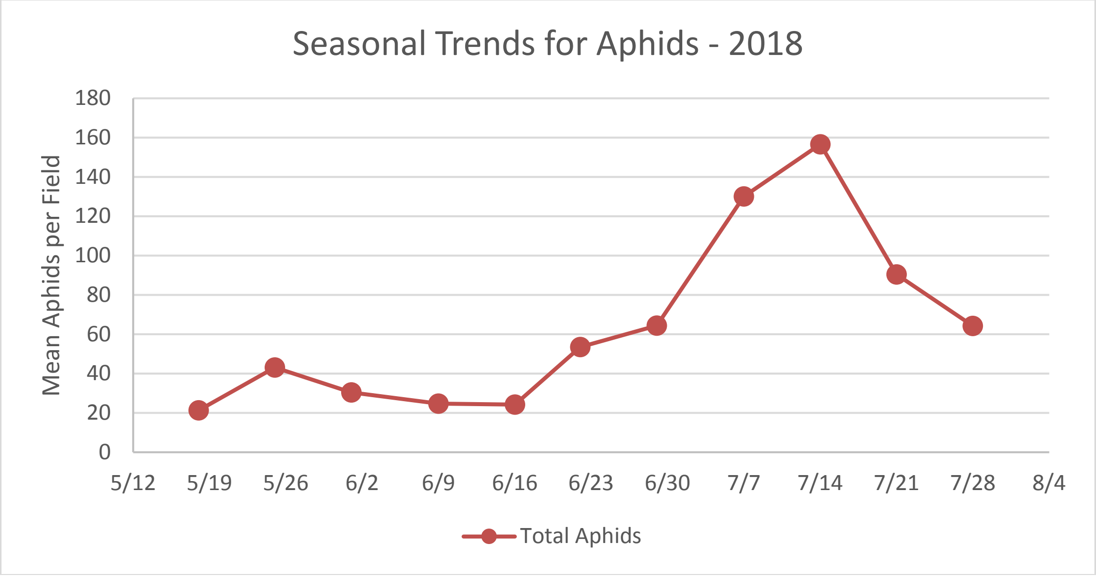


Figure 3. Seasonal dynamics of aphids found in commercial potato fields in Malheur County, Oregon during 2018. Numbers are the mean per field per week for 28 fields.

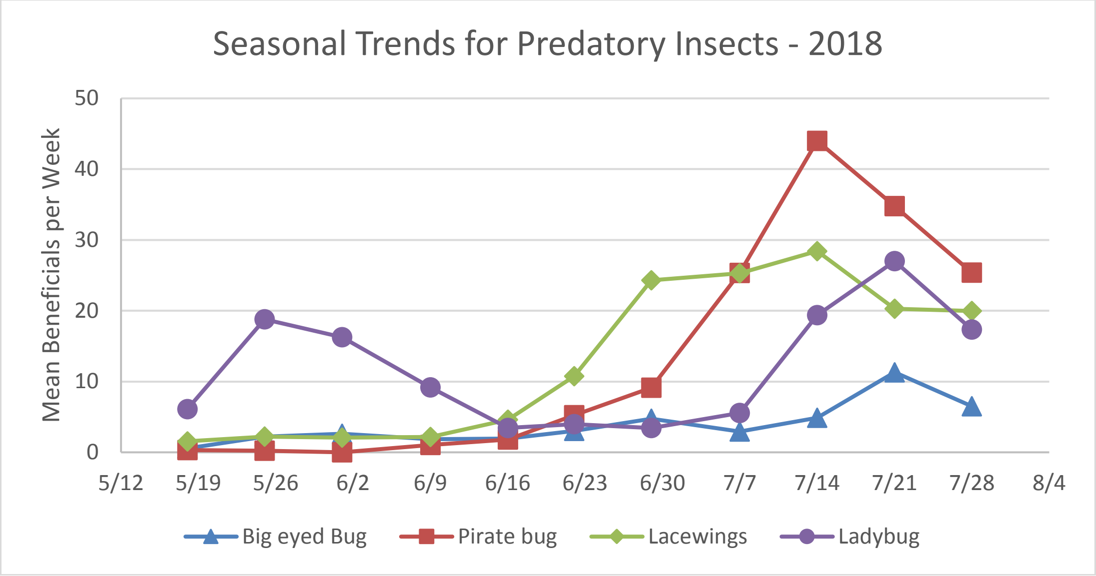


Figure 4. Seasonal dynamics of predatory insects found in commercial potato fields in Malheur County, Oregon during 2018. Numbers are the mean per field per week for 28 fields.

EVALUATION OF TWO AUTOMATED IRRIGATION SCHEDULING METHODS FOR DRIP IRRIGATED POTATO

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Ami Gips, Yechiam Gets, Lior Doron, Ofer Halperin, Netafim, Tel Aviv, Israel

John Taberna, Western Labs, Parma, ID

Introduction

Irrigation scheduling for potato can use soil water tension, soil water content, or crop evapotranspiration estimates. Measurement of evapotranspiration and the use of an allowable soil water depletion value can be used to automatically schedule irrigations. Netafim (Fresno, CA) has developed an irrigation scheduling method for potato using evapotranspiration estimates. The Malheur Experiment Station has developed soil water tension criteria for automatically or manually initiating potato irrigations. A range of soil water tensions were evaluated for their effect on potato yield, grade and processing quality under furrow, sprinkler, and drip irrigation on silt loam soil. For furrow or sprinkler irrigated potato the ideal irrigation criterion is 50 to 60 cb (Eldredge et al., 1992; Shock et al., 1993, 2003). For drip irrigation, which uses a higher irrigation frequency, the ideal criterion is 25 to 30 cb (Shock et al., 2002). Soil water tension has been measured using granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Riverside, CA). Granular matrix sensors were calibrated to soil water tension (Shock, 2003). Granular matrix sensors are inexpensive, require little maintenance, and can be used to schedule irrigations automatically using controllers and electric valves. This trial tested two automatic drip irrigation scheduling methods with two new processing potato varieties (Payette Russet and Clearwater Russet).

Methods

The trial was conducted on an Owyhee silt loam previously planted to wheat at the Malheur Experiment Station, Ontario, Oregon. A soil analysis taken in the fall of 2017 showed that the top foot of soil had a pH of 7.8, 2.6% organic matter, 8 ppm nitrate-N, 3 ppm ammonium-N, 37 ppm phosphorus (P), 469 ppm potassium (K), 16 ppm sulfur (S), 3243 ppm calcium (Ca), 563 ppm magnesium (Mg), 278 ppm sodium, 7 ppm zinc (Zn), 4 ppm manganese (Mn), 2.4 ppm copper (Cu), 11 ppm iron, and 0.3 ppm boron (B). In the fall of 2017, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. Based on the soil analysis, 25 lb of N/acre as urea 44 lb of P/acre as monoammonium phosphate, 104 lb of K/acre as potassium chloride, 200 lb of S/acre as elemental sulfur, 7 lb of Mn/acre as manganese sulfate, 1 lb of Cu/acre as copper sulfate, 1 lb per acre Zn as zinc sulfate, and 4 lb of B/acre as Granubor II were broadcast before plowing.

Following plowing, the field was fumigated with 20 gal/acre of Telone® II (dichloropropene) and bedded on 36-inch row spacing.

On March 29, 2018, 100 lb N as urea and Admire® (Imidacloprid) at 7 oz/acre (0.25 lb ai/acre) was shanked into both sides of the beds at 6-inch depth. On April 3, seed of Payette Russet and Clearwater Russet was cut by hand into 2.5-oz seed pieces, treated with Maxim® MZ (fludioxonil, mancozeb) dust, and stored to suberize. To accelerate inherent slow sprouting, Payette Russet seed pieces were dipped for five minutes in a solution of 2 mg of giberellic acid/liter prior to application of Maxim MZ dust.

The experimental design was a randomized complete block design with two treatments, two variety split plots, and six replicates. The treatments were two automated irrigation scheduling methods: 1) irrigation scheduling based on soil water tension (OSU), 2) irrigation scheduling based on potato evapotranspiration (Netbeat). Main plots were six potato rows wide by 80 ft long. Each main plot was divided into two variety split plots (Payette Russet and Clearwater Russet).

Potato seed pieces were planted on April 4-5 using a using a 2-row assist-feed planter with 9-inch seed spacing in 36-inch rows. Red potatoes were planted between variety split plots as markers to separate the split plots at harvest.

After planting, the plots were reconfigured by slightly flattening the 36-inch hills to create 72-inch beds with two potato rows. Drip tape was installed 2 inches deep and 4 inches to the inside of each potato row. The drip tape (Dripnet PC, Netafim, Fresno, CA) had emitters spaced 12 inches apart and an emitter flow rate of 0.16 gal/hour at 10 psi.

After all bed preparation operations were finished, a sprinkler irrigation system was installed and herbicide was broadcast on the whole field using a ground sprayer. Herbicide was a mixture of 1.33 pints per acre (1.3 lb ai) of Dual II Magnum® (metolachlor), 2 pints (0.83 lb ai) per acre of Prowl® (pendimethalin), and 32 oz/acre of Roundup®. The herbicides were incorporated by applying 0.75 inch of water to the whole field with the sprinkler irrigation system. After the herbicide was incorporated, the sprinkler system was removed and the drip irrigation system for the treatments was connected. The field was sprayed with Matrix® herbicide (rimsulfuron) at 1.5 oz/acre (0.4 oz ai/acre) on May 22.

Soil water tension in all main plots of all treatments was measured using four granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Riverside, CA) in Clearwater Russet split plots. The sensors were installed at 8-inch depth below each of the middle two potato rows in each Clearwater Russet split plot. The datalogger (CR1000, Campbell Scientific, Logan, UT) read and recorded the SWT every hour.

The OSU treatment was irrigated automatically using the datalogger based on soil water tension (SWT) feedback. The datalogger automatically irrigated all plots in the OSU treatment when the average SWT of all OSU treatment plots reached or exceeded 25 cb. Irrigation durations were 7 hours to apply 0.6 inches of water. The datalogger made irrigation decisions every 8 hours. The datalogger controlled the irrigations for the OSU treatment using a controller (SDM CD16AC controller, Campbell Scientific) and solenoid valves (Rainbird, Azusa, CA). Automatic irrigations were started on May 31 and terminated on September 2.

The Netbeat treatment was irrigated automatically based on potato evapotranspiration using a controller (NMC-Junior Pro Irrigation, Netafim).

The water for the drip system was supplied by a well that maintained a continuous and constant water pressure of 30 psi. Water applied to each treatment was measured by totalizing flow meters (model M, Netafim) read five times per week. The total water applied to each treatment was measured from emergence to the last irrigation on September 2. Approximately 2 inches of water were applied uniformly to each treatment from emergence to the start of automated irrigations on May 31. Potato evapotranspiration (ET_c) was calculated with a modified Penman equation (Wright, 1982) using data collected at the Malheur Experiment Station by an AgriMet weather station. Potato ET_c was estimated and recorded from crop emergence on May 6 until September 9.

Plant nutrition was monitored by weekly petiole and soil solution analyses starting June 8 and ending August 10 (Tables 2, 3, and 4). To avoid damage to the harvest rows, petiole and soil samples were collected from the border rows in each split plot. Composite petiole and soil samples were made that combined the samples from all the replicates of each variety in each treatment. The petiole and soil samples were analyzed by Western Laboratories, Inc., Parma Idaho. Plant nutrients were applied through the drip system to the respective treatments only if both the root tissue and soil solution analyses concurrently indicated a deficiency (Table 5).

The potatoes were sprayed aerially on June 12 and June 27 with the fungicide Bravo® (chlorothalonil) at 1 pt/acre (0.75 lb ai/acre). The field was sprayed aerially on July 28 and August 20 with the insecticides Agri-Mek® (abamectin) at 3.5 oz/acre (0.02 lb ai/acre) and Movento® (Spirotetramat) at 5 oz/acre (0.08 lb ai/acre).

On August 21, plants in each split plot were evaluated subjectively for maturity.

The potato vines were flailed on October 1. Thirty feet of the middle four rows of each variety split plot in each main plot were harvested on October 15. All tubers from each split plot were placed into burlap sacks and placed in a barn where they were kept under tarps. All sacks from each split plot were weighed. Four sacks from a representative area in each split plot were selected for grading. Tubers were graded by market class (U.S. No. 1 and U.S. No. 2) and weight (<4 oz, 4-6 oz, 6-10 oz, 10-20 oz, and >20 oz). Tubers were graded as U.S. No. 2 if any of the following conditions occurred: growth cracks, bottleneck shape, abnormally curved shape, or two or more knobs. Marketable tubers are U.S. No. 1 and U.S. No. 2 larger than 4 oz. A 20-tuber sample from each split plot was placed into storage. The storage temperature was gradually reduced to 45°F.

After 6 weeks in storage, a 10-tuber sample from each plot was evaluated for specific gravity, fry color, and internal defects. Ten tubers per plot were cut lengthwise and the center slices from each tuber were fried for 2.5 min in 375°F soybean oil. Percent light reflectance was measured on the stem and bud ends of each slice. Percent light reflectance was measured using a Photovolt Reflectance Meter model 577-A (Photovolt Instruments, Minneapolis, MN), with a green tristimulus filter, calibrated to read 0% light reflectance on the black standard cup and 71.7% light reflectance on the white porcelain standard plate. Specific gravity of all varieties was measured from a 10-tuber sample from each plot using the weight-in-air, weight-in-water method.

On January 24, 2019, ten tubers from each split plot of the OSU and Netbeat treatments were analyzed for nutrient content and moisture. Tuber nutrient content and moisture were used to calculate tuber nutrient uptake in the harvested yield.

Data were analyzed with the General Linear Models analysis of variance procedure using NCSS (Number Cruncher Statistical Systems, Kaysville, UT) using Fisher's protected LSD (least significant difference) for means separation at the 95% confidence level.

Results and Discussion

The petiole NO_3 concentration for Payette Russet remained above the critical level during the season for both irrigation scheduling systems (Fig. 1). For Clearwater Russet, the petiole NO_3 concentration remained close to the critical level during the season for both irrigation scheduling systems (Fig. 2). The soil solution nitrogen concentration remained above the critical level all season for both varieties with both irrigation scheduling systems (Fig. 3). A total of 25 lb N/acre was applied through the drip tape during the season (Table 1). Despite the limited amount of N applied during the season, the soil contained substantial amounts of total available N (Table 2). Previous research has shown that with carefully scheduled irrigations, N fertilizer requirements for potato are low (Feibert et al., 1998). Soil solution and petiole analyses for the other nutrients are found in tables 3 and 4 and the amounts of nutrients applied based on the analyses are in table 2.

Treatment differences

The three irrigation scheduling systems maintained the soil water tension around the target values (Fig. 4). The OSU irrigation scheduling applied 41 irrigations and on average each irrigation applied 0.79 inches of water (Table 5). The Netbeat and Arable irrigation scheduling applied fewer irrigations (29 and 26 irrigations, respectively) and on average each irrigation applied 1.1 inches and 1.3 inches of water, respectively.

From crop emergence on May 6 until the last irrigation, potato ET_c totaled 31.5 inches and precipitation totaled 1.05 inches. The total amounts of water applied plus precipitation were similar: 33.4, 33.5, and 33.5 inches for the OSU, Netbeat, and Arable irrigation scheduling, respectively (Table 5). All three irrigation scheduling systems applied water at a rate that closely tracked ET_c (Fig. 5).

There were no statistically significant differences in yield or grade between irrigation scheduling systems, except for yield of tubers 4 to 6 oz (Table 6). The Netbeat irrigation scheduling had slightly lower yield of tubers 4 to 6 oz than the other irrigation scheduling systems. There was no statistically significant difference in water use efficiency between irrigation scheduling systems. There was no statistically significant difference in tuber fry color and specific gravity between irrigation scheduling systems. The only internal tuber defect encountered was internal brown spot, with no statistically significant difference between treatments.

There was no statistically significant difference between treatments in tuber nutrient content or tuber nutrient uptake (Tables 7 and 8).

Variety differences

Averaged over treatments, Clearwater Russet had higher total and marketable yield than Payette Russet (Table 6). Averaged over treatments, Clearwater Russet had higher yield of larger tubers than Payette Russet. Payette Russet had higher yields of smaller tubers than Clearwater Russet. There was no statistically significant difference in tuber fry color and specific gravity between varieties. There was no statistically significant difference in the percentage of tubers with internal brown spot between varieties.

Averaged over treatments, the harvested tubers of Clearwater Russet removed 275 lb/acre of nitrogen and 433 lb/acre of potassium, considerably more than the amounts of fertilizer applied. Clearwater Russet had higher tuber concentrations of potassium and magnesium than Payette Russet (Table 7). Based on total yield, Clearwater Russet had higher tuber uptake of nitrogen, phosphorus, potassium, sulfur, magnesium, and boron than Payette Russet (Table 8).

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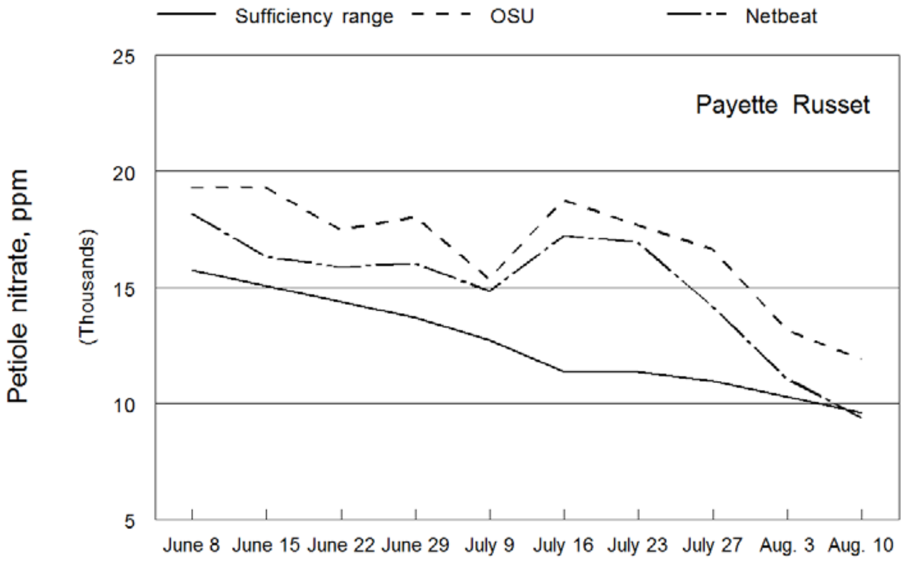

Figure 1. Payette Russet petiole nitrate over time with two irrigation scheduling treatments. Malheur Experiment Station, Oregon State University, Ontario, OR.

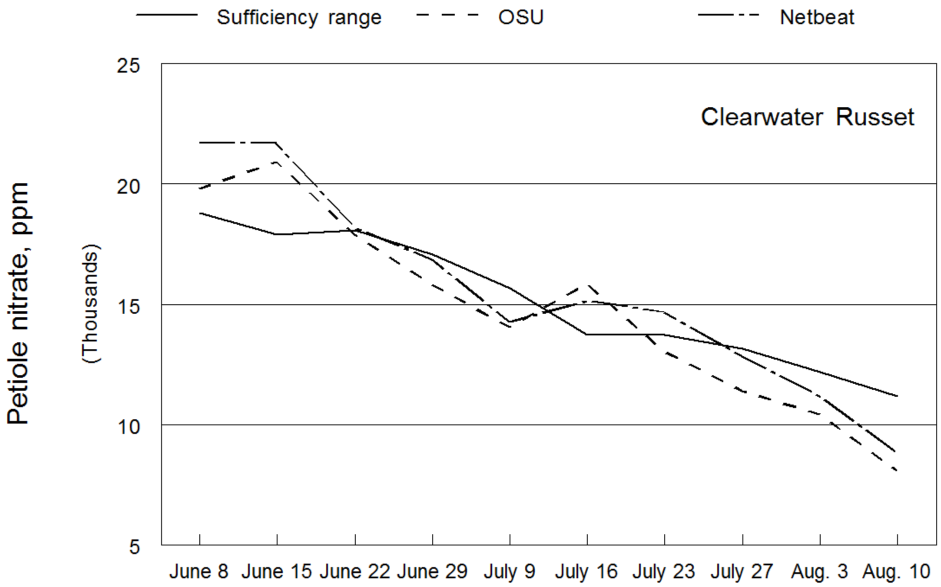

Figure 2. Clearwater Russet petiole nitrate over time with two irrigation scheduling treatments. Malheur Experiment Station, Oregon State University, Ontario, OR.

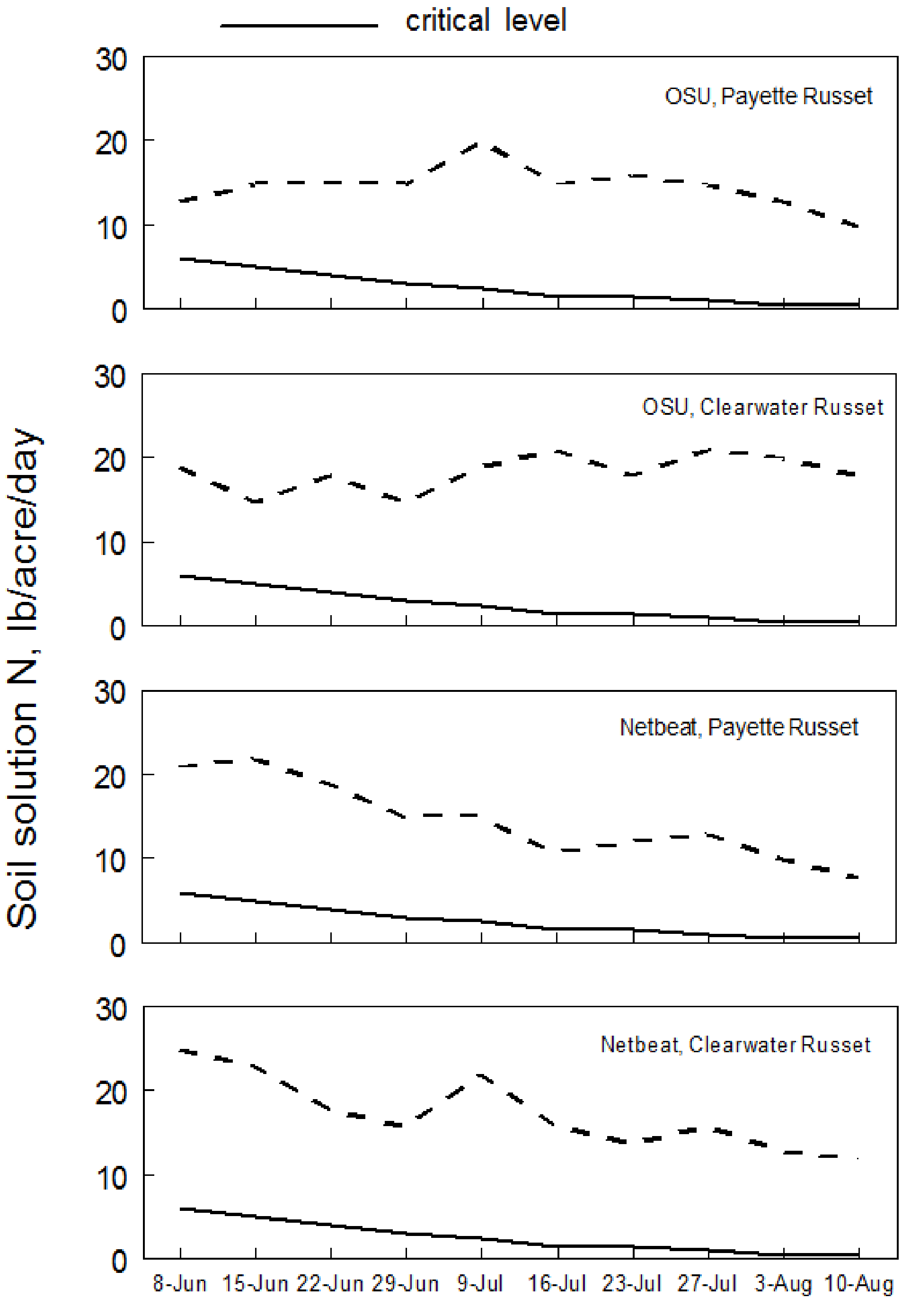

Figure 3. Soil solution nitrogen over time with two irrigation scheduling treatments and two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR.

Table 1. Nutrients applied to two potato varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

Date	N	K	Mg	Mn	S
13-Jun			5	0.25	
20-Jun		5	5		
29-Jun	10	10	3		
5-Jul	15	10	3		5
20-Jul		18			
25-Jul		15			
30-Jul		10			
7-Aug		10			
14-Aug		20			
Total	25	98	16	0.25	5

Nitrogen was applied as Uran (32% N), potassium as potassium chloride, manganese was applied as manganese carbonate (5%), magnesium was applied as magnesium carbonate (3%), and sulfur as elemental sulfur (52%).

Table 2. Total available soil N for two potato varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

	OSU		Netbeat	
Date	Payette Russet	Clearwater Russet	Payette Russet	Clearwater Russet
	-------- lb/acre ---------			
8-Jun	93	132	144	174
15-Jun	108	105	156	162
22-Jun	102	129	132	129
29-Jun	105	108	105	114
9-Jul	138	135	108	153
16-Jul	102	144	75	114
23-Jul	114	126	84	99
27-Jul	102	147	90	114
3-Aug	90	141	69	90
10-Aug	72	126	57	81

Table 3. Potato petiole analyses for two varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on next page.

	OSU		Netbeat	
Date	Payette Russet	Clearwater Russet	Payette Russet	Clearwater Russet
P, 0.2 - 0.55 %				
8-Jun	0.7	0.61	0.69	0.64
15-Jun	0.71	0.69	0.72	0.67
22-Jun	0.74	0.54	0.67	0.6
29-Jun	0.47	0.59	0.59	0.46
9-Jul	0.55	0.38	0.51	0.43
16-Jul	0.36	0.30	0.36	0.31
23-Jul	0.29	0.25	0.28	0.26
27-Jul	0.26	0.24	0.28	0.21
3-Aug	0.29	0.26	0.26	0.3
10-Aug	0.3	0.25	0.25	0.26
K, 7.5 - 15%				
8-Jun	10.0	8.6	9.1	8.3
15-Jun	8.8	9.1	9.2	8.9
22-Jun	9.3	9.1	8.9	9.5
29-Jun	10.0	10.8	10.7	10.6
9-Jul	9.4	9.3	9.5	9.9
16-Jul	8.3	8.2	8.5	8.5
23-Jul	6.6	6.6	7.6	8.6
27-Jul	7.8	7.5	7.8	7.9
3-Aug	8.3	7.5	7.5	7.7
10-Aug	6.7	7.5	7.0	6.9
S, 0.2 - 0.55%				
8-Jun	0.28	0.3	0.31	0.29
15-Jun	0.32	0.36	0.31	0.33
22-Jun	0.37	0.31	0.33	0.30
29-Jun	0.31	0.40	0.38	0.34
9-Jul	0.35	0.29	0.31	0.31
16-Jul	0.35	0.35	0.39	0.29
23-Jul	0.35	0.37	0.38	0.34
27-Jul	0.38	0.41	0.41	0.28
3-Aug	0.39	0.32	0.37	0.3
10-Aug	0.37	0.29	0.39	0.3
Ca, 0.45 - 2%				
8-Jun	1.22	0.82	1.21	0.95
15-Jun	1.11	0.87	1.18	0.89
22-Jun	1.35	1.11	1.36	0.99
29-Jun	1.46	1.28	1.56	1.08
9-Jul	1.83	1.35	1.58	1.26
16-Jul	2.14	1.46	1.98	1.41
23-Jul	1.72	1.62	1.77	1.46
27-Jul	2.06	2.05	2.08	1.55
3-Aug	2.31	2.22	1.89	1.74
10-Aug	1.9	2.06	1.8	1.6
Mg, 0.4 - 1.7%				
8-Jun	0.42	0.37	0.42	0.47
15-Jun	0.37	0.35	0.39	0.37
22-Jun	0.42	0.41	0.41	0.4
29-Jun	0.50	0.50	0.43	0.43
9-Jul	0.54	0.56	0.44	0.46
16-Jul	0.66	0.52	0.55	0.51
23-Jul	0.54	0.56	0.55	0.50
27-Jul	0.68	0.72	0.64	0.62
3-Aug	0.71	0.70	0.5	0.60
10-Aug	0.66	0.70	0.61	0.52

Table 3. (Continued.) Potato petiole analyses for two varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

	OSU		Netbeat	
Date	Payette Russet	Clearwater Russet	Payette Russet	Clearwater Russet
------------------------ Zn, 23 - 55 ppm ----------------------------				
8-Jun	52	58	75	61
15-Jun	40	54	69	71
22-Jun	32	50	58	68
29-Jun	41	41	53	62
9-Jul	42	52	65	74
16-Jul	50	42	52	66
23-Jul	35	37	40	51
27-Jul	42	27	34	41
3-Aug	40	31	32	41
10-Aug	47	37	39	32
------------------------------ Mn, 33 - 70 ppm -------------------------------				
8-Jun	101	96	90	80
15-Jun	79	82	82	77
22-Jun	88	77	65	72
29-Jun	71	65	67	60
9-Jul	69	72	62	71
16-Jul	68	85	68	84
23-Jul	68	81	50	77
27-Jul	84	83	50	86
3-Aug	93	62	58	94
10-Aug	84	57	41	92
------------------------------------ Cu, 5 - 30 ppm ---------------------------------------				
8-Jun	21	24	27	23
15-Jun	19	17	21	21
22-Jun	16	15	18	18
29-Jun	13	12	13	14
9-Jul	12	11	13	11
16-Jul	11	10	12	9
23-Jul	10	8	11	8
27-Jul	9	8	9	6
3-Aug	7	9	7	7
10-Aug	7	9	8	7
--------------------------- B, 21 - 55 ppm ----------------------------				
8-Jun	61	60	52	53
15-Jun	79	45	37	42
22-Jun	63	35	31	37
29-Jun	52	41	32	44
9-Jul	46	44	41	32
16-Jul	45	57	48	40
23-Jul	32	48	34	33
27-Jul	39	55	38	40
3-Aug	40	53	37	52
10-Aug	37	42	35	43

Table 4. Soil solution analyses for two potato varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on next page.

	OSU		Netbeat	
Date	Payette Russet	Clearwater Russet	Payette Russet	Clearwater Russet
P, 0.6 lbs				
8-Jun	1.10	2.20	1.60	2.30
15-Jun	1.60	1.30	2.10	1.50
22-Jun	2.40	1.10	2.30	2.20
29-Jun	2.50	1.50	2.80	1.90
9-Jul	1.60	1.50	2.50	1.60
16-Jul	1.90	1.70	2.00	1.30
23-Jul	1.90	1.80	2.00	1.80
27-Jul	2.00	2.20	1.20	1.90
3-Aug	1.60	1.90	1.60	1.70
10-Aug	1.30	1.50	1.20	2.00
K, 7 lbs				
8-Jun	6.5	9.8	10.2	11.2
15-Jun	5.5	11.2	9.2	8.5
22-Jun	5.0	10.3	7.0	7.8
29-Jun	4.3	7.9	6.1	7.4
9-Jul	4.9	6.6	5.3	6.4
16-Jul	4.6	5.8	5.1	5.1
23-Jul	5.0	6.1	5.6	6.0
27-Jul	5.6	7.2	6.5	6.3
3-Aug	4.6	5.6	5.8	5.1
10-Aug	5.4	4.8	4.7	5.1
S, 2 lbs				
8-Jun	5.1	4.2	3.0	3.3
15-Jun	4.9	3.9	4.0	2.9
22-Jun	5.3	4.3	4.6	3.1
29-Jun	4.8	2.5	2.5	2.8
9-Jul	4.1	3.7	3.4	3.8
16-Jul	3.7	3.6	3.5	2.0
23-Jul	4.0	2.0	4.1	1.2
27-Jul	6.0	2.9	5.9	1.8
3-Aug	3.9	3.3	3.2	2.2
10-Aug	3.5	3.2	1.6	2.6
Ca, 3 lbs				
8-Jun	6.2	6.2	6.4	5.9
15-Jun	6.4	5.0	6.2	4.8
22-Jun	4.9	5.3	5.0	5.5
29-Jun	4.8	5.1	5.4	5.4
9-Jul	3.8	4.3	5.8	4.3
16-Jul	4.4	5.0	6.1	5.3
23-Jul	4.6	3.8	4.7	4.6
27-Jul	4.6	4.6	4.7	4.6
3-Aug	5.2	5.3	4.8	4.8
10-Aug	4.9	5.1	4.0	4.5
Mg, 1 lb				
8-Jun	0.5	0.4	0.5	0.4
15-Jun	0.4	0.5	0.5	0.3
22-Jun	0.7	0.5	0.8	0.5
29-Jun	0.8	0.6	0.8	0.6
9-Jul	0.8	0.7	1.0	0.8
16-Jul	1.0	0.8	1.2	0.9
23-Jul	1.3	1.1	1.3	1.0
27-Jul	1.1	1.3	1.2	1.1
3-Aug	0.9	1.0	1.1	0.9
10-Aug	0.9	0.9	0.8	0.8

Table 4. (Continued.) Soil solution analyses for two potato varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

	OSU		Netbeat	
Date	Payette Russet	Clearwater Russet	Payette Russet	Clearwater Russet
Zn, 56 g				
8-Jun	183	168	156	141
15-Jun	135	126	180	123
22-Jun	168	96	168	129
29-Jun	147	78	141	129
9-Jul	108	96	105	105
16-Jul	87	117	75	90
23-Jul	72	123	90	75
27-Jul	90	96	105	96
3-Aug	66	78	81	78
10-Aug	66	57	69	60
Mn, 40 g				
8-Jun	15	66	69	42
15-Jun	18	78	60	30
22-Jun	18	57	42	24
29-Jun	21	75	54	33
9-Jul	27	93	48	42
16-Jul	33	81	60	54
23-Jul	36	105	63	66
27-Jul	33	84	54	48
3-Aug	39	69	42	39
10-Aug	33	60	45	33
Cu, 28 g				
8-Jun	129	162	144	78
15-Jun	117	135	117	90
22-Jun	108	132	102	96
29-Jun	96	99	96	90
9-Jul	81	84	69	81
16-Jul	75	75	60	69
23-Jul	78	84	69	78
27-Jul	60	72	57	63
3-Aug	54	54	51	57
10-Aug	48	45	39	66
B, 28 g				
8-Jun	21	14	17	23
15-Jun	15	15	15	20
22-Jun	20	17	12	24
29-Jun	24	20	18	32
9-Jul	29	23	23	33
16-Jul	36	21	18	30
23-Jul	32	27	23	32
27-Jul	38	30	27	36
3-Aug	27	26	23	26
10-Aug	23	20	18	23

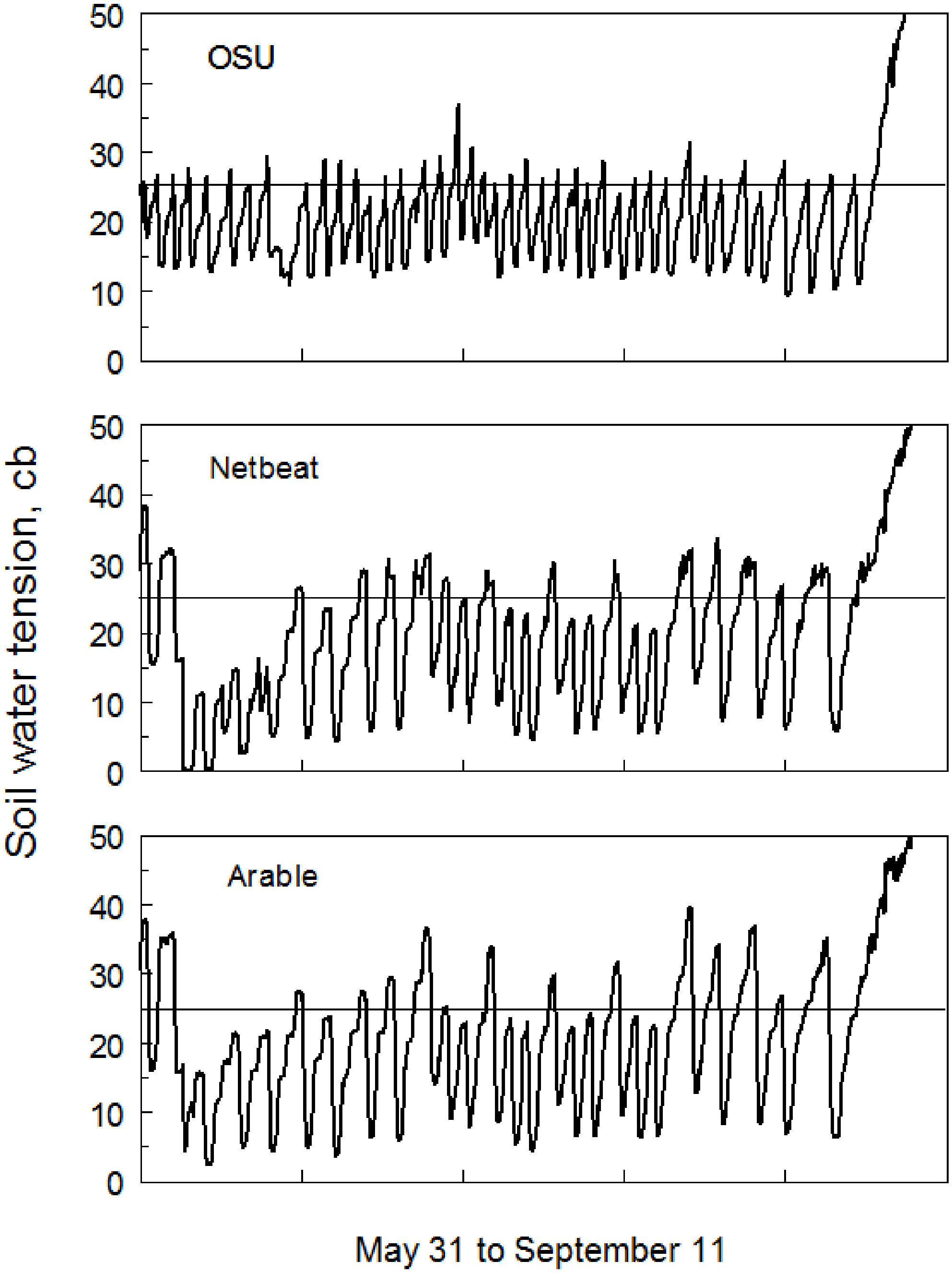

Figure 4. Soil water tension at 8-inch depth for three irrigation scheduling treatments. Malheur Experiment Station, Oregon State University, Ontario, OR.

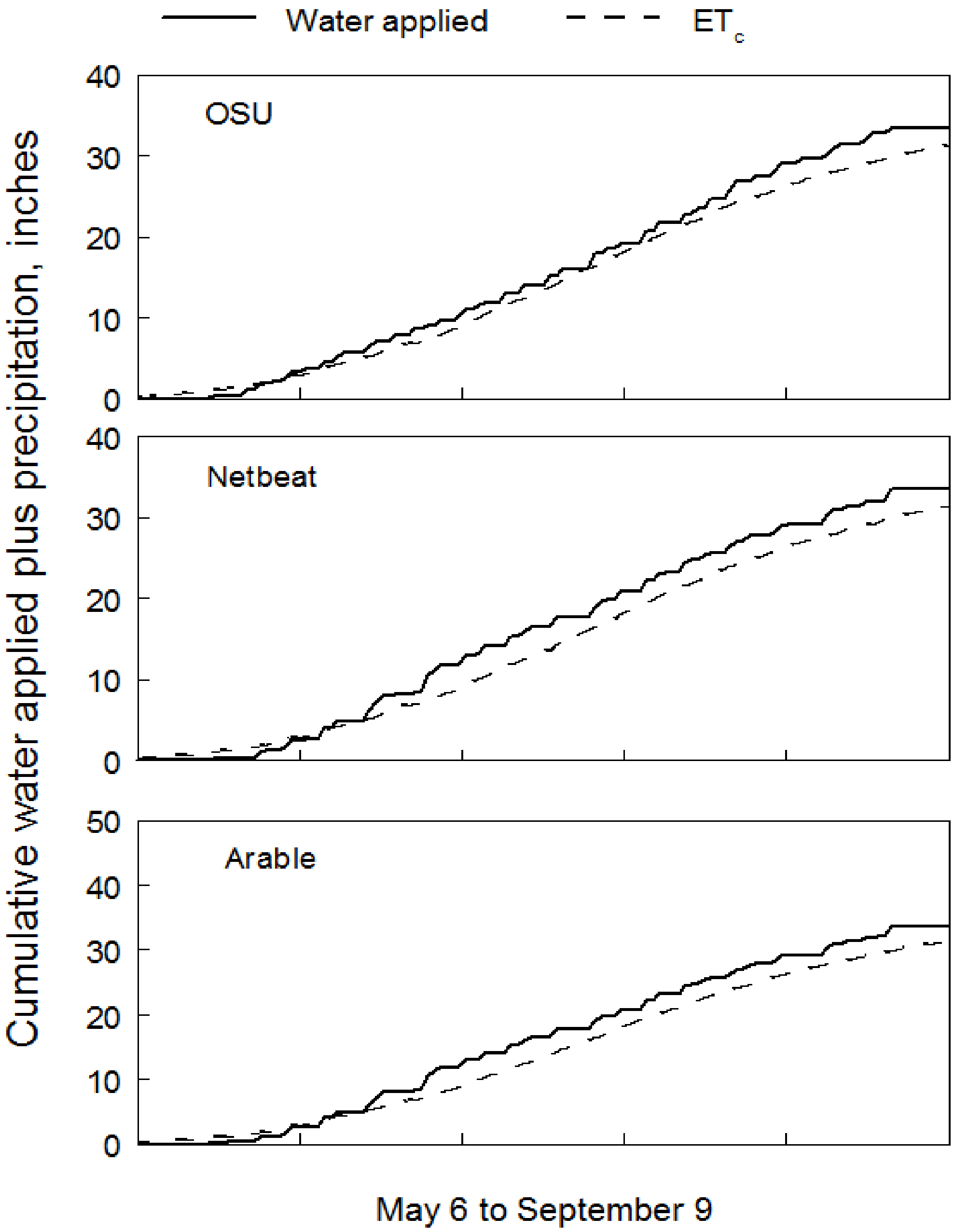

Figure 5. Cumulative water applied plus precipitation for three irrigation scheduling treatments. Malheur Experiment Station, Oregon State University, Ontario, OR.

Table 5. Number of irrigations, total water applied, and average soil water tension for three irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

Irrigation scheduling	No. of irrigations	Water applied/irrigation	Total water applied plus precipitation		Average soil water tension
		inches	inches	% of ET_c	cb
OSU	41	0.8	33.4	106.4	19.5
Netbeat	29	1.1	33.5	106.7	17.4
Arable	26	1.3	33.5	106.7	19.0

Table 6. Yield, grade, and processing quality of two potato varieties grown with three irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

					U.S. No. 1												
Irrigation scheduling	Variety	Total yield	Marketable	U.S. No. 1	Total	>20 oz	10-20 oz	6-10 oz	4-6 oz	U.S. No. 2	< 4 oz	Cull	Water use efficiency*	Fry color	Sugar ends	Internal brown spot	Specific gravity
		---- cwt/acre ----		%	-------------------- cwt/acre ------------------------									--------- % ---------			
OSU	Payette Russet	748.3	737.1	98.5	737.1	1.7	131.6	247.5	201.9	4.3	154.4	6.9	22.4	42.2	0	10.0	1.100
	Clearwater Russet	861.6	839.6	97.3	839.6	63.6	401.7	224.8	97.5	19.1	52.0	3.0	25.8	39.9	0	18.3	1.093
	Average	805.0	788.4	97.9	788.4	32.7	266.7	236.1	149.7	11.7	103.2	4.9	24.1	41.0	0	14.2	1.097
Netbeat	Payette Russet	743.9	732.7	98.5	732.7	1.8	162.2	287.9	152.3	6.5	128.6	4.7	22.2	41.3	0	18.3	1.099
	Clearwater Russet	904.4	878.4	97.1	878.4	65.8	404.6	263.0	93.0	21.0	52.0	5.1	27.0	40.6	0	10.0	1.091
	Average	824.2	805.5	97.8	805.5	33.8	283.4	275.4	122.6	13.7	90.3	4.9	24.6	40.9	0	14.2	1.095
Arable	Payette Russet	766.8	758.0	98.8	758.0	3.9	155.0	276.8	186.8	4.5	135.5	4.2	22.9	43.5	0	8.3	1.100
	Clearwater Russet	879.1	846.2	96.2	846.2	63.4	371.8	260.5	94.6	30.4	55.8	2.5	26.2	41.6	0	3.3	1.103
	Average	822.9	802.1	97.5	802.1	33.7	263.4	268.6	140.7	17.5	95.7	3.4	24.6	42.6	0	5.8	1.102
Average	Payette Russet	753.0	603.1	98.6	742.6	2.5	149.6	270.7	180.3	5.1	139.5	5.3	22.5	42.3	0	12.2	1.100
	Clearwater Russet	881.7	801.4	96.9	854.7	64.3	392.7	249.4	95.0	23.5	53.3	3.5	26.3	40.7	0	10.6	1.096
LSD (0.05)	Treatment	NS	NS	NS	NS	NS	NS	NS	18.8	NS	NS	NS	NS	NS	NS	NS	NS
	Variety	22.7	34.4	NS	25.9	18.3	27.0	NS	15.9	9.8	15.4	NS	0.7	NS	NS	NS	NS
	Trt X Var	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 7. Tuber nutrient concentration (dry weight basis) of two potato varieties grown with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

Irrigation scheduling	Variety	N	P	K	S	Ca	Mg	Zn	Mn	Cu	Fe	B
		%						ppm				
OSU	Payette Russet	1.21	0.22	1.75	0.12	0.09	0.09	10.33	38.17	3.67	264.50	23.67
	Clearwater Russet	1.21	0.22	1.86	0.12	0.07	0.11	9.83	39.17	2.83	285.83	25.50
	Average	1.21	0.22	1.81	0.12	0.08	0.10	10.08	38.67	3.25	275.17	24.58
Netbeat	Payette Russet	1.32	0.22	1.82	0.12	0.08	0.10	11.50	33.33	2.67	287.00	26.00
	Clearwater Russet	1.31	0.25	2.11	0.13	0.08	0.12	12.17	36.33	2.50	285.67	25.83
	Average	1.31	0.24	1.96	0.13	0.08	0.11	11.83	34.83	2.58	286.33	25.92
Average	Payette Russet	1.26	0.22	1.79	0.12	0.08	0.10	10.92	35.75	3.17	275.75	24.83
	Clearwater Russet	1.26	0.24	1.98	0.12	0.07	0.12	11.00	37.75	2.67	285.75	25.67
LSD (0.05)	Treatment	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Variety	NS	NS	0.16	NS	NS	0.02	NS	NS	NS	NS	NS
	Trt X Var	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 8. Tuber nutrient uptake in the harvested tubers of two potato varieties grown with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

Irrigation scheduling	Variety	N	P	K	S	Ca	Mg	Zn	Mn	Cu	Fe	B
		lb/acre										
OSU	Payette Russet	229.2	41.7	330.1	22.2	16.9	17.6	0.2	0.7	0.1	4.9	0.5
	Clearwater Russet	262.2	47.8	401.6	25.6	14.2	23.9	0.2	0.8	0.1	6.1	0.6
	Average	245.7	44.8	365.9	23.9	15.6	20.8	0.2	0.8	0.1	5.5	0.5
Netbeat	Payette Russet	242.4	41.1	335.5	22.3	14.1	18.0	0.2	0.6	0.1	5.3	0.5
	Clearwater Russet	287.9	55.9	465.0	28.4	16.9	26.9	0.3	0.8	0.1	6.4	0.6
	Average	265.1	48.5	400.2	25.3	15.5	22.4	0.2	0.7	0.1	5.9	0.5
Average	Payette Russet	235.8	41.4	332.8	22.2	15.5	17.8	0.2	0.7	0.1	5.1	0.5
	Clearwater Russet	275.1	51.8	433.3	27.0	15.5	25.4	0.2	0.8	0.1	6.3	0.6
LSD (0.05)	Treatment	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Variety	12.4	4.7	28.9	3.1	NS	3.0	NS	NS	NS	NS	0.1
	Trt X Var	NS	NS	40.9	NS	NS	NS	NS	NS	NS	NS	NS

EVALUATION OF TWO AUTOMATED IRRIGATION SCHEDULING METHODS FOR SPRINKLER IRRIGATED POTATO

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Introduction

Irrigation scheduling for potato can use soil water tension, soil water content, or crop evapotranspiration estimates. Measurement of evapotranspiration and the use of an allowable soil water depletion value can be used to automatically schedule irrigations. Netafim (Fresno, CA) has developed an irrigation scheduling method for potato using evapotranspiration estimates. The Malheur Experiment Station has developed soil water tension criteria for automatically or manually initiating potato irrigations. A range of soil water tensions were evaluated for their effect on potato yield, grade and processing quality under furrow, sprinkler, and drip irrigation on silt loam soil. For furrow or sprinkler irrigated potato the ideal irrigation criterion is 50 to 60 cb (Eldredge et al., 1992; Shock et al., 1993, 2003). Soil water tension has been measured using granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Riverside, CA). Granular matrix sensors were calibrated to soil water tension (Shock, 2003). Granular matrix sensors are inexpensive, require little maintenance, and can be used to schedule irrigations automatically using controllers and electric valves. This trial tested two automatic sprinkler irrigation scheduling methods with two new processing potato varieties (Payette Russet and Clearwater Russet).

Methods

The trial was conducted on an Owyhee silt loam previously planted to wheat at the Malheur Experiment Station, Ontario, Oregon. A soil analysis taken in the fall of 2017 showed that the top foot of soil had a pH of 7.8, 2.6% organic matter, 8 ppm nitrate-N, 3 ppm ammonium-N, 37 ppm phosphorus (P), 469 ppm potassium (K), 16 ppm sulfur (S), 3243 ppm calcium, 563 ppm magnesium (Mg), 278 ppm sodium, 7 ppm zinc (Zn), 4 ppm manganese (Mn), 2.4 ppm copper (Cu), 11 ppm iron, and 0.3 ppm boron (B). In the fall of 2017, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. Based on the soil analysis, 25 lb of N/acre as urea 44 lb of P/acre as monoammonium phosphate, 104 lb of K/acre as potassium chloride, 200 lb of S/acre as elemental sulfur, 7 lb of Mn/acre as manganese sulfate, 1 lb of Cu/acre as copper sulfate, 1 lb per acre Zn as zinc sulfate, and 4 lb of B/acre as Granubor II were broadcast before plowing. Following plowing, the field was fumigated with 20 gal/acre of Telone® II and bedded on 36-inch row spacing.

On March 29, 2018, 100 lb N as urea and Admire (Imidacloprid) at 7 oz/acre (0.25 lb ai/acre) was shanked into both sides of the beds at 6-inch depth. On April 3, seed of Payette Russet and Clearwater Russet was cut by hand into 2.5-oz seed pieces, treated with Maxim® MZ dust, and stored to suberize. Payette Russet seed pieces were treated with giberellic acid to accelerate inherent slow sprouting. Payette Russet seed pieces were dipped for five minutes in a solution of 2 mg of giberellic acid/liter prior to application of Maxim MZ dust.

The experimental design was a randomized complete block design with two treatments, two variety split plots, and six replicates. The treatments were two automated irrigation scheduling methods: 1) irrigation scheduling based on soil water tension (OSU), 2) irrigation scheduling based on potato evapotranspiration (Netbeat). Main plots were six potato rows wide by 120 ft long. Each main plot was divided into two variety split plots (Payette Russet and Clearwater Russet).

Potato seed pieces were planted on April 4-5 using a using a 2-row assist-feed planter with 9-inch seed spacing in 36-inch rows. Red potatoes were planted between variety split plots as markers to separate the split plots at harvest

After all bed preparation operations were finished, a sprinkler irrigation system was installed and herbicide was broadcast on the whole field using a ground sprayer. Herbicide was a mixture of 1.33 pt/acre (1.3 lb ai) of Dual II Magnum® (metolachlor), 2 pt/acre (0.83 lb ai) of Prowl® (pendimethalin), and 32 oz/acre of Roundup® (glyphosate). The herbicides were incorporated by applying 0.75 inch of water to the whole field with the sprinkler irrigation system.

After the herbicide was incorporated, the sprinkler system was rearranged according to the experimental design. Each plot had two sprinkler lines spaced 20 ft apart installed on a blank bed on each side of the plot. Sprinkler risers (Netafim Meganet yellow nozzles) were installed 20 ft apart on the sprinkler line. Wooden guards were installed behind each sprinkler to separate irrigations between adjacent plots.

Soil water tension in all main plots of all treatments was measured using four granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200SS, Irrometer Co., Riverside, CA) in Clearwater Russet split plots. The sensors were installed at 8-inch depth below each of the middle two potato rows in each Clearwater Russet split plot. The datalogger (CR1000, Campbell Scientific, Logan, UT) read and recorded the SWT every hour.

The plots of each treatment were divided into two irrigation zones due to water flow limitations. The OSU treatment was irrigated automatically using the datalogger based on soil water tension (SWT) feedback. The datalogger automatically irrigated all plots in each OSU treatment zone when the average SWT of all OSU treatment plots in each zone reached or exceeded 50 cb. Irrigation durations were 5 hours, 49 minutes to apply 1.1 inches of water. The datalogger made irrigation decisions for each zone every 24 hours with zone 1 having decisions at 12 AM and zone 2 at 12 PM. The datalogger controlled the irrigations for each OSU zone using a controller (SDM CD16AC controller, Campbell Scientific) and solenoid valves (Dorot, Tulsa, OK). Automatic irrigations were started on June 6 and terminated on September 2.

The Netbeat treatment in each trial was irrigated automatically based on potato evapotranspiration using a controller (NMC-Junior Pro Irrigation, Netafim) and solenoid valves (Dorot). The controller made irrigation decisions for each zone every 24 hours with zone 1 having decisions at 6 AM and zone 2 at 6 PM.

The water for the sprinkler system was supplied by a well that maintained a continuous and constant water pressure of 30 psi. Water applied to each treatment was measured by totalizing flow meters (model M, Netafim) read five times per week. The total water applied to each treatment was measured from emergence to the last irrigation on September 2. Approximately 3 inches of water were applied uniformly to each treatment from emergence to the start of automated irrigations on June 6. Potato evapotranspiration (ET_c) was calculated with a modified Penman equation (Wright, 1982) using data collected at the Malheur Experiment Station by an AgriMet weather station. Potato ET_c was estimated and recorded from crop emergence on May 6 until September 9.

Catch can tests were run to determine the water application rate that the sprinkler system actually applied to the harvest rows. The proportion of the water applied to the middle two potato rows relative to the whole plot area was used to adjust the calculations of water applied based on the water meter readings.

Plant nutrition was monitored by weekly petiole and soil solution analyses starting June 8 and ending August 10 (Tables 2, 3, and 4). Petiole samples were collected from the middle two beds in each split plot. To avoid damage to the harvest rows, soil samples were collected from the border rows in each split plot. Composite petiole and soil samples were made that combined the samples from all the replicates of each variety in each treatment. The petiole and soil samples were analyzed by Western Laboratories, Inc., Parma Idaho. Plant nutrients were applied through the sprinkler system to the respective treatments only if both the root tissue and soil solution analyses concurrently indicated a deficiency (Table 5).

The potatoes were sprayed aerially on June 12 and 27 with the fungicide Bravo® (chlorothalonil) at 1 pt/acre (0.75 lb ai/acre). The field was sprayed aerially on July 28 and August 20 with the insecticides Agri-Mek® (abamectin) at 3.5 oz/acre (0.02 lb ai/acre) and Movento® (Spirotetramat) at 5 oz/acre (0.08 lb ai/acre).

On August 21, plants in each split plot were evaluated subjectively for maturity.

The potato vines were flailed on October 1. Fifty feet of the middle two rows of each variety split plot in each main plot were harvested on October 8. All tubers from each split plot were placed into burlap sacks and placed in a barn where they were kept under tarps. All sacks from each split plot were weighed. Four sacks from a representative area in each split plot were selected for grading. Tubers were graded by market class (U.S. No. 1 and U.S. No. 2) and weight (<4 oz, 4-6 oz, 6-10 oz, 10-20 oz, and >20 oz). Tubers were graded as U.S. No. 2 if any of the following conditions occurred: growth cracks, bottleneck shape, abnormally curved shape, or two or more knobs. Marketable tubers are U.S. No. 1 and U.S. No. 2 larger than 4 oz. A 20-tuber sample from each split plot was placed into storage. The storage temperature was gradually reduced to 45°F.

After 6 weeks in storage, a 10-tuber sample from each split plot was evaluated for specific gravity, fry color, and internal defects. Ten tubers per plot were cut lengthwise and the center slices from each tuber were fried for 2.5 min in 375°F soybean oil. Percent light reflectance was measured on the stem and bud ends of each slice. Percent light reflectance was measured using a Photovolt Reflectance Meter model 577-A (Photovolt Instruments, Minneapolis, MN), with a green tristimulus filter, calibrated to read 0% light reflectance on the black standard cup and 71.7% light reflectance on the white porcelain standard plate. Specific gravity of all varieties was measured from a 10-tuber sample from each plot using the weight-in-air, weight-in-water method.

On January 24, 2019, ten tubers from each split plot of the OSU and Netbeat treatments were analyzed for nutrient content and moisture. Tuber nutrient content and moisture were used to calculate tuber nutrient uptake in the harvested yield.

Data were analyzed with the General Linear Models analysis of variance procedure using NCSS (Number Cruncher Statistical Systems, Kaysville, UT) using Fisher's protected LSD (least significant difference) for means separation at the 95% confidence level.

Results and Discussion

The petiole NO_3 concentration for Payette Russet and Clearwater Russet remained above the critical level during the season for both irrigation scheduling systems (Figs. 1 and 2). The soil solution nitrogen concentration remained above the critical level all season for both varieties with both irrigation scheduling systems (Fig. 3). A total of 25 lb N/acre was applied through the drip tape during the season to both irrigation scheduling systems (Table 1). Despite the limited amount of N applied during the season, the soil contained substantial amounts of total available N (Table 2). Previous research has shown that with carefully scheduled irrigations, N fertilizer requirements for potato are low (Feibert et al., 1998). Soil solution and petiole analyses for the other nutrients are found in tables 3 and 4 and the amounts of nutrients applied based on the analyses are in table 2. The amounts of nutrients applied were the same for both irrigation scheduling systems, except that the Netbeat irrigation scheduling received an additional 5 lb Mg/acre.

Treatment differences

The OSU irrigation scheduling system maintained the soil water tension below 50 to 60 cb, close to the target of 50 cb (Fig. 4). The Netbeat irrigation scheduling maintained the soil water tension below 20 to 30 cb during the season. The average soil water tension was 35 cb and 24 cb for the OSU and Netbeat irrigation scheduling, respectively (Table 5).

Both zones of the OSU irrigation scheduling system applied 12 irrigations and on average each irrigation applied 1.6 inches of water. The OSU system should have been calculated and managed to apply only 1.2 inches of water per irrigation. The Netbeat irrigation scheduling applied 18 irrigations in zone 1 and 16 irrigations in zone 2 and on average each irrigation applied 2 inches of water.

Potato ET_c totaled 31.5 inches and precipitation totaled 1.05 inches from crop emergence on May 6 until the last irrigation. The total amount of water applied plus precipitation for the two zones with OSU irrigation scheduling was 25.7 inches and 26.8 inches (Table 5). The total amount of water applied plus precipitation for the two zones with Netbeat irrigation scheduling was 38.7 inches and 34.1 inches. The total amount of water applied plus precipitation for the OSU irrigation scheduling system was 84% of ET_c and for the Netbeat irrigation scheduling system was 116% of ET_c (Table 5).

The Netbeat irrigation scheduling system had higher total yield, marketable yield, total U.S. No.1 yield, and yield of tubers 10 to 20 oz than the OSU irrigation scheduling system (Table 6). There was no statistically significant difference in the percentage of U.S. No. 1 tubers between irrigation scheduling systems. The OSU irrigation scheduling system had higher water use efficiency than the Netbeat irrigation scheduling system. There was no statistically significant difference in tuber fry color and specific gravity between irrigation scheduling systems. The only internal tuber defect encountered was internal brown spot, with no statistically significant difference between treatments.

The Netbeat irrigation scheduling had tubers with higher phosphorus and iron concentrations than the OSU irrigation scheduling (Table 7). Based on total yield, the Netbeat irrigation scheduling had higher phosphorus, calcium, and iron uptake by the tubers than the OSU irrigation scheduling (Table 8).

Variety differences

Averaged over treatments, Clearwater Russet had higher marketable yield, yield of tubers > 20 oz, and yield of tubers 10 to 20 oz than Payette Russet. Averaged over treatments, Payette Russet had higher specific gravity than Clearwater Russet. There was no statistically significant difference in the percentage of tubers with internal brown spot between varieties.

Averaged over treatments, the harvested tubers of Clearwater Russet removed 234 lb/acre of nitrogen and 327 lb/acre of potassium, considerably more than the amounts of fertilizer applied. Clearwater Russet had higher tuber concentrations of magnesium than Payette Russet (Table 7). Based on total yield, Clearwater Russet had higher tuber uptake of magnesium than Payette Russet (Table 8).

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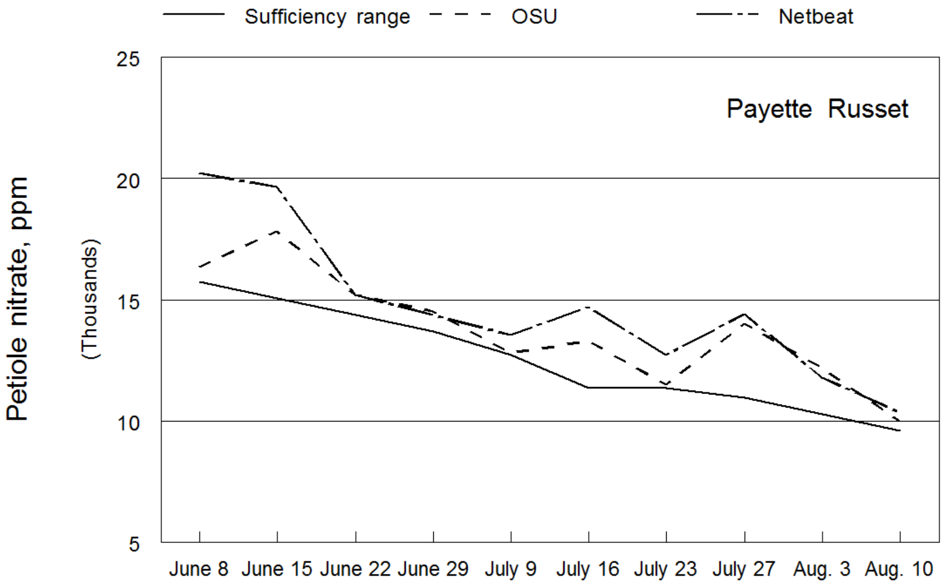

Figure 1. Payette Russet petiole nitrate over time with two irrigation scheduling treatments. Malheur Experiment Station, Oregon State University, Ontario, OR.

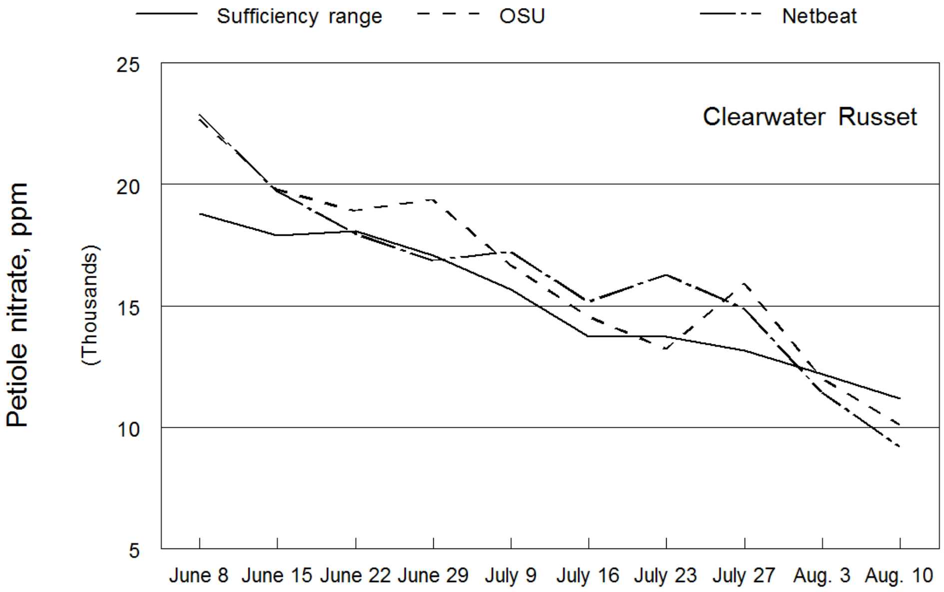

Figure 2. Clearwater Russet petiole nitrate over time with two irrigation scheduling treatments. Malheur Experiment Station, Oregon State University, Ontario, OR.

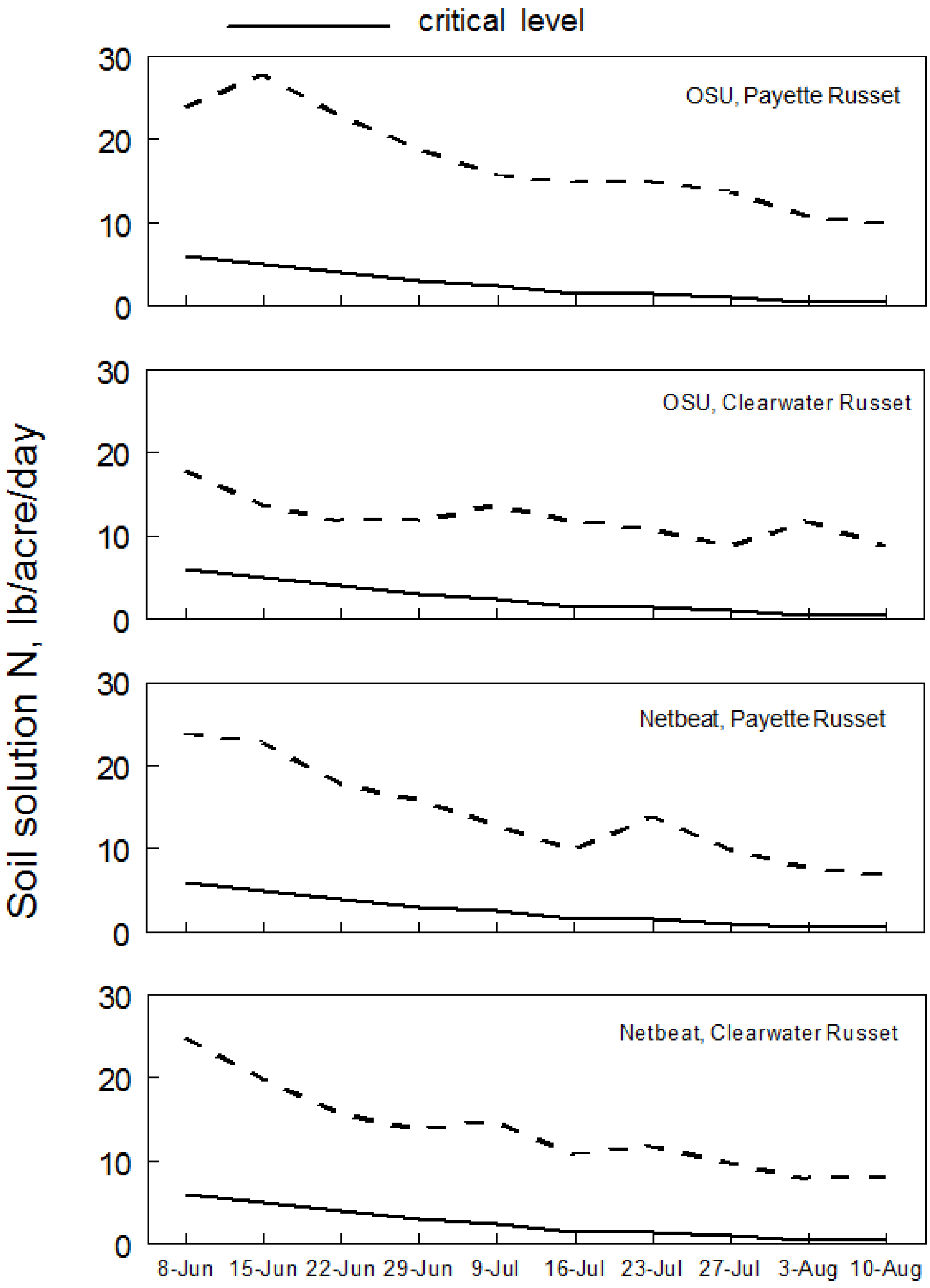

Figure 3. Soil solution nitrogen over time with two irrigation scheduling treatments and two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR.

Table 1. Nutrients applied to two potato varieties and two irrigation scheduling systems. The Netbeat irrigation scheduling had an additional 5 lb Mg/acre applied (total of 21 lbMg/acre). Malheur Experiment Station, Oregon State University, Ontario, OR.

Date	N	K	Mg	Mn	S
13-Jun			5	0.25	
20-Jun		5	5		
29-Jun	10	10	3		
5-Jul	15	10	3		5
20-Jul		18			
25-Jul		15			
30-Jul		10			
7-Aug		10			
14-Aug		20			
Total	25	98	16	0.25	5

Nitrogen was applied as Uran (32% N), potassium as potassium chloride, manganese was applied as manganese carbonate (5%), magnesium was applied as magnesium carbonate (3%), and sulfur as elemental sulfur (52%).

Table 2. Total available soil N for two potato varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

	OSU		Netbeat	
Date	Payette Russet	Clearwater Russet	Payette Russet	Clearwater Russet
	----------------------------------- lb/acre		-----------------------------------	
8-Jun	168	123	171	174
15-Jun	198	99	162	138
22-Jun	159	81	126	111
29-Jun	135	81	114	96
9-Jul	114	99	93	102
16-Jul	108	84	72	75
23-Jul	108	78	96	84
27-Jul	96	66	72	72
3-Aug	75	84	54	57
10-Aug	69	66	48	54

Table 3. Potato petiole analyses for two varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on next page.

	OSU		Netbeat	
Date	Payette Russet	Clearwater Russet	Payette Russet	Clearwater Russet
-------------------- P, 0.2 - 0.55 % ---------------------				
8-Jun	0.69	0.66	0.64	0.60
15-Jun	0.62	0.56	0.68	0.39
22-Jun	0.64	0.49	0.37	0.26
29-Jun	0.53	0.25	0.32	0.24
9-Jul	0.40	0.23	0.36	0.20
16-Jul	0.40	0.31	0.36	0.24
23-Jul	0.33	0.28	0.31	0.30
27-Jul	0.35	0.24	0.33	0.32
3-Aug	0.27	0.29	0.35	0.30
10-Aug	0.28	0.25	0.30	0.26
---------------------------------- K, 7.5 - 15% ----------------------------------				
8-Jun	9.90	9.30	10.30	8.80
15-Jun	8.10	8.40	8.30	9.60
22-Jun	8.70	8.30	9.60	10.20
29-Jun	10.40	5.40	5.80	5.60
9-Jul	8.50	6.60	7.70	6.60
16-Jul	8.30	8.10	8.40	7.80
23-Jul	7.40	6.50	7.00	7.00
27-Jul	7.30	7.10	7.60	7.20
3-Aug	7.20	8.00	8.90	8.30
10-Aug	6.50	7.20	7.60	7.80
------------------------------- S, 0.2 - 0.5% ----------------------------------				
8-Jun	0.35	0.30	0.28	0.29
15-Jun	0.26	0.33	0.38	0.20
22-Jun	0.39	0.36	0.20	0.20
29-Jun	0.36	0.20	0.21	0.20
9-Jul	0.39	0.30	0.28	0.27
16-Jul	0.48	0.44	0.33	0.31
23-Jul	0.38	0.34	0.36	0.31
27-Jul	0.42	0.36	0.39	0.38
3-Aug	0.38	0.32	0.37	0.35
10-Aug	0.34	0.28	0.31	0.32
-------------------------------Ca, 0.45 - 2% ------------------------------				
8-Jun	1.43	1.11	1.65	1.07
15-Jun	1.62	0.98	1.57	1.02
22-Jun	1.40	1.22	1.37	0.96
29-Jun	1.65	1.09	1.22	0.79
9-Jul	1.67	0.80	1.57	0.84
16-Jul	2.10	1.03	2.01	1.03
23-Jul	2.34	1.17	1.85	1.24
27-Jul	2.10	1.47	2.10	1.31
3-Aug	2.30	1.56	2.31	1.65
10-Aug	1.80	1.50	1.95	1.50
----------------------------- Mg, 0.4 - 1.7% -----------------------------				
8-Jun	0.50	0.53	0.65	0.53
15-Jun	0.50	0.53	0.48	0.61
22-Jun	0.58	0.61	0.49	0.57
29-Jun	0.55	0.58	0.46	0.48
9-Jul	0.55	0.51	0.50	0.34
16-Jul	0.60	0.55	0.51	0.42
23-Jul	0.51	0.51	0.55	0.49
27-Jul	0.59	0.65	0.66	0.53
3-Aug	0.75	0.70	0.65	0.65
10-Aug	0.75	0.75	0.64	0.52

Table 3. (Continued.) Potato petiole analyses for two varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

	OSU		Netbeat	
Date	Payette Russet	Clearwater Russet	Payette Russet	Clearwater Russet
Zn, 23 - 55ppm				
8-Jun	42	75	65	42
15-Jun	47	68	71	45
22-Jun	37	63	69	40
29-Jun	34	52	61	49
9-Jul	41	52	62	51
16-Jul	52	51	51	45
23-Jul	46	45	43	36
27-Jul	35	41	52	32
3-Aug	33	34	41	40
10-Aug	37	42	45	41
Mn, 33 - 70 ppm				
8-Jun	80	74	92	85
15-Jun	97	64	89	78
22-Jun	83	74	85	62
29-Jun	74	62	93	70
9-Jul	65	69	89	64
16-Jul	76	79	82	83
23-Jul	95	90	78	65
27-Jul	76	84	71	51
3-Aug	80	82	87	64
10-Aug	86	69	71	58
Cu, 5 - 30 ppm				
8-Jun	21	18	26	20
15-Jun	15	13	19	15
22-Jun	13	10	14	13
29-Jun	12	7	10	10
9-Jul	9	9	13	13
16-Jul	11	11	12	11
23-Jul	9	9	10	9
27-Jul	9	8	8	9
3-Aug	11	9	10	10
10-Aug	12	8	8	8
B, 21 - 55 ppm				
8-Jun	64	52	46	56
15-Jun	73	39	33	43
22-Jun	60	37	35	41
29-Jun	55	42	41	52
9-Jul	50	42	32	41
16-Jul	42	46	40	52
23-Jul	36	39	33	50
27-Jul	29	39	37	43
3-Aug	37	40	37	38
10-Aug	29	36	42	34

Table 4. Soil solution analyses for two potato varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on next page.

	OSU		Netbeat	
Date	Payette Russet	Clearwater Russet	Payette Russet	Clearwater Russet
---------------------------------- P, 0.6 lbs ----------------------------------				
8-Jun	0.8	1.2	1.3	2.0
15-Jun	1.1	1.2	1.7	1.2
22-Jun	1.4	1.2	1.6	1.7
29-Jun	1.9	1.0	1.4	1.2
9-Jul	1.0	1.4	1.2	1.5
16-Jul	1.2	1.3	1.3	1.5
23-Jul	1.2	1.4	1.3	1.5
27-Jul	1.8	1.8	1.6	2.1
3-Aug	1.8	2.0	2.1	1.5
10-Aug	1.2	1.6	1.5	1.8
--------------------------------- K, 7 lbs ----------------------------------				
8-Jun	12.2	9.9	8.5	7.4
15-Jun	9.6	8.8	6.9	8.5
22-Jun	8.7	7.5	7.5	7.3
29-Jun	7.8	7.3	8.0	6.8
9-Jul	6.3	6.7	7.4	5.9
16-Jul	5.0	5.5	7.2	5.6
23-Jul	6.2	5.9	8.4	6.2
27-Jul	7.3	6.6	7.8	7.7
3-Aug	5.9	5.7	6.3	6.2
10-Aug	7.1	6.7	6.7	7.1
------------------------------- S, 2 lbs ----------------------------------				
8-Jun	5.7	4.9	6.4	4.2
15-Jun	6.2	5.2	5.2	4.3
22-Jun	4.3	4.3	4.2	3.8
29-Jun	3.8	3.7	5.9	4.4
9-Jul	4.6	3.4	5.3	3.3
16-Jul	4.5	2.7	3.0	2.8
23-Jul	3.6	1.5	1.7	1.5
27-Jul	2.9	2.1	2.3	2.0
3-Aug	2.7	2.6	3.0	1.7
10-Aug	2.1	2.4	2.5	2.0
------------------------------ Ca, 3 lbs ----------------------------------				
8-Jun	4.0	5.0	6.1	6.5
15-Jun	5.2	5.8	6.5	4.8
22-Jun	5.1	5.5	5.0	5.1
29-Jun	4.3	4.5	5.1	5.5
9-Jul	4.7	3.6	4.2	4.8
16-Jul	5.4	4.3	4.0	5.7
23-Jul	4.6	4.6	3.0	4.6
27-Jul	5.1	5.2	3.3	5.8
3-Aug	5.1	4.7	3.8	4.7
10-Aug	4.8	4.4	4.5	4.6
------------------------------- Mg, 1 lb ---------------------------------				
8-Jun	0.5	0.4	0.3	0.3
15-Jun	0.5	0.3	0.2	0.3
22-Jun	0.6	0.4	0.5	0.4
29-Jun	0.7	0.4	0.6	0.5
9-Jul	0.9	0.5	0.7	0.6
16-Jul	1.0	0.6	0.8	0.7
23-Jul	1.3	0.8	0.9	0.8
27-Jul	1.0	1.0	1.0	1.0
3-Aug	0.8	0.8	0.7	0.7
10-Aug	0.9	0.8	0.8	0.8

Table 4. (Continued.) Soil solution analyses for two potato varieties with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

	OSU		Netbeat	
Date	Payette Russet	Clearwater Russet	Payette Russet	Clearwater Russet
Zn, 56 g				
8-Jun	141	183	180	153
15-Jun	126	210	186	162
22-Jun	135	189	159	132
29-Jun	105	171	153	120
9-Jul	117	141	123	102
16-Jul	87	123	120	84
23-Jul	78	111	114	78
27-Jul	87	87	99	87
3-Aug	72	63	81	75
10-Aug	75	75	69	63
Mn, 40 g				
8-Jun	30	36	42	84
15-Jun	39	42	54	69
22-Jun	30	30	45	54
29-Jun	39	24	39	48
9-Jul	45	33	48	60
16-Jul	48	30	54	51
23-Jul	51	39	69	48
27-Jul	57	30	57	42
3-Aug	42	24	48	36
10-Aug	48	27	42	27
Cu, 28 g				
8-Jun	162	114	120	96
15-Jun	129	105	114	120
22-Jun	99	87	96	99
29-Jun	102	75	90	96
9-Jul	81	57	63	84
16-Jul	72	48	54	72
23-Jul	72	60	66	51
27-Jul	54	51	60	45
3-Aug	45	57	57	51
10-Aug	45	48	45	42
B, 28 g				
8-Jun	20	17	17	20
15-Jun	15	15	20	23
22-Jun	18	14	24	23
29-Jun	23	15	26	27
9-Jul	20	20	30	33
16-Jul	21	18	27	30
23-Jul	20	20	21	23
27-Jul	24	23	24	26
3-Aug	21	18	30	24
10-Aug	23	20	26	20

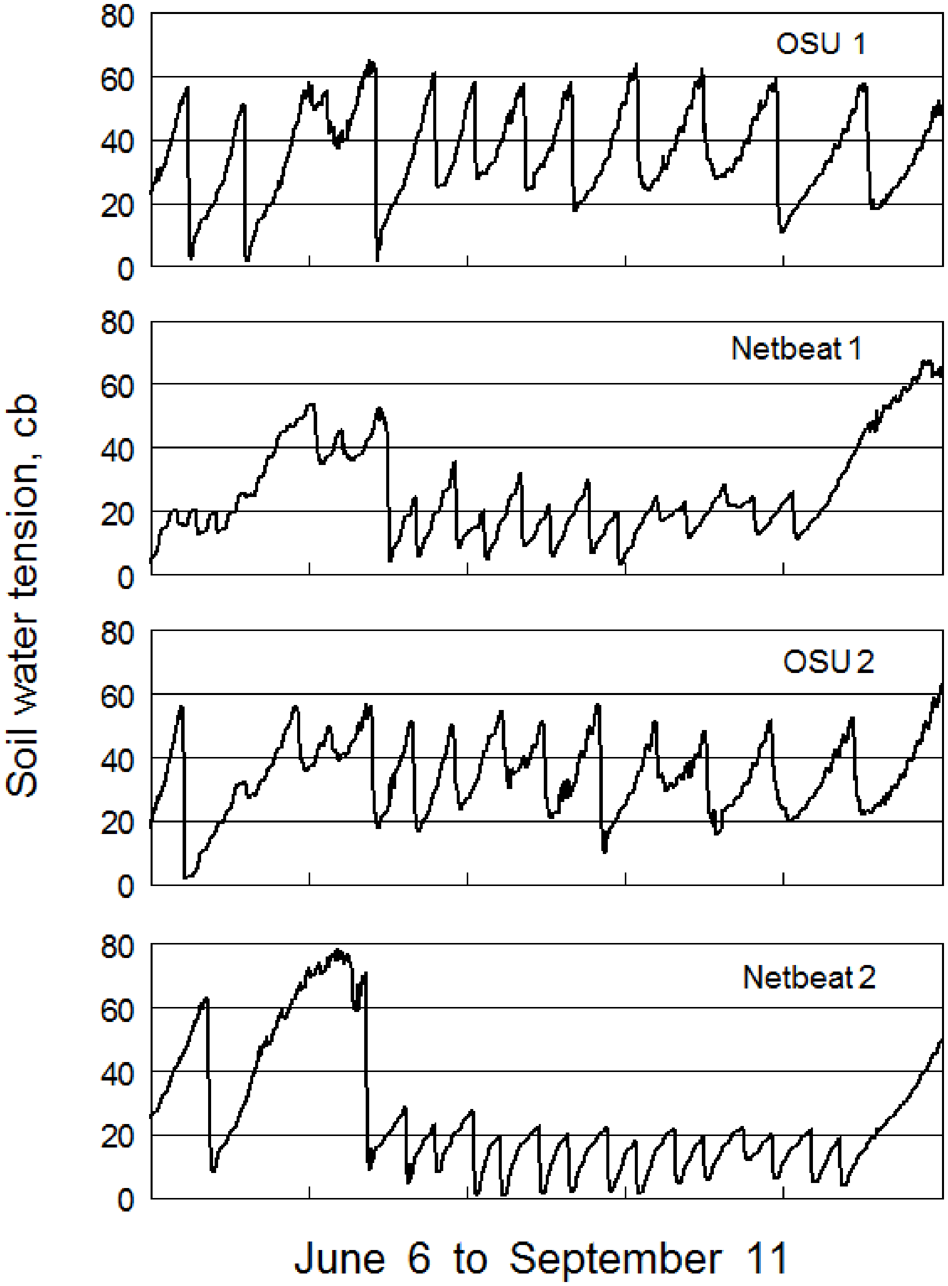

Figure 4. Soil water tension at 8-inch depth for two irrigation scheduling treatments. Malheur Experiment Station, Oregon State University, Ontario, OR.

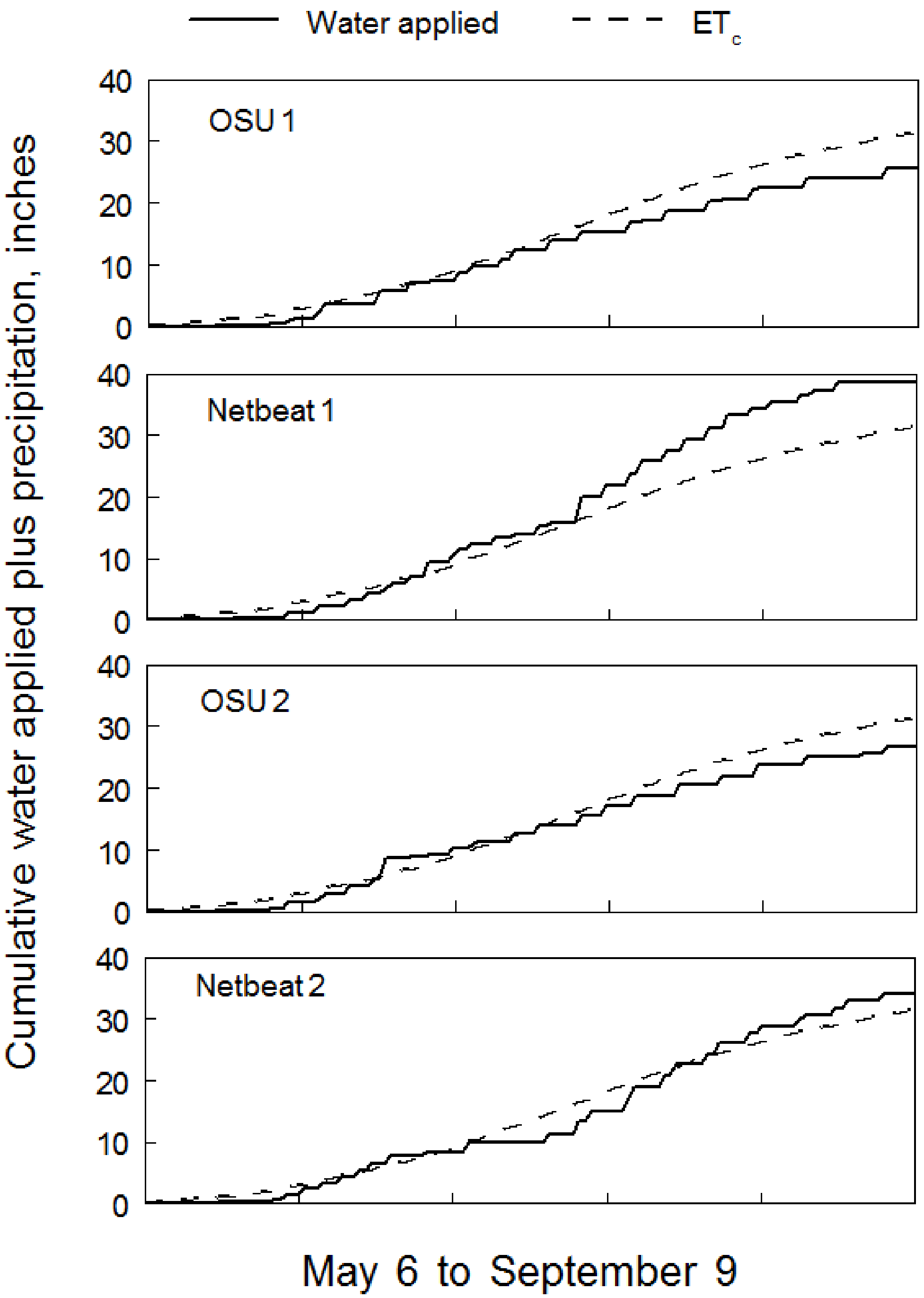

Figure 5. Cumulative water applied plus precipitation for two irrigation scheduling treatments. Malheur Experiment Station, Oregon State University, Ontario, OR.

Table 5. Number of irrigations, total water applied, and average soil tension for two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

Irrigation scheduling	No. of irrigations	Total water applied plus precipitation		Average soil water tension
		inches	% of ET_c	cb
OSU zone 1	12	25.8	82.2	36.0
OSU zone 2	12	26.9	85.7	34.0
OSU average	12	26.4	83.9	35.0
Netbeat zone 1	18	38.7	123.2	22.1
Netbeat zone 2	16	34.2	108.9	25.5
Netbeat average	17	36.5	116.1	23.8

Table 6. Yield, grade, and processing quality of two potato varieties grown with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

					U.S. No. 1												
Irrigation scheduling	Variety	Total yield	Marketable	U.S. No. 1	Total	>20 oz	10 - 20 oz	6 - 10 oz	4 - 6 oz	U.S. No. 2	< 4 oz	Cull	Water use efficiency*	Fry color	Sugar ends	Internal brown spot	Specific gravity
		---- cwt/acre ----		%	------------------------ cwt/acre ---------------------------									--------- % ---------			
OSU	Payette Russet	694.2	538.4	98.1	681.1	3.2	162.2	221.1	151.9	1.9	142.7	11.2	26.4	44.4	0.0	12	1.102
	Clearwater Russet	743.1	659.0	96.4	716.7	17.0	300.8	233.9	107.3	19.2	57.7	7.2	28.2	44.9	0.0	0	1.090
	Average	718.6	598.7	97.3	698.9	10.1	231.5	227.5	129.6	10.5	100.2	9.2	27.3	44.7	0.0	6	1.096
Netbeat	Payette Russet	772.7	629.6	97.9	756.4	6.0	234.4	251.8	137.4	9.8	126.8	6.4	21.3	43.9	0.0	5	1.100
	Clearwater Russet	802.4	694.9	93.6	749.7	29.2	345.2	233.3	87.2	35.9	54.8	16.8	22.2	42.4	3.3	5	1.088
	Average	787.5	662.2	95.8	753.1	17.6	289.8	242.6	112.3	22.9	90.8	11.6	21.7	43.1	1.7	5	1.094
Average	Payette Russet	733.4	584.0	98.0	718.8	4.6	198.3	236.5	144.6	5.9	134.8	8.8	23.8	44.1	0.0	8	1.101
	Clearwater Russet	772.7	676.9	95.0	733.2	23.1	323.0	233.6	97.2	27.5	56.3	12.0	25.2	43.6	1.7	3	1.089
LSD (0.05)	Treatment	67.4	54.2	NS	52.3	NS	39.5	NS	NS	NS	NS	NS	3.8	NS	NS	NS	NS
	Variety	NS	41.7	2.7	NS	18.8	51.1	NS	23.6	17.9	22.2	NS	NS	NS	NS	NS	0.006
	Trt X Var	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*cwt total yield/inch of water applied

Table 7. Tuber nutrient concentration (dry weight basis) of two potato varieties grown with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

Irrigation scheduling	Variety	N	P	K	S	Ca	Mg	Zn	Mn	Cu	Fe	B
		%						ppm				
OSU	Payette Russet	1.26	0.19	1.70	0.10	0.06	0.07	8.8	35.5	3.8	76.0	26.3
	Clearwater Russet	1.26	0.19	1.73	0.09	0.05	0.08	8.2	36.5	3.8	78.7	26.7
	Average	1.26	0.19	1.71	0.09	0.06	0.07	8.5	36.0	3.8	77.3	26.5
Netbeat	Payette Russet	1.19	0.22	1.76	0.10	0.06	0.07	15.3	32.5	3.7	152.0	24.0
	Clearwater Russet	1.20	0.21	1.70	0.10	0.06	0.09	10.5	34.7	3.2	157.5	23.2
	Average	1.20	0.22	1.73	0.10	0.06	0.08	12.9	33.6	3.4	154.8	23.6
Average	Payette Russet	1.23	0.21	1.73	0.10	0.06	0.07	12.1	34.0	3.8	114.0	25.2
	Clearwater Russet	1.23	0.20	1.72	0.09	0.06	0.08	9.3	35.6	3.5	118.1	24.9
LSD (0.05)	Treatment	NS	0.02	NS	NS	NS	NS	NS	NS	NS	39.6	NS
	Variety	NS	NS	NS	NS	NS	0.01	NS	NS	NS	NS	NS
	Trt X Var	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 8. Tuber nutrient uptake in the harvested tubers of two potato varieties grown with two irrigation scheduling systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

Irrigation scheduling	Variety	N	P	K	S	Ca	Mg	Zn	Mn	Cu	Fe	B
		lb/acre										
OSU	Payette Russet	233.7	35.5	314.9	17.9	10.4	12.3	0.2	0.7	0.1	1.4	0.5
	Clearwater Russet	234.7	35.5	323.1	16.7	10.0	15.0	0.1	0.7	0.1	1.5	0.5
	Average	234.2	35.5	319.0	17.3	10.2	13.6	0.2	0.7	0.1	1.4	0.5
Netbeat	Payette Russet	254.7	46.9	371.9	21.9	12.9	15.6	0.3	0.7	0.1	3.3	0.5
	Clearwater Russet	232.6	40.9	330.9	18.8	12.2	17.1	0.2	0.7	0.1	3.0	0.5
	Average	243.6	43.9	351.4	20.4	12.5	16.3	0.3	0.7	0.1	3.1	0.5
Average	Payette Russet	244.2	41.2	343.4	19.9	11.6	13.9	0.2	0.7	0.1	2.3	0.5
	Clearwater Russet	233.6	38.2	327.0	17.8	11.1	16.0	0.2	0.7	0.1	2.3	0.5
LSD (0.05)	Treatment	NS	7.9	NS	NS	2.3	NS	NS	NS	NS	0.8	NS
	Variety	NS	NS	NS	NS	NS	2.0	NS	NS	NS	NS	NS
	Trt X Var	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

SUGAR BEET RESPONSE AND YELLOW NUTSEDGE CONTROL WITH DUAL MAGNUM® APPLIED EARLY FALL OF PRECEDING YEAR AND PRE-PLANT OF CROPPING YEAR

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018

Introduction

Weed control is an important component of sugar beet production. One of the most problematic weeds in some Treasure Valley fields is yellow nutsedge, which presents a crop production challenge particularly if not effectively managed in all crops grown in a rotation. The populations can expand and contract in individual fields based on a variety of environmental and management factors. However, given its perennial nature, yellow nutsedge remains a problem once it produces mature tubers in a field.

The current Dual Magnum® label allows post-emergence application after sugar beet plants are at the first true leaf stage, but at that time yellow nutsedge may have already emerged. Dual Magnum, a pre-emergence herbicide, does not control weeds that have already emerged including yellow nutsedge. Therefore, the use of Dual Magnum or Outlook® (which has the same mode of action) as post-emergence herbicides tank-mixed with glyphosate has largely failed to reduce yellow nutsedge in sugar beet fields.

Growers are advised to employ crop rotation as a technique to manage yellow nutsedge. Onion growers secured an indemnified label for Dual Magnum application to control yellow nutsedge the summer-fall preceding onion. Growers in the Treasure Valley would like this approach evaluated for sugar beet response. This study addresses that grower request.

The objective of this study was to evaluate sugar beet response to Dual Magnum applied and incorporated in the soil during late summer to early fall of the year preceding sugar beet.

Materials and Methods

A field study was initiated during fall 2017 in a field near Ontario, Oregon previously planted to wheat. The predominant soil was a Greenleaf silt loam with a pH of 7.2 and 1.79% organic matter. Wheat stubble was flailed and the field was irrigated, disked, ripped, and rototilled in August 2017. The study had a randomized complete block design with four replications. Individual plots were 14 ft wide (8 rows) by 35 ft long. Plow-down herbicide treatments were applied on September 5, 2017 and the field was immediately disked twice to incorporate the herbicides in the soil. The area was moldboard plowed on September 8 and ground-hogged on

September 11, 2017. Post-plowing treatments were applied on September 13 and plots immediately disked twice. Fall fertilizer was broadcast on October 4, 2017 based on soil analysis. The field was fumigated with Telone® C-35 and beds formed at 22-inch spacing on October 18, 2017.

Sugar beet hybrid BTS 27RR20 was planted on April 3, 2018. Pre-emergence treatments were applied immediately after planting. All plots (except untreated control) were sprayed with glyphosate at 32 fl oz/acre plus Outlook at 21 fl oz/acre in the third week of May. Sugar beet were grown following local production practices.

Evaluation for plant injury and weed control was done visually based on a scale of 0% (no sugar beet injury or no yellow nutsedge control) to 100% (complete sugar beet plant kill or total yellow nutsedge control). Evaluations were done at 42 and 56 days after sugar beet planting. In-season fertilizer was applied according the soil test results. Preventative sprays for diseases and insects were applied aerially by a commercial contractor. Roots were harvested in the third week of September and analyzed for sucrose content.

Results

Sugar beet emergence was observed April 13, 2018. Visual evaluation on May 15, 2018 indicated 0% injury for plants growing in plots treated with Dual Magnum at 1 pt/acre and 10% injury for Dual Magnum 1.33 pt/acre. Injury from surface-applied (after moldboard plowing and disking) Dual Magnum at 0.5 to 1 pt/acre was 6 and 9%, respectively. Evaluations on May 29 indicated plant injury had subsided but was still apparent in the surface applied treatments. The injury symptoms were characterized by ‘lettuce like’ growth habit with poorly unfurled leaves. Injury symptoms were transient and plants looked normal at about the 12-leaf stage.

Early season yellow nutsedge control on May 15 ranged from 79 to 86% for plow-down treatments, 90 to 94% for surface-broadcast treatments, and 69 to 75% for treatments applied pre-emergence (after planting in the year the sugar beets were grown) (data not shown). Mid-season yellow nutsedge control ranged from 88 to 95% for treatments applied the previous fall compared to 70 to 75% for the grower standard and pre-emergence treatments.

There were no differences in root yield across herbicide treatments. Root yield ranged from 43.3 to 47 ton/acre for Dual Magnum treatments compared to 16.1 ton/acre for fumigation only treatment (Table 1). The estimated recoverable sugar was reduced in the treatments that received Dual Magnum plow-down at 1.33 pt/acre and 0.75 pt/acre applied pre-emergence.

The prevailing weather conditions may have contributed to the results. The winter weather in 2017 and spring 2018 was dry, possibly slowing down herbicide breakdown and thus resulting in sugar beet injury from fall-applied Dual Magnum.

Acknowledgements

This project was funded by the Sugar Beet Seed Alliance, Oregon State University, the Malheur County Education Service District, and supported by Formula Grant nos. 2018-31100-06041 and 2018-31200-06041 from the USDA National Institute of Food and Agriculture.

Table 1. Sugar beet response to Dual Magnum (s-metolachlor) applied the previous fall at the Malheur Experiment Station, Ontario, OR, 2018.

Treatment	**Rate**	**Timing** [z]	**Conductivity**	**Nitrate**	**Sucrose**	**Tare**	**Root yield** [y]	**ERS** [x]
	per acre		mmhos	ppm	%	%	ton/acre	lb/acre
Fumigation			0.97	381.75	15.71 bc	4.1 ab	16.1 b [w]	4,142 c [w]
Dual Magnum	1 pt	Fall/plow	0.87	475.88	16.02 abc	3.4 ab	44.9 a	11,957 ab
Dual Magnum	1.33 pt	Fall/plow	0.95	530.38	15.91 abc	4.5 a	43.4 a	11,344 b
Dual Magnum + EPTAM	1 pt 7 pt	Fall/plow	0.95	490.38	15.85 abc	2.8 ab	46.1 a	12,029 ab
Dual Magnum + EPTAM	1.33 pt 7 pt	Fall/plow	0.88	368.13	16.52 a	3.0 ab	47.0 a	12,934 a
Dual Magnum + EPTAM fb* Dual Magnum	0.5 pt + 7 pt 0.5 pt	Fall/surface fb POST	0.89	384.75	16.37 ab	3.4 ab	43.3 a	11,761 ab
Dual Magnum + EPTAM	1 pt 7 pt	Fall/surface	0.89	435.13	16.37 ab	2.6 b	45.2 a	12,240 ab
Dual Magnum Dual Magnum	0.5 pt 0.5 pt	Fall/ plow fb POST	0.92	446.75	16.17 abc	3.7 ab	44.5 a	11,895 ab
Dual Magnum	0.75 pt	PRE	0.95	470.50	15.66 ab	3.6 ab	44.0 a	11,304 b
Roundup + Outlook	22 fl oz 21 fl oz	POST	0.84	429.00	16.35 ab	3.3 ab	43.6 a	11,938 ab
LSD (0.05)			NS	NS	0.68	1.8	4.2	1,277

*fb = followed by.

[z] Fall/plowdown = Treatments applied the fall preceding sugar beet; Fall/surface = treatments applied after soil tillage and disked in the soil twice during fall of preceding year; PRE = herbicide applied prior to sugar beet planting. POST = herbicide applied in-season to sugar beet at the 2-leaf stage.

[y] Root yield was tared.

[x] ERS = Estimated recoverable sucrose.

[w] Means within a column followed by the same letter are not significantly different according to Fisher's protected least significant difference (LSD), $P \leq 0.05$.

Disclaimer: *products used in this study were for experimental purpose only and are NOT registered for use in sugar beet production*.

SOYBEAN PERFORMANCE IN ONTARIO IN 2018

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Introduction

Soybean is a potentially valuable new crop for the Pacific Northwest (PNW). Soybean can provide raw materials for biodiesel, high-quality protein, and oil for human consumption, all of which are in short supply in the PNW. In addition, edible or vegetable soybean production can provide a raw material for specialized food products. Soybean is valuable as a rotation crop because of the soil-improvement effects of its residues and its nitrogen (N_2) -fixing capability. Because high-value irrigated crops are typically grown in the Snake River Valley, soybeans may be economically feasible only at high yields. The most common rotation crop in the Treasure Valley is irrigated winter wheat, so soybeans need to be competitive in value with winter wheat.

This report summarizes work done in 2018 as part of our continuing breeding and selection program to adapt soybeans to eastern Oregon and includes the added yield enhancements achieved by changing the planting configuration. Our soybean reports from the last decade are available at our station web site <http://www.cropinfo.net>. There is a search function on the home page that will conveniently find all of our recent reports dealing with soybeans by using the key word “soybean”.

Materials and Methods

The 2018 trial was conducted on Greenleaf silt loam soil previously planted to wheat. A soil analysis taken in the fall of 2017 showed that the top foot of soil had a pH of 7.9, 2.9% organic matter, 4 ppm nitrate, 1 ppm ammonium, 47 ppm phosphorus (P), 358 ppm potassium (K), 23 ppm sulfur (S), 2131 ppm calcium, 486 ppm magnesium (Mg), 125 ppm sodium, 4.2 ppm zinc (Zn), 3 ppm manganese (Mn), 1.8 ppm copper (Cu), 10 ppm iron, and 0.2 ppm boron (B). In the fall of 2017, the wheat stubble was shredded and the field was irrigated. The field was then disked. Based on a soil analysis, 104 lb K/acre, 53 lb of S/acre, 9 lb of Mn/acre, and 1 lb of B/acre were broadcast before plowing. After the fertilizer was spread, the field was moldboard plowed, groundhogged twice, and bedded to 30-inch rows. On May 14, Outlook® herbicide was applied at 18 oz (0.84 lb ai)/acre and incorporated during planting.

Fifty-five lines selected in 2009 and 2010 were evaluated. The 55 selections were planted in plots 4 rows wide by 25 ft long. The experimental design was a randomized complete block design with four replicates. The seed was planted on May 15 at 200,000 seeds/acre in 3 rows on each 30-inch bed using a plot drill with disc openers. The rows were spaced 7 inches apart. *Bradyrhizobium japonicum* inoculant (ABI Inoculant, Advanced Biological Marketing, Inc., Van Wert, OH) was applied to the seed before planting. Emergence started on May 22. The field was furrow irrigated to maintain the soil water tension below 60 cb at 8-inch depth.

Plant height in each plot was measured on July 30. Each plot was evaluated for lodging and seed shatter on October 15. Lodging was rated as the degree to which the plants were leaning over (0 = vertical, 10 = prostrate). The middle two beds in each four-bed plot were harvested on October 22-24 using a Wintersteiger Nurserymaster small-plot combine. Beans were cleaned, weighed, and a subsample was oven dried to determine moisture content. Moisture at the time of analysis was determined by oven drying at 100°C for 24 hours. Dry bean yields were corrected to 13% moisture.

Results and Discussion

Plant stands in 2018 were fair to poor. Seed were drilled into uneven beds that dried too quickly. The poor plant stands compromised productivity. Yields in 2018 averaged 55 bu/acre and ranged from 44 bu/acre for selection 20-7-09 to 68 bu/acre for selection 11-3-2010 (Table 1). Many lines had seed counts sufficient for the manufacturing of tofu (<2,270 seeds/lb). All of the soybean materials evaluated had light-colored seed coats and pale hilums. Averaged over cultivars and years, seed yields averaged 59 bu/acre and seed size averaged 2,336 seeds/lb (Table 2).

Summary

Reasonable soybean yields can be achieved in the Treasure Valley by employing varieties selected for the environment, high planting rates, modest fertilization, use of *Bradyrhizobium japonicum* inoculation, proper May planting dates, appropriate irrigation, and timely control of lygus bugs and spider mites.

Acknowledgements

This project was funded by Oregon State University, Malheur County Education Service District, and was supported by Formula Grant nos. 2018-31100-06041 and 2018-31200-06041 from the USDA National Institute of Food and Agriculture.

Table 1. Performance of soybean cultivars in 2018. Malheur Experiment Station, Oregon State University, Ontario, OR. Table 1 continues on the next page.

Selection	Cross	Interm. sel.	Yield	Height	Days to maturity	Lodging	Seed size
			bu/acre	cm	from emergence	0-10	seeds/lb
8-2-10	Korada		58.8	103	113	7	2,259
11-21-09	M92-330	M1	50.8	100	113	6	2,265
11-3-10	M92-330	M1	68.0	101	113	6	2,121
12-1-10	M92-330	M2	49.7	102	106	8	2,128
12-7-10	M92-330	M2	55.4	101	106	5	2,064
14-3-10	M92-330	M4	53.0	103	106	5	2,124
14-4-10	M92-330	M4	55.9	102	106	4	2,045
14-5-10	M92-330	M4	57.2	103	106	3	2,045
14-8-10	M92-330	M4	56.3	102	106	5	2,141
15-3-10	M92-330	M9	57.7	104	106	5	2,115
16-8-10	M92-330	M12	59.4	104	106	6	2,030
16-10-10	M92-330	M12	59.2	103	106	6	2,127
17-4-10	M92-330	M13	57.5	104	106	4	2,132
17-5-10	M92-330	M13	55.4	101	106	3	1,979
17-10-10	M92-330	M13	57.9	103	106	6	2,009
18-2-10	M92-330	M15	56.6	102	113	4	2,094
18-7-10	M92-330	M15	56.8	102	106	6	1,966
18-8-10	M92-330	M15	63.7	103	106	4	1,949
19-6-10	M92-330	M16	59.4	103	106	5	1,954
19-7-10	M92-330	M16	60.6	103	106	6	2,028
19-8-10	M92-330	M16	57.2	103	106	5	1,967
19-9-10	M92-330	M16	56.6	103	113	8	2,186
19-10-10	M92-330	M16	59.2	104	106	3	2,058
20-7-09	M92-085	101	43.8	103	106	5	2,202
20-11-09	M92-085	101	49.3	104	113	5	2,217
20-11-09	M92-085	101	45.3	101	113	5	2,556
20-1-10	M92-085	101	52.6	103	106	5	2,062

Table 1. (Continued.) Performance of soybean cultivars in 2018. Malheur Experiment Station, Oregon State University, Ontario, OR.

Selection	Cross	Interm. sel.	Yield	Height	Days to maturity	Lodging	Seed size
			bu/acre	cm	from emergence	0-10	seeds/lb
20-4-10	M92-085	101	55.6	100	106	4	1,972
20-6-10	M92-085	101	58.6	103	106	5	2,152
20-7-10	M92-085	101	50.3	102	113	6	2,001
21-12-10	M92-085	103	59.4	103	113	7	2,140
23-6-10	M92-085	106	61.3	104	113	6	1,988
24-1-09	M92-085	107	58.8	99	113	2	2,425
24-2-09	M92-085	107	48.0	103	113	7	2,245
24-2-09	M92-085	107	46.9	103	113	7	2,415
24-3-10	M92-085	107	58.3	102	106	4	2,058
30-1-10	M92-220	303	48.2	99	113	5	2,357
30-3-10	M92-220	303	53.2	100	113	4	2,266
30-5-10	M92-220	303	53.0	98	113	6	2,135
31-1-10	M92-220	305	47.3	102	113	7	2,349
31-3-10	M92-220	305	51.4	103	113	6	2,345
31-5-10	M92-220	305	47.4	101	113	5	2,287
31-8-10	M92-220	305	50.6	102	118	3	2,302
32-3-10	M92-220	307	51.6	100	118	3	2,262
34-1-10	M92-220	309	51.2	100	106	6	2,138
34-11-10	M92-220	309	47.8	98	113	7	2,139
35-6-10	M92-220	311	52.1	102	113	5	2,184
36-6-10	M92-220	312	50.0	100	113	5	2,435
36-7-10	M92-220	312	52.9	104	106	4	2,225
36-10-10	M92-220	312	58.8	102	106	4	2,055
37-9-10	M92-220	313	64.9	102	106	6	2,722
40-3-10	M92-314	601	59.5	103	113	5	1,978
41-3-10	M92-314	608	60.1	103	113	6	1,973
42-8-10	OR-6	905	48.0	105	120	10	2,541
43-10-10	OR-6	909	44.7	108	120	10	2,254
Average			54.6	102	110	5.3	2,167
LSD (0.05)			8.6	4		2.4	207

Table 2. Yield and seed size for soybean cultivars from 2014 to 2018. Malheur Experiment Station, Oregon State University, Ontario, OR. Planting dates were: May 28, 2014, May 26, 2015, June 3, 2016, May 19, 2017, and May 15, 2018. Table 2 continues on next page.

	Yield						Seed size					
Selection	2014	2015	2016	2017	2018	Average	2014	2015	2016	2017	2018	Average
	bu/acre						seeds/lb					
8-2-10	63.1	61.0	53.9	57.1	58.8	58.8	2364	2138	2570	2630	2259	2392
11-21-09	70.3	73.8	46.8	61.2	50.8	60.6	2302	2245	2717	2815	2265	2509
11-3-10	64.5	73.4	56.8	64.8	68.0	65.5	2322	1945	2719	2398	2121	2336
12-1-10	62.2	64.0	49.9	58.7	49.7	56.9	2182	1964	2710	2452	2128	2287
12-7-10	71.6	66.2	41.6	59.2	55.4	58.8	1991	1837	2629	2429	2064	2190
14-3-10	64.2	68.5	40.5	64.5	53.0	57.3	2072	1936	2684	2343	2124	2232
14-4-10	71.4	75.6	45.8	60.8	55.9	61.9	2104	1971	2680	2389	2045	2238
14-5-10	66.5	70.6	47.0	63.1	57.2	60.9	2106	1943	2642	2326	2045	2213
14-8-10	71.2	73.3	51.3	63.0	56.3	63.0	2091	1883	2711	2401	2141	2245
15-3-10	67.6	73.6	48.0	64.6	57.7	62.3	2172	1952	2626	2389	2115	2251
16-8-10	72.4	73.2	53.9	63.4	59.4	64.5	2154	1869	2700	2378	2030	2226
16-10-10	66.8	70.2	42.5	59.8	59.2	59.7	2091	1917	2717	2430	2127	2284
17-4-10	70.2	71.6	51.0	63.3	57.5	62.7	2121	1941	2693	2436	2132	2264
17-5-10	68.4	69.0	46.8	61.0	55.4	60.1	2079	1919	2741	2451	1979	2234
17-10-10	62.7	72.5	45.4	61.1	57.9	59.9	2199	1942	2686	2377	2009	2243
18-2-10	65.3	71.9	44.2	61.6	56.6	59.9	2183	1942	2641	2462	2094	2265
18-7-10	67.4	68.7	46.4	56.5	56.8	59.2	2014	1894	2828	2403	1966	2221
18-8-10	70.2	64.5	46.8	61.9	63.7	61.4	2093	1911	2638	2340	1949	2186
19-6-10	67.2	70.8	42.6	67.1	59.4	60.8	2045	1944	2627	2312	1954	2176
19-7-10	61.4	69.2	46.6	66.9	60.6	60.6	2105	1953	2663	2461	2028	2242
19-8-10	75.1	65.5	44.0	65.8	57.2	61.5	1998	1961	2595	2317	1967	2168
19-9-10	65.1	67.4	55.8	65.1	56.6	62.0	2195	2055	2742	2624	2186	2360
19-10-10	63.1	62.7	54.8	61.9	59.2	60.3	2087	1872	2624	2412	2058	2211
20-7-09	61.8	66.8	42.0	58.8	43.8	54.6	2318	2225	2707	2876	2202	2466
20-11-09	68.1	65.0	44.0	60.0	49.3	57.3	2368	2368	2725	2809	2217	2497
20-11-09	64.6	67.0	46.0	59.1	45.3	56.4	2359	2187	2667	2901	2556	2534
20-1-10	60.2	72.2	45.3	58.6	52.6	57.8	2169	1978	2589	2307	2062	2221

Table 2. (Continued.) Yield and seed size for soybean cultivars from 2014 to 2018. Malheur Experiment Station, Oregon State University, Ontario, OR.

	Yield						Seed size					
Selection	2014	2015	2016	2017	2018	Average	2014	2015	2016	2017	2018	Average
	---------------------- bu/acre ----------------------						---------------------- seeds/lb ----------------------					
20-4-10	67.2	70.2	45.3	61.7	55.6	60.0	2079	1,941	2,658	2,392	1,972	2208
20-6-10	67.7	68.3	48.3	54.2	58.6	59.4	2116	1,952	2,603	2,462	2,152	2274
20-7-10	60.8	67.1	44.5	63.2	50.3	57.2	2062	1,905	2,665	2,334	2,001	2193
21-12-10	65.6	68.4	51.3	58.5	59.4	60.7	2178	2,014	2,645	2,528	2,140	2301
23-6-10	57.5	68.7	51.9	62.6	61.3	60.4	2098	1,973	2,587	2,428	1,988	2215
24-1-09	63.7	60.7	51.8	63.8	58.8	59.7	2458	2,443	2,815	2,896	2,425	2637
24-2-09	59.3	62.7	54.3	55.6	48.0	56.0	2350	2,099	2,734	2,923	2,245	2470
24-2-09	67.0	57.6	41.5	58.7	46.9	54.3	2392	2,139	2,678	2,943	2,415	2560
24-3-10	68.4	58.9	50.4	60.3	58.3	59.3	2131	1,977	2,688	2,291	2,058	2229
30-1-10	65.5	62.4	45.3	62.9	48.2	56.9	2279	2,269	2,635	2,880	2,357	2484
30-3-10	66.8	63.7	48.4	59.1	53.2	58.2	2296	2,200	2,666	2,727	2,266	2431
30-5-10	67.8	65.0	51.9	61.3	53.0	59.8	2347	2,259	2,767	2,717	2,135	2445
31-1-10	65.8	68.2	48.3	58.5	47.3	57.6	2294	2,154	2,587	2,775	2,349	2432
31-3-10	66.3	63.5	48.7	59.1	51.4	57.8	2244	2,181	2,646	2,773	2,345	2438
31-5-10	65.2	59.6	49.9	61.8	47.4	56.8	2362	2,185	2,658	2,892	2,287	2477
31-8-10	64.3	58.7	53.1	66.1	50.6	58.5	2202	2,148	2,684	2,712	2,302	2410
32-3-10	69.6	60.9	50.2	62.5	51.6	59.0	2355	2,112	2,682	2,744	2,262	2431
34-1-10	65.9	58.3	45.0	57.0	51.2	55.5	2170	2,062	2,670	2,766	2,138	2361
34-11-10	57.0	61.2	45.2	53.0	47.8	52.8	2302	2,036	2,745	2,838	2,139	2412
35-6-10	62.6	65.1	48.8	69.6	52.1	59.7	2445	2,127	2,647	2,875	2,184	2455
36-6-10	55.7	62.9	37.0	59.4	50.0	53.0	2383	2,118	2,739	2,911	2,435	2517
36-7-10	58.5	59.9	48.6	62.6	52.9	56.5	2310	2,171	2,729	2,826	2,225	2452
36-10-10	67.5	66.7	53.7	61.6	58.8	61.7	2065	1,907	2,637	2,356	2,055	2204
37-9-10	69.5	68.1	49.9	61.3	64.9	62.8	2097	1,995	2,735	2,528	2,722	2357
40-3-10	67.6	60.7	47.7	65.0	59.5	60.1	2163	1,947	2,812	2,460	1,978	2272
41-3-10	66.7	56.2	53.7	65.6	60.1	60.4	2134	1,916	2,614	2,329	1,973	2193
42-8-10	29.9	53.4	52.4	48.2	48.0	46.4	2848	2,241	2,688	2,783	2,541	2620
43-10-10	52.3	53.4	56.2	43.9	44.7	50.1	2121	1,944	2,457	2,885	2,254	2332
Average	64.8	65.8	48.2	60.8	54.6	58.8	2210	2038	2675	2579	2167	2336
LSD(0.05)	8.9	4.7	8.7	8.4	8.6	3.7	152	93	NS	170	207	80

APPENDIX A. HERBICIDES AND ADJUVANTS

Trade name	Common or code name	Manufacturer
AAtrex	atrazine	Syngenta
Aim	carfentrazone-ethyl	FMC Corp.
Alion	Indaziflam	Bayer CropScience
Betamix	desmedipham	Bayer CropScience
Boundary	s-metolachlor + metribuzin	Syngenta
Bronate Advanced	bromoxynil	Bayer CropScience
Bronc Max	ammonium sulfate	Wilbur-Ellis Co.
Brox 2EC	bromoxynil	Albaugh
Buccaneer	isopropylamine salt of glyphosate	Tenkoz, Inc.
Buctril	bromoxynil	Bayer CropScience
Chateau	flumioxazin	Valent Corporation
Clarity	3,6-dichloro-o-anisic acid	BASF Ag Products
Defendor	florasulam	Dow AgroSciences
Destiny	methylated soybean oil	Winfield Solutions
Distinct	sodium salt of diflufenzopyr	BASF Ag Products
Dual Magnum, Dual II Magnum	s-metolachlor	Syngenta
Dyne-Amic	Methyl esters of C16-C18 fatty acids, polyalkyleneoxide modified polydimethylsiloxane, alkylphenol ethoxylate	Helena Chemical
Eptam	EPTC	Gowan Company
Ethotron SC	ethofumesate	United Phosphorus
Goal 2XL, GoalTender	oxyfluorfen	Dow AgroSciences
Gramoxone	parquet dichloride	Syngenta
Halex GT	s-metolachlor + glyphosate + mesotrione	Syngenta
Herbimax	petroleum hydrocarbons	Loveland Products
Huskie	pyrasulfotole	Bayer CropScience
Integrity	saflufenacil	BASF Ag Products
Laudis	tembotrione	Bayer CropScience
Linex, Lorox	linuron	Tessenderlo Kerley
Matrix	rimsulfuron	DuPont
Nortron	ethofumesate	Bayer CropScience
Oust	sulfometuron methyl	Bayer CropScience
Outlook	dimethenamid-p	BASF Ag Products
Paramount	quinclorac	BASF Ag Products
Pierce	methylated seed oil	Simplot
Poast, Poast HC	sethoxydim	BASF Ag Products
Preference	alkylphenol ethoxylate	Winfield Solutions
Prowl, Prowl H_2O	pendimethalin	BASF Ag Products
PureSpray Green	mineral oil	Petro-Canada
R-11	alkylphenol ethoxylate	Wilbur-Ellis Co.
Raptor	imazamox	BASF Ag Products
Reflex	fomesafen	Syngenta
Roundup PowerMax,	glyphosate	Monsanto
Sandea	halosulfuron	Gowan Company
Select, Select Max	clethodim	Valent

APPENDIX A. HERBICIDES AND ADJUVANTS (CONTINUED)

Trade name	Common or code name	Manufacturer
Sequence	glyphosate + s-metolachlor	Syngenta
Shadow	clethodim	Arysta LifeScience
Sharpen	saflufenacil	BASF Ag Products
Starane Ultra	fluroxypyr	Dow AgroSciences
Status	diflufenzopyr	BASF Ag Products
Stinger	clopyralid	Dow AgroSciences
Touchdown	glyphosate	Syngenta
Treflan	trifluralin	Dow AgroSciences
TriCor DF	metribuzin	United Phosphorus
UpBeet	triflusulfuron	DuPont
Warrant	acetochlor	Monsanto
WETCIT	alcohol ethoxylat	Oro Agri
Valor	flumioxazin	Valent Corporation
Velpar	hexazinone + diuron	DuPont
Volunteer	clethodim	Tenkoz
Yukon	halosulfuron-methyl+dicamba	Gowan Company
Zeba SP	cornstarch	United Phosphorus
Zidua	pyroxasulfone	BASF Ag Products

APPENDIX B. INSECTICIDES, FUNGICIDES, AND NEMATICIDES

Trade name	Common or code name	Manufacturer
Acephate	acephate	various
Admire	imidacloprid	Bayer CropScience
Agri-Mek, Agri-Mek SC	abamectin	Syngenta
Aproach Prima	picoxystrobin + cyproconazole	DuPont
Aza-Direct	azadirachtin	Gowan Company
Badge	copper oxychloride + copper hydroxide	Gowan Company
Beleaf	flonicamid	FMC Corp.
Blackhawk	spinosad	Dow AgroSciences
Bravo, Bravo Ultrex, Bravo Weather Stik	chlorothalanil	Syngenta
Brigade	bifenthrin	FMC Corp
Captan	N-trichloromethylthio-4-cyclohexene-1, 2-dicarboximide	various
Captiva	capsacin oleoresin, garlic oil, soybean oil	Gowan Company
Capture 2EC	bifenthrin	FMC Corp
Carzol	formetanate hydrochloride	Gowan Company
Counter 20 CR, Counter 15G	terbufos	BASF Ag Products
Dithane	mancozeb	Dow AgroSciences
Dividend XL	difenoconazole + mefenoxam	Syngenta
Enable	fenbuconazole	Dow AgroSciences
Entrust	spinosad	Dow AgroSciences
Exirel	cyantraniliprole	FMC
Fontelis	penthiopyrad	DuPont
Gaucho	imidacloprid	Gowan Company
Gavel	mancozeb + zoxamide	Gowan Company
Gem	trifloxystrobin	Bayer CropScience
Gladiator	zeta-cypermethrin + avermectin B1	FMC Corp
Headline	pyraclostrobin	BASF Ag Products
Inspire	difenoconazole	Syngenta
Knack	pyriproxyfen	Valent
Kocide	copper hydroxide	DuPont
K-Pam	potassium N-methyldithiocarbamate	Amvac Chemical
Lannate	methomyl	DuPont
Lifegard WG	Bacillus mycoides isolate J*	Certis
Lorsban, Lorsban 15G	chlorpyrifos	Dow AgroSciences
Luna Tranquility	pyrimethanil	Bayer CropScience
ManKocide	mancozeb	DuPont
Maxim MZ	mancozeb + fludioxonil	Syngenta
M-Pede	potassium salts of fatty acids	Gowan Company
Minecto Pro	abamectin + cyantraniliprole	Syngenta
Movento	spirotetramat	Bayer CropScience
Mustang	zeta-cypermethrin	FMC Corp
Nexter	pyridaben	Gowan Company
Orthene	acephate	Amvac Chemical
Pic-Clor 60	dichloropropene + chloropicrin	Trical, Inc.
Proline	prothioconazole	Bayer CropScience

APPENDIX B. INSECTICIDES, FUNGICIDES, AND NEMATICIDES (continued)

Trade name	**Common or code name**	**Manufacturer**
Propulse	flupyram + prothioconazole	Bayer CropScience
Quadris Opti	azoxystrobin	Syngenta
Radiant	spinetoram	Dow AgriSciences
Requiem	*Chenopodium ambrosioides*	Bayer CropScience
Ridomil Gold SL	mefanoxam	Syngenta
Ridomil MZ58	metalaxyl	Syngenta
Rimon	novaluron	Arysta LifeScience
Rovral	iprodione	various
Scala	pyrimethanil	Bayer CropScience
Scorpion	dinotefuran	Gowan Company
Serenade	QST 713 strain of *Bacillus subtilis*	Bayer CropScience
Sivanto	flupyradifurone	Bayer CropScience
Success	spinosad	Dow AgroSciences
Tanos	famoxadone + cymoxanil	Du Pont
Tebuzol	tebuconazole	United Phosphorus
Telone C-17, Telone II	dichloropropene + chloropicrin	Dow AgroSciences
Thiram	thiram	Bayer CropScience
Topsin M	thiophanate-methyl	United Phosphorus
Tops-MZ	thiophanate-methyl	Bayer CropScience
Torac	tolfenpyrad	Nichino America
Transform	sulfoxaflor	Dow AgroSciences
Trilogy	extract of neem oil	Certis USA
Ultiflora	milbemectin	Gowan Company
Vapam	metham sodium	Amvac
Venerate	Burkholderia strain A396	Marrone Bio
Venom	dinotefuran	Valent
Verimark	cyantraniliprole	FMC
Vydate, Vydate L	oxamyl	DuPont
Warrior	lambda-cyhalothrin	Syngenta
Zing!	zoxamide + chlorothalonil	Gowan Company

APPENDIX C. COMMON AND SCIENTIFIC NAMES OF CROPS, FORAGES, AND FORBS

Common name	Scientific name
alfalfa	*Medicago sativa*
bare-stem desert parsley	*Lomatium nudicaule*
basalt milkvetch	*Astragalus filipes*
bluebunch wheatgrass	*Pseudoroegneria spicata*
blue penstemon	*Penstemon cyaneus*
Canby’s licorice-root	*Ligusticum canbyi*
corn, sweet corn	*Zea mays*
coyote tobacco	*Nicotiana attenuata*
Douglas’ dustymaiden	*Chaenactis douglasii*
dry edible beans	*Phaseolus* spp.
fernleaf biscuitroot, desert parsley	*Lomatium dissectum*
golden beeplant	*Cleome platycarpa*
Gray’s lomatium	*Lomatium grayi*
Hayden’s cymopterus	*Cymopterus bipinnatus*
hoary tansyaster	*Machaeranthera canescens*
hotrock penstemon, scabland penstemon	*Penstemon deustus*
manyflower thelypody	*Thelypodium milleflorum*
miscanthus	*Miscanthus giganteus*
mountain monardella	*Monardella odoratissima*
nakedstem sunray	*Enceliopsis nudicaulis*
nineleaf desertparsley	*Lomatium triternatum*
onion	*Allium cepa*
Pacific yew	*Taxus brevifolia*
parsnip-flowered buckwheat	*Eriogonum heracleoides*
pepper, bell	*Capsicum annuum*
Porter’s licorice-root	*Ligusticum porteri*
potato	*Solanum tuberosum*
quinoa	*Chenopodium quinoa*
Rocky Mountain beeplant	*Cleome serrulata*
sagebrush penstemon	*Penstemon speciosus*
scarlet gilia	*Ipomopsis aggregata*
Searls’ prairie clover	*Dalea searlsiae*
sharpleaf penstemon, sandhill penstemon	*Penstemon acuminatus*
showy goldeneye	*Heliomeris multiflora*
silverleaf phacelia	*Phacelia hastata*
soybeans	*Glycine max*
spearmint, peppermint	*Mentha* spp.
sugar beet	*Beta vulgaris*
Suksdorf’s desertparsley	*Lomatium suksdorfii*
sulfur buckwheat	*Eriogonum umbellatum*
sweet potato	*Ipomoea batatas*
teff	*Eragrostis tef*
thickleaf beardtongue	*Penstemon pachyphyllus*
threadleaf phacelia	*Phacelia linearis*

APPENDIX C. COMMON AND SCIENTIFIC NAMES OF CROPS, FORAGES, AND FORBS (CONTINUED)

Common name	Scientific name
tomato	*Solanum lycopersicum*
triticale	*Triticum* x *Secale*
western prairie clover	*Dalea ornata*
western yarrow	*Achillea millifolium*
wheat	*Triticum aestivum*
yellow beeplant	*Cleome lutea*

APPENDIX D. COMMON AND SCIENTIFIC NAMES OF WEEDS

Common name	Scientific name
annual sowthistle	*Sonchus oleraceus*
barnyardgrass	*Echinochloa crus-galli*
Bittersweet nightshade	*Solanum dulcamara*
black medic	*Medicago lupulina*
blue mustard	*Chorispora tenella*
bur buttercup	*Ceratocephala testiculata*
common lambsquarters	*Chenopodium album*
common mallow	*Malva neglecta*
common purslane	*Portulaca oleracea*
dodder	*Cuscuta* spp.
downy brome	*Bromus tectorum*
field bindweed	*Convolvulus arvensis*
flixweed	*Descurainia sophia*
green foxtail	*Setaria viridis*
hairy nightshade	*Solanum sarrachoides*
kochia	*Kochia scoparia*
ladysthumb	*Polygonum persicaria*
large crabgrass	*Digitaria sanguinalis*
matrimony vine	*Lycium barbarum*
Powell amaranth	*Amaranthus powellii*
prickly lettuce	*Lactuca serriola*
prostrate knotweed	*Polygonum aviculare*
purple mustard	*Chorispora tenella*
redroot pigweed	*Amaranthus retroflexus*
Russian knapweed	*Acroptilon repens*
shepherd’s purse	*Capsella bursa-pastoris*
tumble pigweed	*Amaranthus albus*
wild oat	*Avena fatua*
whitetop, hoarycress	*Cardaria draba*
yellow nutsedge	*Cyperus esculentus*

APPENDIX E. COMMON AND SCIENTIFIC NAMES OF DISEASES, PHYSIOLOGICAL DISORDERS, INSECTS, AND NEMATODES

Common name	Scientific name
Diseases	
alternaria fungus	*Alternaria* spp.
anthracnose	*Colletotrichum trifolii*
Aphanomyces root rot	*Aphanomyces euteiches*
bacterial wilt	*Clavibacter michiganensis*
fusarium wilt	*Fusarium oxysporum*
iris yellow spot virus	*Iris yellow spot virus*
onion black mold	*Aspergillus niger*
onion leaf blight	*Botrytis squamosa*
onion neck rot, (gray mold)	*Botrytis allii*
onion plate rot	*Fusarium oxysporum*
fusarium neck rot	*Fusarium proliferatum*
phytophthora root rot	*Phytophthora medicaginis*
pink root	*Phoma terrestris*
potato late blight	*Phytophthora infestans*
powdery mildew	*Leveillula taurica*
rust	*Puccinia sherardiana*
squash mosaic virus	*Squash mosaic virus*
verticillium wilt	*Verticillium* spp.
zebra chip (Lso)	Candidatus *Liberibacter solanacearum*
Physiological disorders	
iron deficiency	
onion incomplete scale	
onion translucent scale	
potato jelly ends	
potato sugar ends	
Insects	
alfalfa weevil	*Hypera postica*
armyworms	*Noctuidae* spp.
beet leafhopper	*Circulifer tenellus*
big-eyed bugs	*Geocoris* spp.
cereal leaf beetle	*Oulema melanopus*
Colorado potato beetle	*Leptinotarsa decemlineata*
cutworm	*Noctuidae* spp.
flea beetle	*Chrysomelidae* spp.
green peach aphid	*Myzus persicae*
lacewing	*Chrysopidae* spp.
ladybird beetle	*Coccinellidae* spp.
loopers	*Noctuidae* spp.
lygus bug	*Lygus elisus* and *L. hesperus*
minute pirate bug	*Anthocoridae* spp.
onion maggot	*Delia antiqua*

APPENDIX E. COMMON AND SCIENTIFIC NAMES OF DISEASES, PHYSIOLOGICAL DISORDERS, INSECTS, AND NEMATODES (CONTINUED)

Common name	Scientific name
onion thrips	*Thrips tabaci*
pea aphid	*Acyrthosiphon pisum*
potato aphid	*Macrosiphum euphorbiae*
potato psyllid	*Bactericerca cockerelli*
potato tuberworm	*Phthorimaea operculella*
seed corn maggot	*Delia platura*
spidermite	*Tetranychus* spp.
spotted alfalfa aphid	*Therioaphis maculate*
squash bugs	*Anasa tristis*
stink bug	*Pentatomidae* spp.
sugar beet root maggot	*Tetanops myopaeformis*
two-spotted spider mite	*Tetranychus urticae*
western flower thrips	*Franklinella occidentalis*
willow sharpshooter	*Graphocephala confluens* (Uhler)
wireworm	*Elateridae* spp.
wooly aphid	*Eriosomatinae* spp.
Nematodes	
alfalfa stem nematode	*Ditylenchus dipsaci*
orthern root-knot nematode	*Meloidogyne hapla*