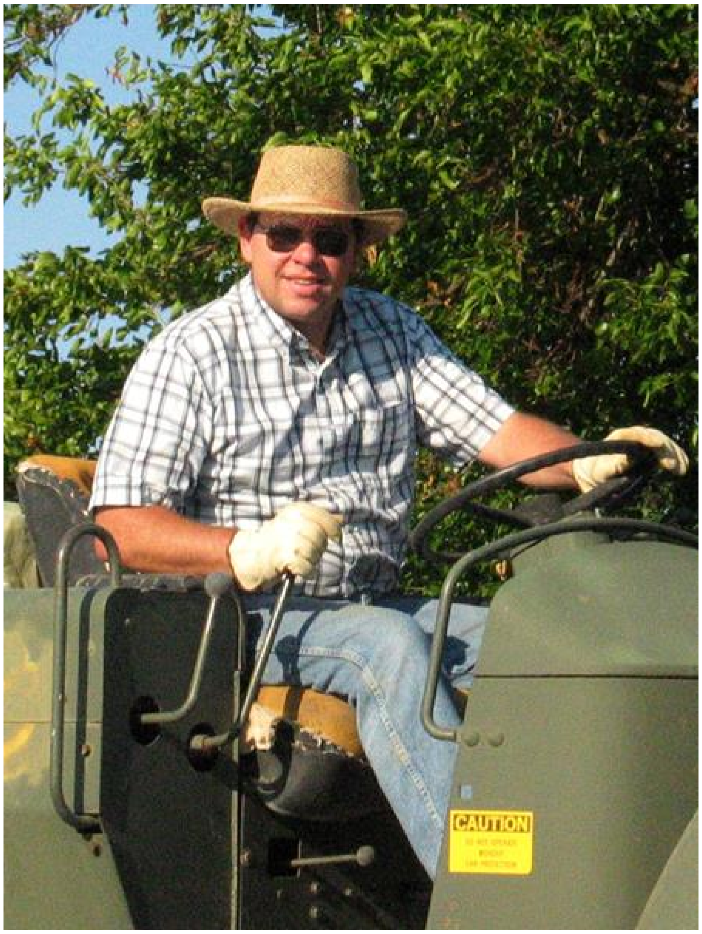
MALHEUR EXPERIMENT STATION ANNUAL REPORT 2017, Ext/CrS 159



Oregon State University
Malheur Experiment Station

Oregon State University, Malheur Experiment Station Annual Report 2017, Department of Crop and Soil Science Ext/CrS 159, July 2018, edited by Clinton C. Shock.

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On the Cover: Monty Saunders driving a front end loader at the OSU Malheur Experiment Station. Monty has contributed to the research of Malheur Experiment Station over the last 30 years.

Agricultural Experiment Station
Oregon State University
Department of Crop and Soil Science Ext/CrS 159, July 2018

Malheur Experiment Station Annual Report 2017

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The information in this report is for the purpose of informing cooperators in industry, colleagues at other universities, and others of the results of research in field crops. Reference to products and companies in this publication is for specific information only and does not endorse or recommend that product or company to the exclusion of others that may be suitable. Nor should information and interpretation thereof be considered as a recommendation for application of any pesticide. **Pesticide labels should always be consulted and followed before any pesticide use.**

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 Oregon State University Malheur Experiment Station.

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2017 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 and 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 for each crop. These crop coefficients vary throughout the growing season based on the plant growth stage (crop cover). 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 harvest, frost, or dormancy. Alfalfa mean ET_c is calculated for an alfalfa crop 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.

2017 Weather

The total precipitation for 2017 (10.93 inches) was slightly higher than the 10-year and 74-year averages (10.09 inches) (Table 1). Precipitation for the months of January through April was higher than average.

Total snowfall for 2017 (31.5 inches) was higher than the 74-year average (17.7 inches) (Table 2). Contributing directly to the snow accumulation problems experienced over the winter of 2016-2017 were the higher than average snowfall and lower than average air temperature in December 2016 and January 2017. Snowfall in December 2016 was 19 inches and in January 2017 was 22 inches. From December 24, 2016 to February 15, 2017 there was a continuous minimum of 10 inches of snow on the ground. The highest snow depth of 28 inches occurred on January 19, 2017 and was the highest since records began in 1943. The average monthly maximum and minimum air temperatures for December of 2016 and January of 2017 were substantially lower than the 74-year average (Table 3). The lowest temperature for the year was -22°F on January 7.

The highest air temperature for 2017 was 102°F on both July 23 and 24. The average maximum air temperature in July and August was higher than average. The average minimum air temperature in July and August was substantially higher than average.

The average monthly maximum and minimum 4-inch soil temperatures were close to the 19-year and 50-year averages (Table 4).

Total monthly wind runs in 2017 were close to the 24-year average (Table 5). Total pan evaporation from May through October in 2017 was higher than the 69-year average (Table 6). Total accumulated reference evapotranspiration (ET_o) in 2017 was below the 25-year average (Table 7).

The year 2017 had 3337 growing degree-days (50 to 86°F), close to the 25-year average of 3300 (Table 8, Fig. 1). The year 2017 had a lower than average frost-free period (150 days) (Table 9). The last spring frost (≤32°F) occurred on May 13, 15 days later than the 41-year-average date of April 28; the first fall frost occurred on October 10, 2 days later than the 41-year-average date of October 8. Snow depth was the only record broken in 2017 (Table 10).

Acknowledgements

This work was supported by the National Oceanic and Atmospheric Administration, U.S. Bureau of Reclamation, Oregon State University, the Malheur County Education Service District and supported by Formula Grant nos. 2017-31100-06041 and 2017-31200-06041 from the USDA National Institute of Food and Agriculture.

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, 1990-2017.

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	0.49	0.69	0.29	7.21
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	9.25
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	8.64
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	13.30
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	10.05
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	14.01
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	12.69
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	9.21
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	15.28
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	7.97
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	9.64
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	7.81
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	6.18
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	8.78
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	11.98
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	14.25
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	12.79
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	7.47
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	7.62
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	11.00
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	15.76
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	11.20
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	9.10
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	7.03
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	11.04
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	11.49
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	8.98
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	10.93
10-yr avg	0.89	0.70	1.00	0.64	1.08	0.79	0.23	0.29	0.62	0.88	0.98	1.97	10.07
74-yr avg	1.25	0.92	0.95	0.79	1.05	0.80	0.23	0.33	0.47	0.74	1.14	1.42	10.09

Table 2. Annual snowfall totals (inches) at the Malheur Experiment Station, Oregon State University, Ontario, OR, 1943-2017. Average annual snowfall (1943-2016) is 17.7 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
13.75	15.50	11.50	4.50	24.00	13.50	12.30	3.75	26.00	13.75
2010	2011	2012	2013	2014	2015	2016	2017		
28.0	1.0	4.0	14.0	22.5	14.0	24.5	31.5		

Table 3. Maximum and minimum air temperatures by month, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Month		Highest	Lowest	2017 avg	74-yr avg
		---------------------- °F ----------------------			
Jan	Max	44	6	26	35
	Min	32	-22	9	19
Feb	Max	49	28	39	43
	Min	35	11	25	25
Mar	Max	72	41	56	55
	Min	48	22	37	31
Apr	Max	72	51	61	64
	Min	50	29	38	37
May	Max	93	52	73	74
	Min	58	32	46	45
Jun	Max	97	65	83	82
	Min	65	45	56	52
Jul	Max	102	89	96	92
	Min	73	57	64	58
Aug	Max	83	83	93	90
	Min	51	51	60	56
Sep	Max	97	61	80	80
	Min	63	37	50	46
Oct	Max	72	47	63	65
	Min	48	27	35	37
Nov	Max	43	43	49	48
	Min	23	23	32	28
Dec	Max	46	23	35	37
	Min	31	10	22	22

Table 4. Monthly soil temperature at 4-inch depth, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

	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 ----------------------																							
2017 avg	33	33	34	33	43	42	49	47	58	53	67	63	73	70	73	70	66	63	54	51	45	44	35	34
Highest	34	34	34	34	48	47	53	50	66	59	73	69	75	72	75	72	72	69	61	59	51	48	40	39
Lowest	32	29	32	31	34	32	46	44	51	48	60	59	69	63	71	68	58	55	49	46	41	40	32	30
19-yr avg	33	32	36	35	43	41	50	46	60	55	68	62	74	68	72	67	65	61	55	52	43	42	35	34
50-yr avg	33	32	37	34	49	40	59	47	71	57	79	66	87	73	85	72	75	63	60	51	44	40	34	33

[a]1998-2016 average. Ground covered with turf in 1997.

Table 5. Daily and monthly wind-run, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Daily	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	------ miles/day ------											
Mean	88	119	126	164	140	121	102	91	101	100	95	77
Max	427	477	443	367	445	288	186	191	256	228	223	253
Min	31	59	63	51	59	61	62	54	47	42	32	23
Monthly total	------ miles/month ------											
2017	2741	3333	3903	4917	4337	3628	3168	2816	3029	3102	2850	2401
24-yr average	2828	3198	4210	4618	4182	3668	3356	3273	3162	3286	3010	3284

Table 6. Daily and monthly pan-evaporation, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Totals	April	May	Jun	Jul	Aug	Sep	Oct	Total
Daily	------ inches/day ------							
Mean	0.19	0.26	0.33	0.41	0.33	0.22	0.13	
Max	0.32	0.54	0.61	0.56	0.48	0.36	0.31	
Min	0.04	0.07	0.15	0.24	0.20	0.06	0.00	
Monthly	------ inches/month ------							
2017	5.64	8.13	9.99	12.69	10.11	6.74	4.08	57.38
69-yr avg	5.79	7.91	9.21	11.44	9.80	6.44	3.41	54.00

Table 7. Total accumulated reference evapotranspiration (ET_o) and estimated crop evapotranspiration (ET_c) (acre-inches/acre) for various crops, Malheur Experiment Station, Oregon State University, Ontario, OR, 1992-2017.

										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
Avg												
inch	56.1	43.9	25.1	27.5	35.3	30.6	28.7	22.1	29.1	24.5	38.1	46.1
mm	1426	1115	638	699	896	778	730	561	740	621	969	1170

Table 8. Monthly total growing degree-days (50-86°F), Malheur Experiment Station, Oregon State University, Ontario, OR, 1993-2017.

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
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
Avg 1993-2016	1	15	108	200	371	511	702	662	470	230	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, 1990-2017.

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	0ct 22	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
avg 1976-2016	28-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 degree-days	2015
Fewest yearly growing degree-days	2768 degree-days	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

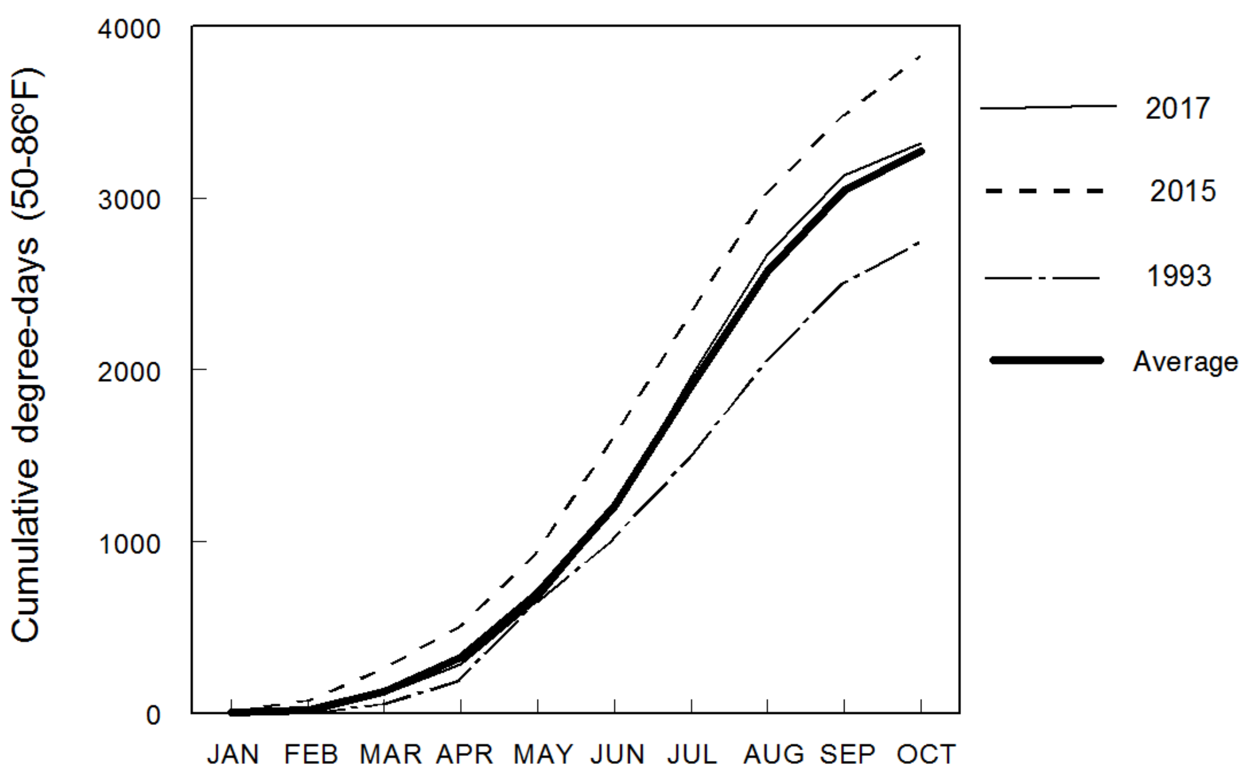

Figure 1. Cumulative growing degree-days (50-86°F) over time for 2017 compared to the years with lowest (1993) and highest (2015) totals since 1993 and to the 24-year average (1993-2016), Malheur Experiment Station, Oregon State University, Ontario, OR.

2017 ONION VARIETY TRIALS

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Introduction

Direct-seeded yellow, white, and red onion varieties were evaluated in the field 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 April and were harvested and graded in early August. Fifty-one full-season varieties (34 yellow, 14 red, and 3 white) were planted in April, harvested in October, and were graded out of storage in January 2018. 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 are evaluated objectively for bolting, yield, grade, single centers, and storability. Varieties are 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 2017 on an Owyhee silt loam previously planted to wheat. A soil analysis taken in the fall of 2016 showed that the top foot of soil had a pH of 8.2, 3.7% organic matter, 4 ppm nitrate, 3 ppm ammonium, 15 ppm phosphorus (P), 395 ppm potassium (K), 9 ppm sulfur (S), 3774 ppm calcium, 549 ppm magnesium (Mg), 208 ppm sodium, 0.6 ppm zinc (Zn), 17 ppm manganese (Mn), 0.4 ppm copper (Cu), 47 ppm iron, and 0.5 ppm boron (B). In the fall of 2016, the wheat stubble was shredded and the field was irrigated. The field was then disked. Based on a soil analysis, 55 lb of P/acre, 200 lb of S/acre, 9 lb of Zn/acre, 1 lb Cu/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 April 4 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 51 varieties from 10 seed companies.

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 20. On May 2, alleys 4 ft wide were cut between plots, leaving plots 23 ft long. On May 23-25, 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: Prowl® H_2O at 0.83 lb ai/acre (2 pt/acre) and Poast® at 0.25 lb ai/acre (16 oz/acre) on May 4; GoalTender® at 0.09 lb ai/acre (4 oz/acre) and Buctril® at 16 oz/acre on May 15; and Prowl H_2O at 0.31 lb ai/acre (0.75 pt/acre) and Poast at 0.5 lb ai/acre (32 oz/acre) on June 4.

For thrips control, the following insecticides were applied by ground: Movento® at 5 oz/acre on May 26; Movento at 5 oz/acre and Aza-Direct® at 12 oz/acre on June 2; Agri-Mek® SC at 3.5 oz/acre on June 15 and 23. The following insecticides were applied by air: Radiant® at 10 oz/acre on July 1, 8, and 30; Lannate® at 3 pt/acre on July 17 and 23.

Urea ammonium nitrate solution (URAN) was applied through the drip tape weekly starting May 1 and ending June 28, totaling 120 lb N/acre. Starting on May 26, root tissue and soil solution 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 only if both the root tissue and soil solution analyses concurrently indicated a deficiency (Table 3). Nitrogen was applied at the fixed amount previously mentioned, but was limited to 120 lb/acre, because the soil solution test indicated the soil was supplying the crop with adequate amounts of N after June 27. The amounts of total available soil N went above the critical level of 80 lb N/acre (Sullivan et al. 2001) starting July 11 (Table 4).

Table 1. Onion root tissue nutrient content in the onion variety trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Nutrient		26-May	12-Jun	19-Jun	27-Jun	4-Jul	11-Jul	17-Jul	24-Jul	31-Jul	7-Aug
NO_3-N (ppm)	Sufficiency range	8500	7667	7000	6000	5000	4338	3000	2000	1834	1000
NO_3-N (ppm)		3743	4431	3988	4378	5472	6782	5746	5134	3944	3704
P (%)	0.32 - 0.7	0.34	0.27	0.39	0.47	0.52	0.58	0.5	0.48	0.43	0.62
K (%)	2.7 - 6.0	2.81	3.11	3.74	4.44	4.37	4.09	3.18	2.93	2.03	2.32
S (%)	0.24 - 0.85	0.72	0.7	0.95	0.99	0.81	0.96	0.77	0.74	0.72	0.91
Ca (%)	0.4 - 1.2	1.03	0.92	0.72	0.83	1	1.15	1.03	0.84	1.01	1.12
Mg (%)	0.3 - 0.6	0.4	0.35	0.33	0.33	0.3	0.37	0.34	0.38	0.4	0.47
Zn (ppm)	25 - 50	44	33	41	31	37	34	35	32	31	27
Mn (ppm)	35 - 100	124	114	131	109	116	120	115	97	76	90
Cu (ppm)	6 - 20	17	14	20	15	14	11	9	8	9	7
B (ppm)	19 - 60	22	20	25	19	22	25	31	35	42	33

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. Numbers following each nutrient are the critical levels. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Nutrient	Critical level, lb or g/acre	26-May	12-Jun	19-Jun	27-Jun	4-Jul	11-Jul	17-Jul	24-Jul	31-Jul	7-Aug
N	Critical level, lb/acre	8.6	7.8	7	6	5	4.6	4	3	2	2
N		5.4	4.6	4	6.6	10.9	12.9	13.1	16	16	14.6
P	0.7 lb	1	1.3	0.7	0.8	1.1	1.3	1.5	1.1	1.2	1
K	5 lb	5	5.1	4.3	5.3	4.3	5.3	6	6.9	5.2	6.5
S	1 lb	4.1	3.1	2.1	2	2.4	3	3.7	4.4	5.1	3.9
Ca	3 lb	9.5	7.8	10.5	8.8	7.8	6.9	6.8	5.9	5.2	5.1
Mg	2 lb	17.9	14	8.3	8	6.8	7.5	7.8	8.3	8.8	7.5
Zn	28 g	27	33	27	33	42	51	63	72	75	66
Mn	28 g	24	18	9	15	27	30	33	30	36	39
Cu	12 g	6	9	6	12	15	18	15	18	21	24

Table 3. Nutrients applied through the drip irrigation system in the onion variety trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Date	N	P	K
	------- lb/acre --------		
1-May	30		
26-May	15		11
2-Jun	15	5	
9-Jun	15		
13-Jun	15		
22-Jun	15		
28-Jun	15		
Total	120	5	11

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, 2017.

Date	Available soil N, lb/acre
26-May	38
12-Jun	32
19-Jun	28
27-Jun	46
4-Jul	76
11-Jul	90
17-Jul	92
24-Jul	112
31-Jul	112
7-Aug	102

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 10 and irrigations ended on September 5.

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 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. 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.

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.

The onions in the full-season trial were lifted on September 22 to field cure. Onions from the middle two rows in each plot of the full-season trial were topped by hand and bagged on October 2. The bags were put in storage on October 11. 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 9-12, 2018.

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.

During grading, one bag from each plot was saved for additional evaluations of internal bulb quality. Fifty 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 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. This evaluation was not finished at the time of the printing of this report. The results will be published later.

After grading, two replicates of each yellow and red variety were evaluated for bulb shape, bulb shape uniformity, firmness, skin color, skin retention, and flesh brightness on January 16, 2018. 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. Variety performance varies by year. Growers are encouraged to review performance 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 2017 were close to the 24-year average, until July (Fig. 1), which had higher than average growing degree-days (Fig. 2). The SWT remained close to the target during the season (Fig. 3).

Early-maturing Trial

On August 11, all varieties had at least 39% tops down (Table 5). After 2 weeks of storage, bulb sprouting and decomposition were low, averaging 0.4% of total bulbs (Table 5). The percentage of onions that were functionally single centered averaged 55.9% and ranged from 49.9% for 'Avalon' and 'Great Western' to 65.2% for 'Spanish Medallion' (Table 6). Total yield averaged 1087 cwt/acre, ranging from 1019 cwt/acre for Great Western to 1122 cwt/acre for 'Scout' (Table 7).

Full-season Trial

On August 1, the percentage of tops down averaged 9% and ranged from 0% for several varieties to 82% for 10058 (Table 8). By August 15, the percentage of tops down averaged 53% and ranged from 16% for 'Sedona' to 96% for 10058. The severity of thrips leaf damage, on a scale from 0 to10, averaged 2.6 and ranged from 1.0 for 'Lasso' and 10043 to 5.2 for ROL221-222. None of the varieties had bolting in 2017. Iris yellow spot virus severity was low in this trial, with all varieties having a rating of 1 (0-25% of foliage diseased), with no statistically significant differences among varieties.

The percentage of functionally single-centered bulbs averaged 68% and ranged from 26% for TAS027 to 98.7% for 'Oloroso' (Table 9).

Marketable yield averaged 957 cwt/acre and ranged from 298 cwt/acre for ROM 223-224 to 1357 cwt/acre for Scout (Table 10). 'Joaquin', Scout, SV6672, 'Ranchero', 'Morpheus', 'Barbaro', SV6646, 16000, 'Dulce Reina', and 'Grand Perfection' were among the varieties with the highest marketable yield. Storage decomposition averaged 3% and ranged from 0.2% for 'Arcero' to 22% for 'White Cloud'.

Subjective Quality Evaluation

Subjective bulb quality ratings can be found in Table 13 and explanation of the rating system can be found in Figure 4 and Tables 11 and 12. 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 12% for 10043 to 97% for 'Marenge' (Table 14). The percentage of bulbs with internal decomposition, regardless of incomplete or dry scales, averaged 2% and ranged from 0% for 'Delgado', Avalon, 'Caoba', 10043, and 10058 to 12% for ROM223-224. For most varieties, most of the internal decomposition occurred in bulbs with incomplete scales. In 2017, most of the internal decomposition was caused by black mold (Table 15).

Acknowledgements

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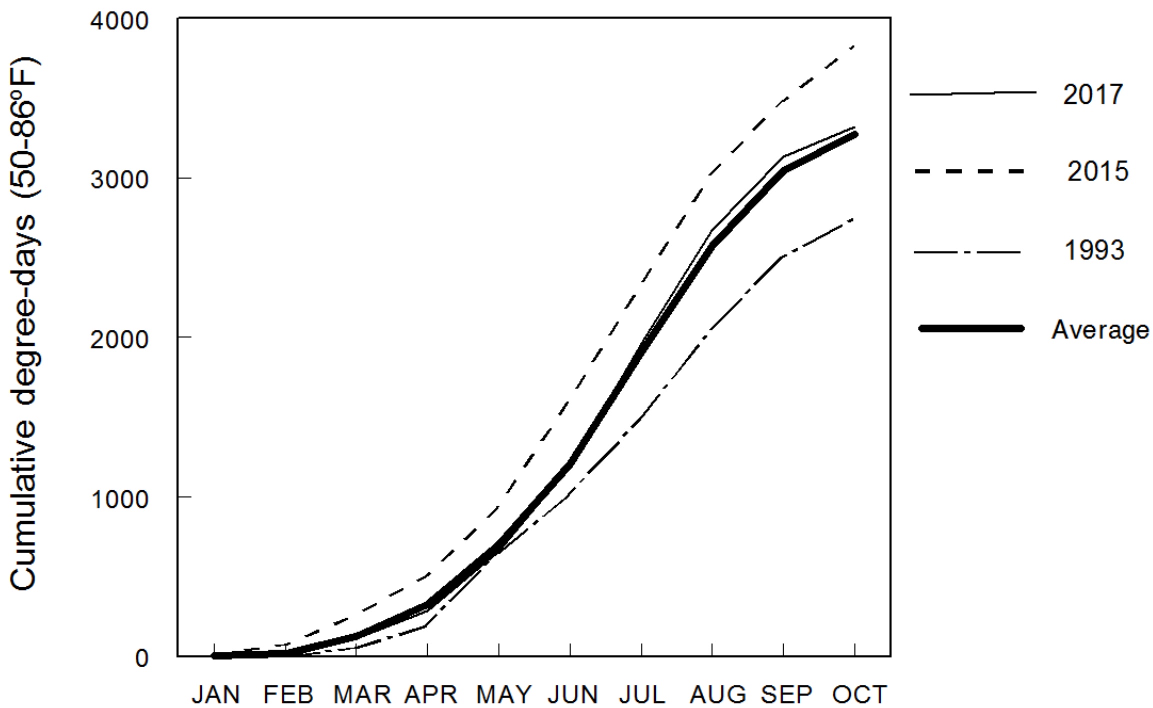

Figure 1. Cumulative growing degree-days (50-86°F) for 2015-2017 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

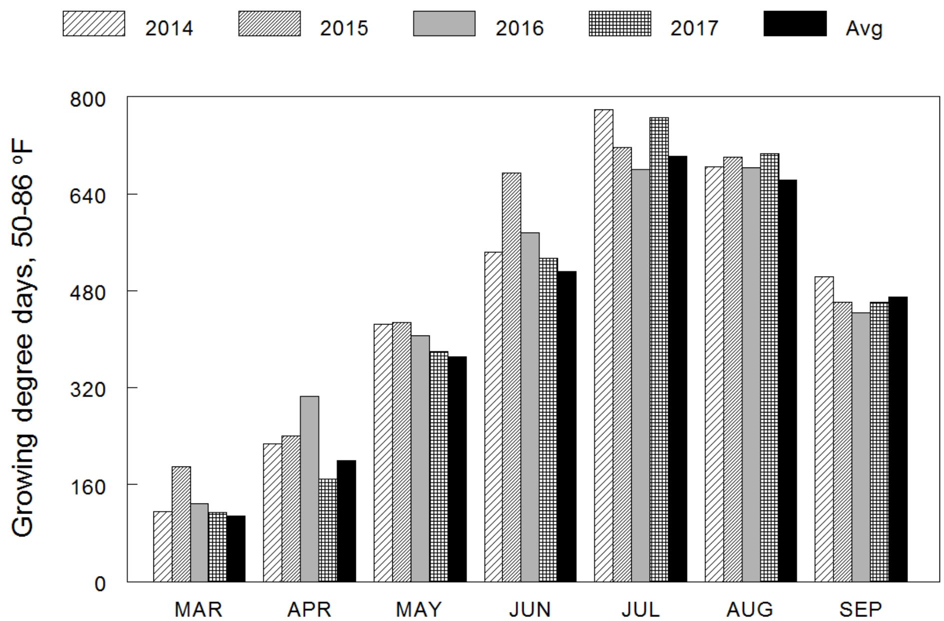

Figure 2. Monthly growing degree-days (50-86°F) for 2014-2017 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

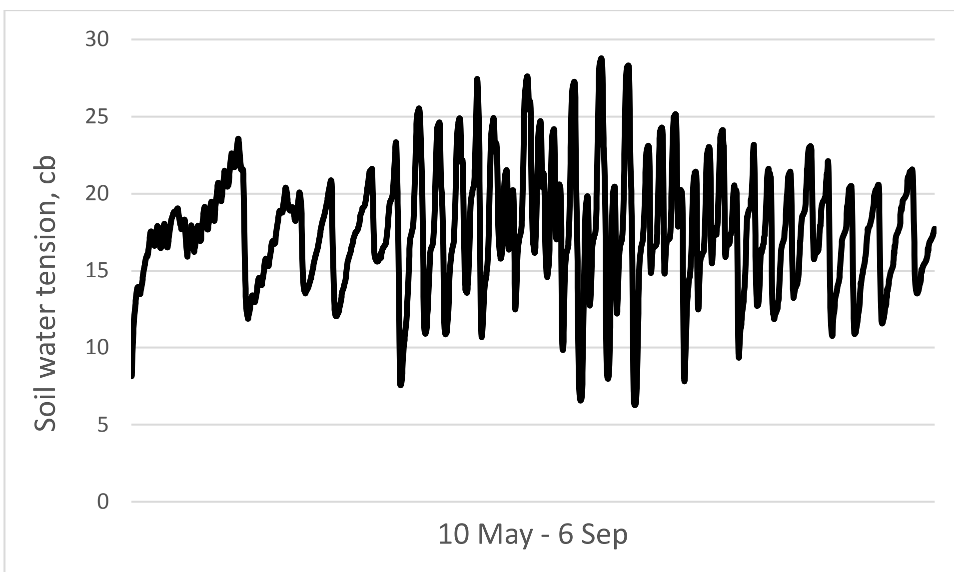

Figure 3. Soil water tension at 8-inch depth below the onion row. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Table 5. Bulb quality 2 weeks after harvest for early-maturing onion varieties lifted and harvested August 14, 2017, Malheur Experiment Station, Oregon State University, Ontario, OR.

Seed company	Variety	Maturity Aug. 11		Bulb quality 2 weeks after harvest			
		Tops down	Leaf dryness	sprouted	decomposed	sprouted and decomposed	total sprouted or decomposed
		%					
Crookham	Avalon	39	4	0.0	0.2	0.0	0.0
	Scout	41	4	0.0	0.7	0.0	0.7
Sakata	Great Western	50	10	0.5	0.2	0.0	0.7
	Spanish Medallion	43	5	0.0	0.4	0.0	0.4
	Average	43	6	0.1	0.4	0.0	0.4
LSD (0.05)		NS	3	NS	NS	NS	NS

Table 6. Single- and multiple-center bulb ratings for early-maturing onion varieties lifted and harvested August 14, 2017, Malheur Experiment Station, Oregon State University, Ontario, OR.

Seed company	Variety	Multiple center			Single center	
		large	medium	small	functional[a]	bullet
		%				
Crookham	Avalon	22.1	28.0	13.5	49.9	36.5
	Scout	14.3	27.2	20.5	58.5	38.0
Sakata	Great Western	21.3	28.8	12.3	49.9	37.6
	Spanish Medallion	11.8	23.0	21.8	65.2	43.4
	Average	17.4	26.8	17.0	55.9	38.9
LSD (0.05)		NS	NS	NS	NS	NS

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

Table 7. Yield and grade performance of early-maturing onion varieties lifted and harvested August 14, 2017, Malheur Experiment Station, Oregon State University, Ontario, OR.

Seed company	Variety	Total yield	Marketable yield by grade					Small	No. 2s	Total rot	Neck rot	Plate rot	Bulb counts >4¼ in
			Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in						
		---------- cwt/acre ----------								--------- % ---------			#/50 lb
Crookham	Avalon	1104.2	1094.8	40.6	376.6	658.8	18.9	7.3	0.0	0.0	0.0	0.0	31.5
	Scout	1122.4	1114.5	44.1	403.8	647.9	18.7	6.1	0.0	0.0	0.0	0.0	32.0
Sakata	Great Western	1018.8	977.4	29.9	222.1	680.5	44.9	16.8	4.3	0.0	0.0	0.0	32.6
	Spanish Medallion	1103.0	1094.5	81.7	398.8	590.2	23.8	8.6	0.0	0.0	0.0	0.0	31.1
	Average	1087.1	1070.3	49.1	350.3	644.4	26.6	9.7	1.1	0.0	0.0	0.0	31.8
LSD (0.05)		NS	88.4	NS	81.9	NS	17.4	NS	NS	NS	NS	NS	NS

Table 8. Maturity, bolting, and thrips leaf damage ratings of full-season onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Seed company	Variety	Bulb color	1-Aug Tops down	1-Aug Leaf dryness	15-Aug Tops down	15-Aug Leaf dryness	9-Aug Thrips leaf damage[a]
			%	%	%	%	0 - 10
A. Takii	Grand Perfection	Y	2	0	26	8	2.2
Bejo	Dawson	Y	6	0	58	10	2.6
	Delgado	Y	4	0	70	10	2.0
	Hamilton	Y	6	0	16	10	3.2
	Legend	Y	6	0	76	8	1.8
	Sedona	Y	0	0	16	10	2.8
Crookham	Avalon	Y	12	0	76	9	1.4
	Scout	Y	10	0	70	9	1.8
	Morpheus	Y	4	0	62	8	1.2
	Advantage	Y	0	0	24	7	1.4
	OLYX08-640	Y	18	0	82	16	3.6
	Red Devil	R	6	0	72	19	4.4
	Red Beret	R	4	4	62	22	4.2
	Purple Haze	R	0	0	30	22	4.6
	White Cloud	W	6	0	72	10	1.6
Enza Zaden	Caoba	Y	6	0	44	8	1.2
	10043	Y	6	0	70	8	1.0
	Monastrell	R	68	10	90	26	3.8
	10058	R	82	12	96	30	4.2
Hazera	Rhino	Y	2	0	82	9	1.8
New Zealand Onion	TAS016	R	2	6	22	28	5.0
	TAS018	R	64	10	90	26	4.0
	TAS027	R	46	10	86	22	4.0
	ROL221-222	R	8	10	30	34	5.2
	ROM223-224	R	0	4	18	32	4.8
Nunhems	Annillo	Y	4	0	26	10	2.6
	Arcero	Y	2	0	26	10	2.2
	Granero	Y	2	0	64	10	2.2
	Ranchero	Y	4	0	59	10	2.4
	Joaquin	Y	0	0	30	7	1.6
	Montero	Y	8	2	69	11	3.0
	Oloroso	Y	2	2	26	10	2.6
	Pandero	Y	0	0	32	9	2.0
	Vaquero	Y	4	0	52	10	1.8
	Salsa	R	2	2	22	22	4.4
	Marenge	R	6	2	56	20	3.4
Sakata	Aruba	Y	6	0	72	8	1.4
	Lasso	Y	10	0	70	9	1.0
	Dulce Reina	Y	4	0	54	8	1.2
	Yukon	Y	4	0	56	10	2.0
Seminis	Barbaro	Y	0	0	22	9	2.2
	Swale	Y	0	0	44	10	2.0
	Tucannon	Y	4	0	68	8	1.4
	16000	Y	4	0	60	9	1.4
	SV4058	W	2	0	44	10	2.0
	SV6646	Y	0	0	42	10	2.2
	SV6672	Y	2	0	38	10	1.8
	SV4643NT	R	24	8	83	28	4.0
D. Palmer	Saffron	Y	2	0	38	10	2.2
	Diamond Swan	W	0	0	36	9	1.8
	Cherry Mountain	R	6	0	54	13	3.4
Average			9	2	53	14	2.6
LSD (0.05)			8	3	11	4	0.7

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

Table 9. Single- and multiple-center ratings for full-season onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Seed company	Variety	Bulb color	Multiple center large	Multiple center medium	Multiple center small	Single center functional[a]	Single center bullet
			%	%	%	%	%
A. Takii	Grand Perfection	Y	16.0	22.0	20.0	62.0	42.0
Bejo	Dawson	Y	4.0	8.0	29.6	88.0	58.4
	Delgado	Y	21.6	34.4	21.6	44.0	22.4
	Hamilton	Y	25.6	20.8	23.2	53.6	30.4
	Legend	Y	32.8	35.2	21.6	32.0	10.4
	Sedona	Y	23.2	25.4	34.3	51.4	17.1
Crookham	Avalon	Y	21.9	23.8	25.3	54.3	29.1
	Scout	Y	22.9	27.9	20.4	49.2	28.8
	Morpheus	Y	4.8	4.8	13.6	90.4	76.8
	Advantage	Y	6.4	16.8	12.0	76.8	64.8
	OLYX08-640	Y	2.4	2.4	14.4	95.2	80.8
	Red Devil	R	4.0	5.6	12.0	90.4	78.4
	Red Beret	R	6.4	10.4	11.2	83.2	72.0
	Purple Haze	R	0.0	8.0	15.2	92.0	76.8
	White Cloud	W	24.0	26.4	21.6	49.6	28.0
Enza Zaden	Caoba	Y	36.0	29.6	20.0	34.4	14.4
	10043	Y	31.2	27.2	27.2	41.6	14.4
	Monastrell	R	18.4	32.0	34.4	49.6	15.2
	10058	R	26.0	32.0	37.0	42.0	5.0
Hazera	Rhino	Y	7.2	20.0	26.4	72.8	46.4
New Zealand Onion	TAS016	R	14.5	26.5	46.1	59.0	12.9
	TAS018	R	23.4	34.6	29.2	42.0	12.8
	TAS027	R	39.0	35.0	23.0	26.0	3.0
	ROL221-222	R	23.0	22.0	33.0	55.0	22.1
	ROM223-224	R	20.2	13.6	21.7	66.1	44.4
Nunhems	Annillo	Y	3.2	3.2	6.5	93.6	87.1
	Arcero	Y	3.0	3.0	11.0	94.0	83.0
	Granero	Y	5.6	20.0	20.8	74.4	53.6
	Ranchero	Y	15.2	17.6	29.6	67.2	37.6
	Joaquin	Y	1.6	9.1	22.4	89.3	66.9
	Montero	Y	2.7	5.3	8.0	92.0	84.0
	Oloroso	Y	1.3	0.0	12.0	98.7	86.7
	Pandero	Y	7.5	25.7	35.8	66.8	31.0
	Vaquero	Y	2.4	9.7	29.0	87.9	58.9
	Salsa	R	25.6	20.0	23.2	54.4	31.2
	Marenge	R	8.0	20.3	24.8	71.7	46.9
Sakata	Aruba	Y	12.0	11.2	15.2	76.8	61.6
	Lasso	Y	16.0	13.0	20.0	71.0	51.0
	Dulce Reina	Y	13.6	16.0	22.4	70.4	48.0
	Yukon	Y	19.2	19.2	30.4	61.6	31.2
Seminis	Barbaro	Y	0.8	8.1	17.4	91.1	73.8
	Swale	Y	14.3	17.0	28.7	68.7	39.9
	Tucannon	Y	3.0	7.8	16.8	89.2	72.4
	16000	Y	8.3	12.3	15.5	79.5	64.0
	SV4058	W	5.6	16.8	20.0	77.6	57.6
	SV6646	Y	4.0	16.0	20.0	80.0	60.0
	SV6672	Y	13.0	20.4	20.1	66.5	46.5
	SV4643NT	R	19.2	12.8	23.2	68.0	44.8
D. Palmer	Saffron	Y	22.4	27.2	32.8	50.4	17.6
	Diamond Swan	W	20.8	25.6	27.2	53.6	26.4
	Cherry Mountain	R	16.8	10.4	21.6	72.8	51.2
Average			14.1	17.9	22.5	68.0	45.5
LSD (0.05)			10.2	9.5	11.1	13.0	13.9

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

Table 10. Yield and grade of full-season experimental and commercial onion varieties graded out of storage in January 2018, Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on next page.

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
				Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in							
			cwt/acre								#/50 lb	% of total yield			
A. Takii	Grand Perfection	Y	1183	1157	235.7	469.7	431.7	20.0	7.7	2.7	31.8	1.4	1.2	0.2	0.0
Bejo	Dawson	Y	940	905	22.9	294.9	539.9	47.4	20.6	6.9	34.0	0.9	0.1	0.8	0.0
	Delgado	Y	1025	983	73.0	293.5	571.8	44.3	14.6	20.8	33.5	0.7	0.3	0.3	0.1
	Hamilton	Y	1011	980	56.5	306.2	571.4	45.8	11.0	16.8	31.7	0.3	0.3	0.0	0.0
	Legend	Y	921	879	8.6	202.3	642.1	26.0	9.0	22.4	35.0	1.1	0.8	0.1	0.1
	Sedona	Y	1102	1016	59.4	333.0	596.6	27.0	8.6	69.1	33.1	0.7	0.5	0.1	0.2
Crookham	Avalon	Y	1294	1047	205.1	360.9	450.0	31.1	9.5	10.7	28.9	17.6	10.3	0.1	7.2
	Scout	Y	1357	1243	323.5	506.1	394.9	18.0	7.4	11.1	28.8	7.1	3.4	0.2	3.5
	Morpheus	Y	1237	1203	202.0	503.0	469.3	28.2	6.4	6.0	31.8	1.8	1.4	0.1	0.2
	Advantage	Y	1193	1119	251.9	453.2	397.9	16.2	7.3	3.2	30.6	5.3	4.9	0.1	0.3
	OLYX08-640	Y	811	793	3.2	77.5	650.5	61.7	15.2	1.0	32.5	0.3	0.1	0.2	0.0
	Red Devil	R	606	571	0.0	18.3	457.0	95.9	21.3	7.0		1.3	0.9	0.2	0.2
	Red Beret	R	613	569	5.1	36.3	438.5	89.3	27.3	6.5	30.1	1.8	0.9	0.7	0.2
	Purple Haze	R	633	607	0.0	14.0	482.0	110.8	15.2	3.1		1.2	0.8	0.2	0.2
	White Cloud	W	1191	887	107.9	318.3	436.6	24.2	10.2	36.4	29.9	22.1	0.7	0.3	21.1
Enza Zaden	Caoba	Y	1104	1047	100.7	420.2	498.6	27.8	9.4	32.9	30.8	1.3	0.6	0.4	0.3
	10043	Y	1028	950	73.3	254.8	591.2	30.3	17.0	53.8	31.0	0.7	0.4	0.2	0.1
	Monastrell	R	655	498	6.7	30.4	400.8	60.1	15.6	34.9	31.1	16.8	15.2	0.0	1.6
	10058	R	688	531	5.5	19.5	405.9	100.6	22.7	63.2	28.3	11.6	11.2	0.2	0.2
Hazera	Rhino	Y	1047	1007	99.2	363.8	521.0	22.5	6.5	14.9	32.4	1.9	1.6	0.2	0.0
New Zealand Onion	TAS016	R	448	326	0.0	0.0	140.8	185.3	51.1	70.3		0.2	0.2	0.0	0.0
	TAS018	R	463	392	0.0	1.1	253.2	138.1	45.7	19.9		1.1	0.3	0.8	0.0
	TAS027	R	544	476	0.0	2.1	358.2	115.9	44.6	13.8		1.7	0.5	1.3	0.0
	ROL221-222	R	333	167	0.0	0.0	48.3	118.9	67.9	91.6		2.0	1.9	0.1	0.0
	ROM223-224	R	298	183	0.0	0.0	50.4	133.1	67.1	36.4		4.0	1.8	2.1	0.0

Table 10. (Continued) Yield and grade of full-season experimental and commercial onion varieties graded out of storage in January 2018, Malheur Experiment Station, Oregon State University, Ontario, OR.

Seed company	Variety	Bulb color	Total yield	Marketable yield by grade: 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
			cwt/acre								#/50 lb	% of total yield			
Nunhems	Annillo	Y	1032	1014	73.6	381.3	532.0	27.0	13.6	1.4	31.9	0.4	0.2	0.2	0.0
	Arcero	Y	1094	1073	111.9	410.4	522.4	28.5	16.0	2.4	30.6	0.2	0.1	0.1	0.0
	Granero	Y	1032	997	80.6	337.9	539.0	39.8	20.6	7.2	30.8	0.7	0.2	0.2	0.3
	Ranchero	Y	1249	1204	196.7	480.2	494.4	32.4	14.1	12.5	30.3	1.5	1.0	0.0	0.6
	Joaquin	Y	1268	1251	293.1	464.8	467.7	25.4	8.6	3.4	31.0	0.4	0.2	0.1	0.1
	Montero	Y	966	942	49.0	305.9	550.1	37.2	11.4	4.8	32.5	0.7	0.4	0.3	0.0
	Oloroso	Y	915	893	20.9	202.3	630.9	39.0	10.9	1.7	34.5	1.1	0.4	0.4	0.3
	Pandero	Y	1136	1097	170.6	457.1	441.1	28.5	10.0	15.1	31.6	1.2	0.4	0.6	0.2
	Vaquero	Y	1163	1134	181.3	446.3	468.8	38.1	16.7	4.2	29.7	0.7	0.2	0.1	0.4
	Salsa	R	637	495	0.0	41.5	387.4	65.9	43.8	83.3		2.5	1.7	0.8	0.0
	Marenge	R	739	698	0.0	17.3	612.1	68.2	20.0	16.3		0.7	0.5	0.1	0.1
Sakata	Aruba	Y	1123	1077	209.1	383.7	448.1	35.6	14.4	22.9	30.3	0.8	0.5	0.1	0.2
	Lasso	Y	1061	992	96.8	356.5	507.4	31.2	13.4	13.2	32.2	4.1	4.0	0.1	0.0
	Dulce Reina	Y	1243	1166	294.8	416.2	426.0	29.3	8.1	11.4	30.1	4.6	1.5	0.0	3.1
	Yukon	Y	1201	1115	231.8	440.5	426.0	16.6	8.8	42.6	29.9	3.0	2.2	0.1	0.8
Seminis	Barbaro	Y	1220	1198	373.8	418.4	382.5	23.8	9.6	0.0	29.3	1.0	0.4	0.6	0.0
	Swale	Y	1128	1086	168.8	398.8	490.6	28.0	13.6	9.6	31.2	1.7	0.5	0.7	0.5
	Tucannon	Y	1038	1002	127.5	333.1	501.6	39.5	11.4	15.6	31.5	0.9	0.2	0.2	0.5
	16000	Y	1187	1167	315.4	423.9	406.1	22.0	9.6	3.7	30.1	0.6	0.1	0.4	0.1
	SV4058	W	1091	984	127.8	350.2	483.0	23.0	9.5	6.9	31.1	8.4	2.2	0.3	5.9
	SV6646	Y	1210	1187	258.3	485.3	424.6	19.3	8.8	2.9	29.6	0.9	0.2	0.7	0.0
	SV6672	Y	1252	1204	315.5	444.0	419.5	24.6	10.3	10.1	28.6	2.3	0.9	0.2	1.2
	SV4643NT	R	674	574	3.0	50.4	455.6	64.8	24.2	60.6	34.5	2.7	1.4	1.3	0.0
D. Palmer	Saffron	Y	760	668	11.8	97.7	505.8	52.6	18.2	69.4	37.0	0.6	0.3	0.2	0.1
	Diamond Swan	W	1051	938	98.4	315.0	497.7	26.5	9.2	57.5	32.5	4.5	2.6	0.8	1.1
	Cherry Mountain	R	604	506	0.0	31.7	420.0	54.7	27.0	57.2		2.1	2.0	0.1	0.0
	average		957	886	110.8	270.0	455.7	49.8	18.1	23.4	31.4	3.0	1.7	0.3	1.0
LSD (0.05)			94	110	46.2	68.4	90.5	22.9	10.1	17.0	2.2	4.5	3.9	0.9	2.7

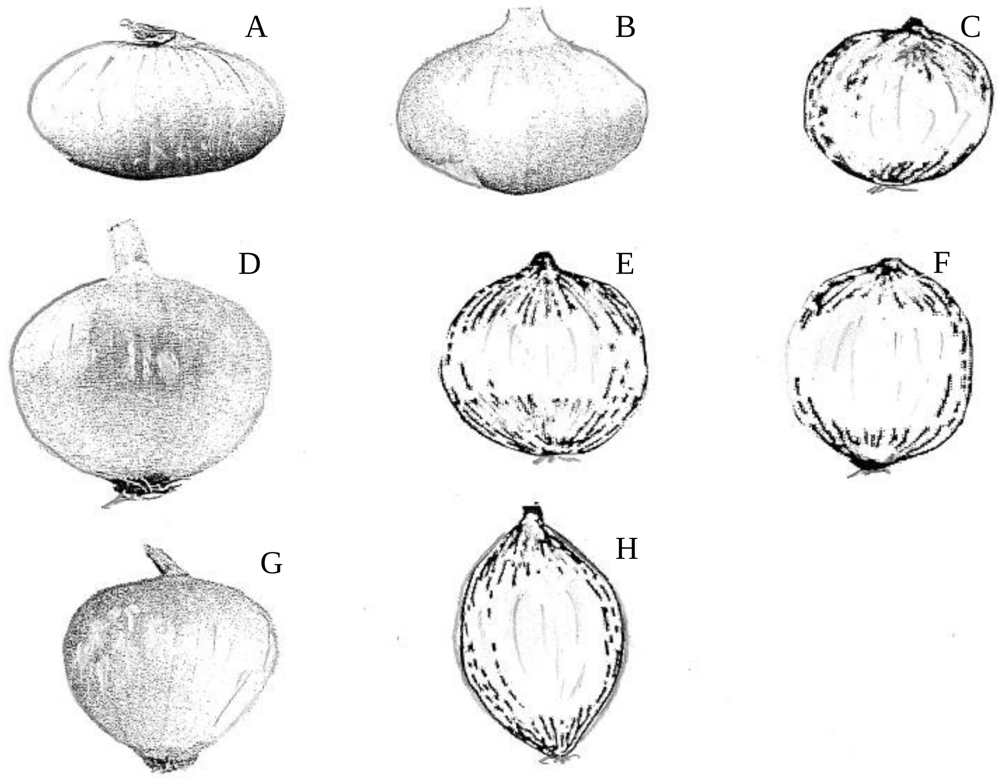

Figure 4. Onion bulb shape rating system (see Table 11). Malheur Experiment Station, Oregon State University, Ontario, OR.

Table 11. 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 12. 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 13. Subjective evaluations of onion appearance and firmness by variety on January 16, 2018, 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	e	3.0	3.8	4.5	3.5	4.0
Bejo	Dawson	Y	d	3.0	4.0	3.8	4.0	3.3
	Delgado	Y	d	3.8	4.0	3.5	4.5	3.5
	Hamilton	Y	d	4.0	4.0	5.0	5.0	4.0
	Legend	Y	d	3.3	3.8	4.0	4.0	3.3
	Sedona	Y	d	3.3	4.0	4.0	4.0	3.5
Crookham	Avalon	Y	c	2.0	2.5	1.5	2.5	4.0
	Scout	Y	d	1.5	2.5	2.3	2.0	3.8
	Morpheus	Y	d	2.3	3.5	3.3	3.5	4.8
	Advantage	Y	e	2.8	3.5	3.0	3.5	3.5
	OLYX08-640	Y	d	4.0	4.0	5.0	5.0	4.0
	Red Devil	R	d	3.0	3.4	3.0	3.0	2.8
	Red Beret	R	d	3.0	3.0	3.0	3.5	2.8
	Purple Haze	R	d	3.0	3.0	3.5	4.0	3.0
	White Cloud	W	d	3.8	4.0	3.0	3.0	3.0
Enza Zaden	Caoba	Y	d	4.0	4.0	4.5	3.8	3.5
	10043	Y	d	3.3	3.5	3.3	3.8	3.3
	Monastrell	R	c	4.0	4.0	3.0	3.0	2.0
	10058	R	a	3.0	4.0	3.0	2.0	3.0
Hazera	Rhino	Y	d	3.5	3.5	3.5	4.0	3.8
New Zealand Onion	TAS016	R	c	3.0	4.0	3.5	4.0	3.0
	TAS018	R	c	2.0	4.0	4.0	2.0	3.0
	TAS027	R	c	3.0	3.0	3.0	2.0	3.0
	ROL221-222	R	d	4.0	4.0	4.0	4.0	3.0
	ROM223-224	R	c	4.0	2.0	3.0	4.0	2.5
Nunhems	Annillo	Y	d	3.5	3.8	4.3	4.3	4.3
	Arcero	Y	d	3.5	4.5	4.0	3.5	4.0
	Granero	Y	d	3.3	4.0	4.1	3.5	3.3
	Ranchero	Y	d	3.0	3.0	3.0	2.8	3.5
	Joaquin	Y	e	3.5	4.0	3.8	4.3	4.0
	Montero	Y	d	3.0	3.0	3.0	3.3	3.6
	Oloroso	Y	d	4.0	4.0	4.0	4.0	4.3
	Pandero	Y	d	3.8	4.0	4.5	4.5	3.5
	Vaquero	Y	d	3.0	4.0	3.5	3.5	3.8
	Salsa	R	d	3.0	3.0	3.0	3.0	3.0
	Marenge	R	d	4.0	3.5	3.0	3.0	2.0
Sakata	Aruba	Y	d	2.0	2.8	2.5	3.0	4.4
	Lasso	Y	d	2.0	3.0	2.0	2.5	4.5
	Dulce Reina	Y	e	2.0	3.0	3.0	3.3	3.8
	Yukon	Y	e	2.5	3.0	2.5	3.5	4.3
Seminis	Barbaro	Y	d	3.0	4.0	3.8	4.0	4.0
	Swale	Y	d	2.5	3.3	3.5	3.5	4.0
	Tucannon	Y	d	4.0	2.0	4.0	4.0	4.5
	16000	Y	e	2.5	3.8	3.8	3.3	4.5
	SV4058	W	d	2.5	3.5	3.3	3.5	4.0
	SV6646	Y	d	3.0	4.0	4.0	4.0	3.5
	SV6672	Y	f	3.0	3.0	3.0	3.0	3.5
	SV4643NT	R	d	4.0	4.0	4.3	4.0	3.0
D. Palmer	Saffron	Y	f	4.3	2.8	5.0	5.0	3.0
	Diamond Swan	W	d	2.5	4.0	4.0	4.0	3.0
	Cherry Mountain	R	d	2.0	3.0	2.0	4.0	4.0
Average			d	3.1	3.5	3.5	3.6	3.5
LSD (0.05)			0.9[c]	0.6	NS	0.6	0.7[c]	0.7

[a]Bulb shape: see Fig. 4. [b]Subjective ratings are described in Table 12. [c]LSD (0.10)

Table 14. Internal defects of full-season experimental and commercial onion varieties evaluated out of storage in January 2018, 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	68.4	0.4	68.8	26.8	4.4	31.2	100	0.0	0.0	0.0	0.0	1.2	1.2	1.2
Bejo	Dawson	Y	43.6	0.0	43.6	46.8	9.6	56.4	100	0.0	0.0	0.0	0.0	0.8	0.8	0.8
	Delgado	Y	54.8	0.0	54.8	38.0	7.2	45.2	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hamilton	Y	49.2	1.2	50.4	32.0	17.6	49.6	100	0.0	0.0	0.0	0.8	0.8	1.6	1.6
	Legend	Y	33.2	0.4	33.6	54.8	11.6	66.4	100	0.4	0.0	0.4	0.0	1.2	1.2	1.6
	Sedona	Y	66.0	0.4	66.4	23.6	10.0	33.6	100	0.0	0.0	0.0	0.4	0.0	0.4	0.4
Crookham	Avalon	Y	57.4	0.4	57.8	35.6	6.6	42.2	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Scout	Y	45.5	1.2	46.7	43.7	9.6	53.3	100	0.0	0.0	0.0	0.8	0.0	0.8	0.8
	Morpheus	Y	60.0	0.4	60.4	29.6	10.0	39.6	100	2.0	0.0	2.0	0.0	0.0	0.0	2.0
	Advantage	Y	86.4	0.0	86.4	11.5	2.1	13.6	100	1.8	0.0	1.8	0.0	0.0	0.0	1.8
	OLYX08-640	Y	33.9	0.4	34.3	45.6	20.0	65.7	100	0.0	0.0	0.0	1.6	0.0	1.6	1.6
	Red Devil	R	22.8	0.4	23.2	56.0	20.8	76.8	100	0.0	0.0	0.0	1.2	0.0	1.2	1.2
	Red Beret	R	39.2	0.0	39.2	46.4	14.4	60.8	100	0.0	0.0	0.0	0.0	1.2	1.2	1.2
	Purple Haze	R	21.2	0.0	21.2	65.6	13.2	78.8	100	0.4	0.0	0.4	0.0	2.0	2.0	2.4
	White Cloud	W	51.1	0.4	51.5	42.5	6.0	48.5	100	0.0	0.0	0.0	0.4	0.8	1.2	1.2
Enza Zaden	Caoba	Y	54.4	0.8	55.2	37.6	7.2	44.8	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10043	Y	87.6	0.0	87.6	11.2	1.2	12.4	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Monastrell	R	11.6	0.4	12.0	77.6	10.4	88.0	100	0.8	0.0	0.8	0.0	0.0	0.0	0.8
	10058	R	7.2	0.0	7.2	90.0	2.8	92.8	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hazera	Rhino	Y	27.6	0.0	27.6	52.0	20.4	72.4	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
N. Zealand Onion	TAS016	R	46.4	0.0	46.4	41.6	12.0	53.6	100	0.0	0.0	0.0	0.4	3.6	4.0	4.0
	TAS018	R	19.7	0.0	19.7	77.1	3.2	80.3	100	0.0	0.0	0.0	0.4	0.8	1.2	1.2
	TAS027	R	16.8	0.0	16.8	73.2	10.0	83.2	100	0.0	0.0	0.0	0.4	1.2	1.6	1.6
	ROL221-222	R	34.8	0.0	34.8	38.4	26.8	65.2	100	0.0	0.0	0.0	0.0	11.2	11.2	11.2
	ROM223-224	R	39.5	0.0	39.5	35.0	25.5	60.5	100	0.0	0.0	0.0	0.0	12.0	12.0	12.0

Table 14. (Continued) Internal defects of full-season experimental and commercial onion varieties evaluated out of storage in January 2018, 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	18.0	0.0	18.0	54.4	27.6	82.0	100	0.8	0.0	0.8	1.2	1.6	2.8	3.6
	Arcero	Y	37.6	0.8	38.4	38.4	23.2	61.6	100	0.8	0.0	0.8	0.0	0.8	0.8	1.6
	Granero	Y	42.4	0.4	42.8	45.6	11.6	57.2	100	0.4	0.0	0.4	0.8	0.0	0.8	1.2
	Ranchero	Y	64.0	1.6	65.6	28.0	6.4	34.4	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	Joaquin	Y	66.8	1.7	68.5	25.1	6.4	31.5	100	0.0	0.0	0.0	0.4	0.4	0.8	0.8
	Montero	Y	18.8	0.8	19.6	46.8	33.6	80.4	100	0.0	0.0	0.0	0.4	1.6	2.0	2.0
	Oloroso	Y	34.4	0.0	34.4	47.2	18.4	65.6	100	0.0	0.0	0.0	0.4	2.4	2.8	2.8
	Pandero	Y	40.0	0.4	40.4	39.2	20.4	59.6	100	0.0	0.0	0.0	0.4	0.0	0.4	0.4
	Vaquero	Y	36.0	4.0	40.0	48.0	12.0	60.0	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	Salsa	R	18.8	0.0	18.8	69.6	11.6	81.2	100	0.4	0.0	0.4	0.4	3.6	4.0	4.4
	Marenge	R	3.2	0.0	3.2	73.6	23.2	96.8	100	0.4	0.0	0.4	2.4	1.2	3.6	4.0
Sakata	Aruba	Y	43.6	0.8	44.4	34.0	21.6	55.6	100	0.4	0.0	0.4	0.0	0.4	0.4	0.8
	Lasso	Y	48.8	0.0	48.8	30.8	20.4	51.2	100	0.4	0.0	0.4	0.0	0.0	0.0	0.4
	Dulce Reina	Y	66.0	0.0	66.0	28.0	6.0	34.0	100	0.0	0.0	0.0	0.4	0.4	0.8	0.8
	Yukon	Y	56.0	0.0	56.0	31.6	12.4	44.0	100	5.6	0.0	5.6	0.0	0.4	0.4	6.0
Seminis	Barbaro	Y	56.4	1.2	57.6	36.0	6.4	42.4	100	0.0	0.0	0.0	1.2	0.8	2.0	2.0
	Swale	Y	56.0	0.4	56.4	34.4	9.2	43.6	100	0.4	0.0	0.4	0.0	0.0	0.0	0.4
	Tucannon	Y	62.4	1.6	64.0	24.4	11.6	36.0	100	0.8	0.0	0.8	0.0	0.8	0.8	1.6
	16000	Y	60.0	0.4	60.4	27.6	12.0	39.6	100	0.0	0.0	0.0	0.0	0.4	0.4	0.4
	SV4058	W	55.6	0.4	56.0	32.0	12.0	44.0	100	2.8	0.0	2.8	1.2	5.2	6.4	9.2
	SV6646	Y	55.8	0.0	55.8	35.3	8.9	44.2	100	0.4	0.0	0.4	0.4	0.0	0.4	0.8
	SV6672	Y	56.0	0.0	56.0	36.0	8.0	44.0	100	0.0	0.0	0.0	0.4	0.0	0.4	0.4
	SV4643NT	R	10.4	0.0	10.4	76.0	13.6	89.6	100	0.0	0.0	0.0	1.2	1.6	2.8	2.8
D. Palmer	Saffron	Y	29.2	0.4	29.6	38.0	32.4	70.4	100	0.0	0.0	0.0	0.4	0.4	0.8	0.8
	Diamond Swan	W	63.2	1.2	64.4	29.2	6.4	35.6	100	0.0	0.0	0.0	0.0	1.6	1.6	1.6
	Cherry Mountain	R	20.4	0.8	21.2	47.2	31.6	78.8	100	0.4	0.0	0.4	0.0	0.8	0.8	1.2
	average		43.1	0.5	43.6	42.9	13.5	56.4	100	0.4	0.0	0.4	0.4	1.2	1.6	2.0
LSD (0.05)			17.5	1.6	17.7	16.0	11.6	17.7		NS	NS	NS	1.2	2.4	2.4	3.4

Table 15. Internal decomposition by disease type of full-season experimental and commercial onion varieties evaluated out of storage in January 2018, 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	0.0	0.8
Bejo	Dawson	Y	0.0	0.0	0.0	0.8
	Delgado	Y	0.0	0.0	0.0	0.0
	Hamilton	Y	0.0	0.4	0.0	1.2
	Legend	Y	0.4	0.0	0.0	1.2
	Sedona	Y	0.0	0.4	0.0	0.0
Crookham	Avalon	Y	0.0	0.0	0.0	0.0
	Scout	Y	0.0	0.0	0.8	0.0
	Morpheus	Y	0.0	0.0	0.8	1.2
	Advantage	Y	0.0	0.0	1.4	0.4
	OLYX08-640	Y	0.0	0.4	0.4	0.8
	Red Devil	R	0.0	0.8	0.0	0.4
	Red Beret	R	0.0	0.0	0.0	1.2
	Purple Haze	R	0.8	0.4	0.0	1.2
	White Cloud	W	0.4	0.4	0.0	0.4
Enza Zaden	Caoba	Y	0.0	0.0	0.0	0.0
	10043	Y	0.0	0.0	0.0	0.0
	Monastrell	R	0.4	0.0	0.4	0.0
	10058	R	0.0	0.0	0.0	0.0
Hazera	Rhino	Y	0.4	0.0	0.0	0.0
New Zealand Onion	TAS016	R	0.0	0.0	0.0	4.0
	TAS018	R	0.4	0.0	0.0	0.8
	TAS027	R	0.8	0.0	0.4	0.4
	ROL221-222	R	0.0	0.0	0.0	11.2
	ROM223-224	R	1.5	0.0	0.0	10.5

Table 15. (Continued) Internal decomposition by disease type of full-season experimental and commercial onion varieties evaluated out of storage in January 2018, Malheur Experiment Station, Oregon State University, Ontario, OR.

Seed company	Variety	Bulb color	Bacterial rot	*Fusarium proliferatum*	Neck rot	Black mold
			------------------------------ % -----------------------------			
Nunhems	Annillo	Y	0.4	0.8	1.2	1.2
	Arcero	Y	0.8	0.0	0.0	0.8
	Granero	Y	0.0	0.4	0.4	0.4
	Ranchero	Y	0.0	0.4	0.0	0.0
	Joaquin	Y	0.0	0.0	0.4	0.4
	Montero	Y	0.4	0.0	0.0	1.6
	Oloroso	Y	0.0	0.4	0.0	2.4
	Pandero	Y	0.0	0.0	0.4	0.0
	Vaquero	Y	0.0	0.0	0.0	0.4
	Salsa	R	0.4	0.0	0.4	3.6
	Marenge	R	0.0	0.0	0.8	3.2
Sakata	Aruba	Y	0.0	0.4	0.4	0.0
	Lasso	Y	0.4	0.0	0.0	0.0
	Dulce Reina	Y	0.4	0.0	0.0	0.4
	Yukon	Y	5.6	0.4	0.0	0.0
Seminis	Barbaro	Y	1.6	0.0	0.0	0.4
	Swale	Y	0.4	0.0	0.0	0.0
	Tucannon	Y	1.2	0.0	0.0	0.4
	16000	Y	0.0	0.4	0.0	0.0
	SV4058	W	8.4	0.8	0.0	0.0
	SV6646	Y	0.8	0.0	0.0	0.0
	SV6672	Y	0.4	0.0	0.0	0.0
	SV4643NT	R	0.4	0.0	0.0	2.4
D. Palmer	Saffron	Y	0.0	0.0	0.0	0.8
	Diamond Swan	W	1.2	0.0	0.0	0.4
	Cherry Mountain	R	0.0	0.0	0.4	0.8
	average		0.6	0.1	0.2	1.1
LSD (0.05)			2.4	NS	NS	2.1

ONION PRODUCTION FROM TRANSPLANTS IN 2017

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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 onions are available locally, which is important for onion processors. Onion varieties suitable for processing into onion rings must be highly single centered, produce large bulbs, and store well. Previous Treasure Valley research showed that when onions are grown from transplants, they can be harvested starting in July (Shock et al. 2004, 2007-2009, and 2011-2017). This trial evaluated eight onion varieties potentially suitable for processing grown from transplants in 2017. Six varieties were grown from transplants produced in a greenhouse at the Oregon State University Malheur Experiment Station (MES), in Ontario, Oregon and two 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 ‘Salute’ (Crookham Co., Caldwell, ID), ‘Avalon’ (Crookham Co.), ‘Avenger’ (Crookham Co.), ‘Minister’ (Seminis, Payette, ID), ‘Chancellor’ (Seminis), and 903S (New Zealand Onion) was planted in the greenhouse on January 27, 2017 in flats with a vacuum seeder at 72 seeds/flat. The seed was sown on a 1-inch layer of Sunshine general purpose potting mix. 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 6. Transplants were grown without supplemental light. Bare-rooted transplants of ‘Montero’ (Nunhems, Parma, ID) and SV0106NG (Seminis) were grown in Arizona during the winter of 2016-2017.

Onions were grown at MES on an Owyhee silt loam previously planted to wheat. In the fall of 2016, 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 2016 showed a pH of 8.2, 3.7% organic matter, 4 ppm nitrogen (N) as nitrate, 3 ppm N as ammonium, 15 ppm phosphorus (P), 395 ppm potassium (K), 9 ppm sulfur (S), 3774 ppm calcium, 549 ppm magnesium, 208 ppm sodium, 0.6 ppm zinc (Zn), 17 ppm manganese (Mn), 0.4 ppm copper (Cu), 47 ppm iron, and 0.5 ppm boron (B). Based on the soil analysis, 55 lb of P/acre, 200 lb of S/acre, 1 lb Cu/acre, 9 lb Zn/acre, and 1 lb of B/acre were broadcast before plowing. In addition to the fertilizer, 10 tons 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 Salute, Avalon, Avenger, Minister, Chancellor and 903S were transplanted on April 5. Variety Montero was transplanted on April 17 and variety SV0106NG was transplanted on April 18. The onions were transplanted on four 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 avoid yield reductions from weeds, pests, diseases, water stress, and nutrient deficiencies. Prowl® H_2O at 2 pt/acre and Poast® at 2 pt/acre were broadcast for weed control on April 25. Thrips were controlled by ground application using the following insecticides: Aza-Direct® at 12 oz/acre and Movento® at 5 oz/acre on May 11 and 23, Radiant® at 10 oz/acre on June 2. Thrips were controlled by aerial application using the following insecticides: Radiant at 10 oz/acre on July 1, 8, and 30, and Lannate® at 3 pt/acre on July 17 and 23.

A total of 90 lb N/acre was applied in 20-lb increments during the season as urea ammonium nitrate solution (URAN) injected through the drip tape. Five pounds of P/acre, 11 lb of K/acre, and 0.5 lb of Mn/acre were applied on May 23 through the drip tape based on root tissue and soil solution analyses.

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 19 and terminated on August 3.

Bolted onions were counted in each plot on July 27. On July 20, 27, and August 3, bulbs from 6 ft of the middle 2 double rows in each plot were topped and bagged. Variety Avenger started maturing earlier than the other varieties and harvest began 1 week earlier. 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, a sample of approximately 100 No. 1 jumbo bulbs of each variety was placed in crates and stored in a shed at ambient temperature for 2 weeks. After 2 weeks the samples were evaluated for the number of sprouted or decomposed bulbs.

Onion bulbs from all harvests were rated for single centers. Twenty-five onions ranging in diameter from 3½ to 4¼ inches from each plot were rated. 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 13 Harvest - Avenger

Marketable yield on July 13 for variety Avenger averaged 1076 cwt/acre (Table 1). The percentage of functionally single-centered bulbs averaged 86.4% (Table 2). The percentage of tops down at harvest averaged 99% and bulb decomposition or sprouting after 2 weeks of storage averaged 2% (Table 3).

July 20 Harvest

Marketable yield on July 20 averaged 975 cwt/acre and ranged from 537 cwt/acre for 903S to 1172 cwt/acre for Minister (Table 1). The percentage of functionally single-centered bulbs averaged 73.5% and ranged from 46% for 903S to 98.4% for Avalon (Table 2). The percentage of tops down at harvest averaged 57% and ranged from 22% for Montero to 100% for Avenger (Table 3). Bulb decomposition or sprouting after 2 weeks of storage averaged 5% and ranged from 1.3% for 903S to 7.5% for Chancellor. Bolting averaged 1% and ranged from 0% for Avenger and Minister to 4.3% for Avalon (Table 1).

July 27 Harvest

Marketable yield on July 27 averaged 1090 cwt/acre and ranged from 615 cwt/acre for 903S to 1314 cwt/acre for Minister (Table 1). The percentage of functionally single-centered bulbs averaged 70.9% and ranged from 44% for 903S to 94% for Avalon (Table 2). The percentage of tops down at harvest averaged 79% and ranged from 64% for Salute to 100% for Avenger (Table 3). Bulb decomposition or sprouting after 2 weeks of storage averaged 3% and ranged from 0.3% for 903S to 15% for Avalon.

August 3 Harvest

Marketable yield on August 3 averaged 1161 cwt/acre and ranged from 593 cwt/acre for 903S to 1385 cwt/acre for Minister (Table 1). The percentage of functionally single-centered bulbs averaged 61% and ranged from 35% for SV0106NG to 93% for Avalon (Table 2). The percentage of tops down at harvest averaged 85% and ranged from 74% for Chancellor to 98% for Minister (Table 3). Bulb decomposition or sprouting after 2 weeks of storage averaged 1.1% and ranged from 0% for Minister and 903S to 3% for Salute.

Overall

In 2017, the accumulated number of growing degree-days was higher than the 24-year average, but was the lowest of the years 2014-2017 (Table 4). For comparison, performance data for varieties Avalon and Montero, which were in the transplant trials in 2014-2017 is presented in Table 5.

Acknowledgements

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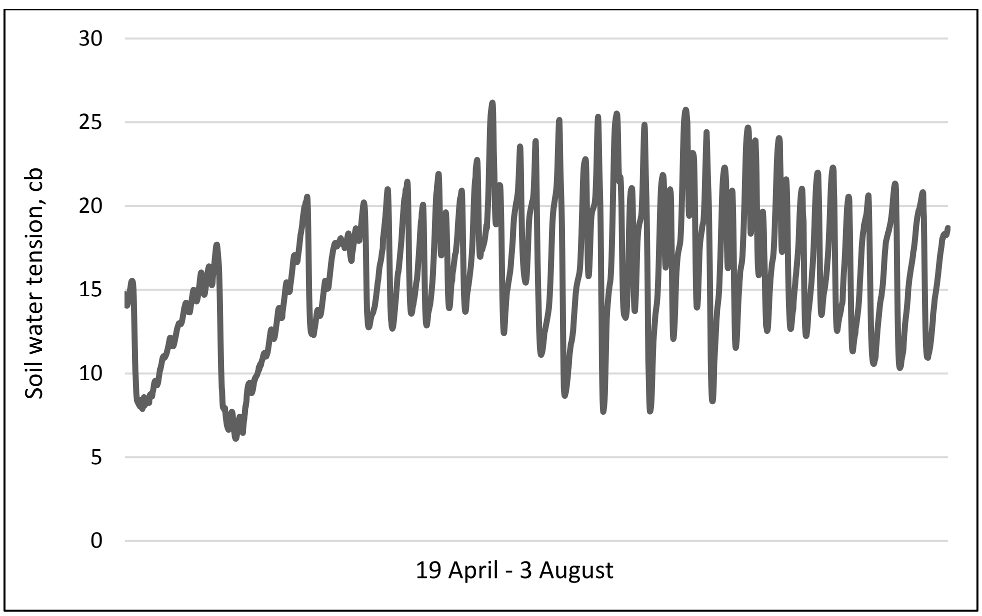

Figure 1. Soil water tension at 8-inch depth. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Table 1. Bulb yield and grade for seven yellow onion varieties and one red variety (903S) grown from transplants over three harvest dates, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. Continued on next page.

Company	Variety	Total yield	Marketable yield by grade Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Small	Doubles	Total rot	Plate rot	Slime rot	Bulb counts >4¼ in
		cwt/acre								%			#/50 lb
					July 13 harvest								
Crookham	Avenger[a]	1079	1076	73.3	357.0	626.9	18.6	3.3	0.0	0.0	0.0	0.0	30.0
					July 20 harvest								
Crookham	Avenger	1150	1139	87.1	464.2	579.0	8.2	1.9	0.0	0.9	0.0	0.9	33.3
	Salute	1130	1128	151.0	498.8	468.3	10.2	0.3	0.0	0.2	0.0	0.2	31.3
	Avalon	928	919	40.7	282.2	580.6	15.2	5.3	0.0	0.4	0.0	0.4	34.1
Nunhems	Montero	778	768	0.0	69.9	656.1	41.7	10.3	0.0	0.0	0.0	0.0	
Seminis	Minister (2102)	1172	1163	128.9	565.0	465.1	4.3	1.6	0.0	0.6	0.0	0.6	34.1
	Chancellor (9131)	953	949	25.2	276.8	637.6	9.2	0.6	1.7	0.2	0.0	0.2	34.6
	SV0106NG	1151	1148	84.6	454.4	594.6	13.9	2.5	1.0	0.0	0.0	0.0	33.9
N. Zealand Onion	903S	537	516	0.0	5.1	367.4	143.1	21.6	0.0	0.0	0.0	0.0	
	Average	950	941	61.5	307.5	538.5	33.9	6.0	0.4	0.2	0.0	0.2	33.6
					July 27 harvest								
Crookham	Avenger	1233	1202	260.1	495.2	441.2	5.7	1.8	0.0	2.3	0.6	1.7	31.8
	Salute	1287	1249	178.3	615.3	451.4	3.5	2.8	0.0	2.8	0.0	2.8	30.1
	Avalon	1138	1111	46.7	528.5	523.7	11.9	4.8	0.0	1.8	0.0	1.8	33.1
Nunhems	Montero	857	841	0.0	109.8	707.5	24.1	9.7	0.0	0.7	0.0	0.7	
Seminis	Minister (2102)	1314	1309	140.9	577.1	587.1	3.7	0.0	0.0	0.4	0.0	0.4	30.4
	Chancellor (9131)	1094	1087	34.3	351.6	694.0	7.3	4.8	0.0	0.2	0.0	0.2	31.5
	SV0106NG	1184	1176	86.1	496.7	577.9	15.8	3.0	0.0	0.5	0.0	0.5	31.6
N. Zealand Onion	903S	615	602	0.0	1.5	450.4	149.9	11.9	0.0	0.2	0.0	0.2	
	Average	1070	1054	69.5	382.9	570.3	30.9	5.3	0.0	0.9	0.0	0.9	31.4
					August 3 harvest								
Crookham	Salute	1347	1330	412.0	560.1	354.8	3.5	0.0	0.0	1.2	0.1	1.1	30.2
	Avalon	1291	1278	375.8	568.2	320.1	13.4	8.5	0.0	0.4	0.2	0.2	30.9
Nunhems	Montero	964	947	37.4	239.2	646.3	24.6	12.5	0.0	0.5	0.5	0.0	32.6
Seminis	Minister (2102)	1385	1352	357.8	565.8	424.6	3.7	0.0	0.0	1.8	0.0	1.8	30.4
	Chancellor (9131)	1197	1178	112.1	476.9	578.5	10.4	4.2	0.0	0.6	0.0	0.6	31.1
	SV0106NG	1352	1340	317.4	575.8	437.5	8.9	5.3	0.0	0.2	0.0	0.2	30.4
N. Zealand Onion	903S	593	572	0.0	0.0	447.3	124.5	21.0	0.0	0.0	0.0	0.0	
	Average	1161	1142	230.3	426.6	458.4	27.0	7.4	0.0	0.7	0.1	0.6	30.9

[a] Data for Avenger were not included in the statistical analysis.

Table 1. (Continued). Bulb yield and grade for seven yellow onion varieties and one red variety (903S) grown from transplants over three harvest dates, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Company	Variety	Total yield	Marketable yield by grade: Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Small	Doubles	Total rot	Plate rot	Slime rot	Bulb counts >4¼ in
			---- cwt/acre ----							---- % ----			#/50 lb
			Average over harvest dates										
Crookham	Avenger[a]	1154	1139	140.2	438.8	549.1	10.8	2.4	0.0	1.1	0.5	0.6	30.7
	Salute	1255	1236	247.1	558.1	424.8	5.7	1.0	0.0	1.4	0.1	1.3	31.2
	Avalon	1119	1102	154.4	459.6	474.8	13.5	6.2	0.0	0.8	0.2	0.7	32.1
Nunhems	Montero	867	852	12.5	139.6	670.0	30.1	10.9	0.0	0.4	0.2	0.2	32.6
Seminis	Minister (2102)	1296	1275	209.2	569.3	492.3	3.9	0.5	0.0	0.9	0.2	0.7	30.8
	Chancellor (9131)	1081	1071	57.2	368.4	636.7	9.0	3.2	1.7	0.3	0.1	0.3	32.2
	SV0106NG	1229	1221	162.7	509.0	536.6	12.9	3.6	1.0	0.2	0.0	0.2	31.6
N. Zealand Onion	903S	582	563	0.0	2.2	421.7	139.2	18.2	0.0	0.1	0.0	0.1	
LSD (0.05) Variety		89.6	93.9	83.4	66.8	79.2	13.4	5.5	NS	NS	NS	NS	NS
LSD (0.05) Date		34.5	34.3	26.5	44.9	38.7	NS	NS	NS	NS	NS	NS	NS
LSD (0.05) Variety x date		91.1	90.9	70.0	118.7	59.1	NS	NS	NS	NS	NS	NS	NS

[a] Data for Avenger were not included in the statistical analysis.

Table 2. Single and multiple bulb centers, and bolting for seven yellow onion varieties and one red variety (903S) grown from transplants over three harvest dates, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

		Multiple center			Single center		
Company	Variety	large	medium	small	functional[a]	bullet	Bolters
		-------------------- % ---------------------					
		July 13 harvest					
Crookham	Avenger	0.0	13.6	45.6	86.4	40.8	
		July 20 harvest					
Crookham	Avenger	0.0	17.8	54.5	82.2	27.7	
	Salute	8.8	37.6	44.0	53.6	9.6	
	Avalon	0.8	0.8	12.0	98.4	86.4	
Nunhems	Montero	0.8	5.6	20.0	93.6	73.6	
Seminis	Minister	3.2	33.6	57.6	63.2	5.6	
	Chancellor	0.0	8.0	38.0	92.0	54.1	
	SV0106NG	0.8	31.2	62.4	68.0	5.6	
N. Zealand Onion	903S	2.0	52.0	46.0	46.0	0.0	
	Average	2.3	24.1	40.0	73.5	33.6	
		July 27 harvest					
Crookham	Avenger	2.4	15.2	53.6	82.4	28.8	0.0
	Salute	10.4	39.2	37.6	50.4	12.8	1.7
	Avalon	0.8	4.8	8.0	94.4	86.4	4.3
Nunhems	Montero	0.8	8.8	15.2	90.4	75.2	0.6
Seminis	Minister	2.9	28.7	54.0	68.4	14.4	0.0
	Chancellor	0.0	17.6	43.2	82.4	39.2	1.1
	SV0106NG	2.4	31.2	52.8	66.4	13.6	0.1
N. Zealand Onion	903S	8.0	48.0	40.0	44.0	4.0	0.1
	Average	3.6	25.5	35.8	70.9	35.1	1.1
		August 3 harvest					
Crookham	Salute	24.0	36.0	25.6	40.0	14.4	
	Avalon	2.4	4.8	17.3	92.8	75.5	
Nunhems	Montero	0.8	8.8	26.4	90.4	64.0	
Seminis	Minister	12.8	45.6	38.4	41.6	3.2	
	Chancellor	3.2	19.2	36.8	77.6	40.8	
	SV0106NG	8.8	56.0	35.2	35.2	0.0	
N. Zealand Onion	903S	6.4	48.0	41.6	45.6	4.0	
	Average	8.3	31.2	31.6	60.5	28.8	
		Average over harvest dates					
Crookham	Avenger	0.8	15.5	51.2	83.7	32.4	
	Salute	14.4	37.6	35.7	48.0	12.3	
	Avalon	1.3	3.5	12.4	95.2	82.8	
Nunhems	Montero	0.8	7.7	20.5	91.5	70.9	
Seminis	Minister	6.3	36.0	50.0	57.7	7.7	
	Chancellor	1.1	14.9	39.3	84.0	44.7	
	SV0106NG	4.0	39.5	50.1	56.5	6.4	
N. Zealand Onion	903S	5.7	49.1	42.3	45.1	2.9	
LSD (0.05) Variety		4.3	7.6	6.5	7.7	6.6	2.0
LSD (0.05) Date		2.2	NS	5.3	4.9	4.1	
LSD (0.05) Variety X Date		5.8	13.0	14.0	13.1	NS	

[a]Functional single centers are the small multiple centers plus the bullet single centers.
[b]Bolted onions were counted in each plot on July 27.

Table 3. Maturity at harvest and bulb quality 2 weeks after harvest for seven yellow onion varieties and one red variety (903S) grown from transplants over three harvest dates, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

		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 13 harvest			
Crookham	Avenger	99	16	0.7	1.3	0.0	2.1
				July 20 harvest			
Crookham	Avenger	100	28	0.0	7.0	0.0	7.0
	Salute	46	10	3.4	3.3	0.0	6.7
	Avalon	30	8	0.0	7.2	0.0	7.2
Nunhems	Montero	22	12	1.8	0.7	0.0	2.5
Seminis	Minister	84	22	0.0	1.4	0.0	1.4
	Chancellor	38	10	4.2	3.3	0.0	7.5
	SV0106NG	78	10	0.6	5.3	0.0	5.9
N. Zealand Onion	903S	58	32	0.5	0.9	0.0	1.3
	Average	51	15	1.5	3.2	0.0	4.7
				July 27 harvest			
Crookham	Avenger	100	32	0.0	2.3	0.0	2.3
	Salute	64	22	1.3	0.0	0.0	1.3
	Avalon	66	14	8.6	6.5	0.0	15.1
Nunhems	Montero	70	24	0.6	3.5	0.0	4.1
Seminis	Minister	90	24	0.0	1.3	0.0	1.3
	Chancellor	68	18	0.0	0.6	0.0	0.6
	SV0106NG	88	24	0.0	0.6	0.0	0.6
N. Zealand Onion	903S	84	38	0.0	0.3	0.0	0.3
	Average	76	23	1.5	1.8	0.0	3.4
				August 3 harvest			
Crookham	Salute	80	24	0.8	2.2	0.0	3.0
	Avalon	78	16	1.5	0.8	0.0	2.3
Nunhems	Montero	80	30	0.0	1.1	0.0	1.1
Seminis	Minister	98	28	0.0	0.0	0.0	0.0
	Chancellor	74	24	0.0	0.7	0.0	0.7
	SV0106NG	93	26	0.0	0.7	0.0	0.7
N. Zealand Onion	903S	92	42	0.0	0.0	0.0	0.0
	Average	85	27	0.3	0.8	0.0	1.1
				Average over harvest dates			
Crookham	Avenger	100	25	0.2	3.5	0.0	3.8
	Salute	63	19	1.8	1.9	0.0	3.7
Crookham	Avalon	58	13	3.4	4.8	0.0	8.2
Nunhems	Montero	57	22	0.8	1.7	0.0	2.6
Seminis	Minister	91	25	0.0	0.9	0.0	0.9
	Chancellor	60	17	1.4	1.6	0.0	2.9
	SV0106NG	86	20	0.2	2.2	0.0	2.4
N. Zealand Onion	903S	78	37	0.1	0.4	0.0	0.5
LSD (0.05) Variety		8	5	NS	NS	NS	3.8
LSD (0.05) Date		4	2	NS	NS	NS	NS
LSD (0.05) Variety X Date		10	5	NS	NS	NS	NS

Table 4. Monthly growing degree-days (50-86°F) in 2014-2017, and the 24-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
Avg 1993-2016	200	371	511	702	1785

Table 5. Percentage of tops down, leaf dryness, and marketable yield at three harvest dates for onion varieties Avalon and Montero grown from transplants in 2014, 2015, 2016, and 2017. Malheur Experiment Station, Oregon State University, Ontario, OR.

		Avalon				Montero			
	Year	Jul 14	Jul 21	Jul 28	Aug 4	Jul 14	Jul 21	Jul 28	Aug 4
% tops down	2014	–	16	30	64	–	12	40	76
	2015	36	46	68	–	18	54	80	–
	2016	0	8	28		0	16	58	
	2017		30	66	78		22	70	80
% dry leaves	2014	–	14	20	76	–	16	28	32
	2015	18	10	20	–	0	20	32	–
	2016	0	3	16		0	12	20	
	2017		8	14	16		12	24	30
Marketable yield	2014	–	1287	1387	1488	–	826	911	1024
cwt/acre	2015	1058	1124	1443	–	730	847	898	–
	2016	692	870	1115		731	931	1154	
	2017		919	1111	1278		768	841	947

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

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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 2017 on an Owyhee silt loam previously planted to wheat. A soil analysis taken in the fall of 2016 showed that the top foot of soil had a pH of 8.1, 3.0% organic matter, 9 ppm nitrate, 3 ppm ammonium, 50 ppm phosphorus (P), 341 ppm potassium (K), 16 ppm sulfur (S), 2927 ppm calcium (Ca), 502 ppm magnesium (Mg), 269 ppm sodium, 2.2 ppm zinc (Zn), 5 ppm manganese (Mn), 0.6 ppm copper (Cu), 4 ppm iron, and 0.5 ppm boron (B). In the fall of 2016, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. Based on a soil analysis, 22 lb P/acre, 42 lb K/acre, 200 lb S/acre, 2 lb Zn/acre, 2 lb Mn/acre, and 1 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 April 5 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. Onion emergence started on April 20. On May 9, alleys 4 ft wide were cut between split plots, leaving split plots 23 ft long. On May 25, 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 26 and ending September 5. 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 26 and July 18. The straw was applied between the onion double rows at 243 ft^3/acre (32 7.5-ft^3 bales/acre) on May 30.

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: Prowl® H_2O at 0.83 lb ai/acre (2 pt/acre) and Poast® at 0.25 lb ai/acre (16 oz/acre) on May 4; GoalTender® at 0.09 lb ai/acre (4 oz/acre) and Buctril® at 16 oz/acre on May 15; and Prowl H_2O at 0.31 lb ai/acre (0.75 pt/acre) and Poast at 0.5 lb ai/acre (32 oz/acre) on June 4.

For thrips control, the following insecticides were applied by ground: Movento® at 5 oz/acre on May 26; Movento at 5 oz/acre and Aza-Direct® at 12 oz/acre on June 2; Agri-Mek® SC at 3.5 oz/acre on June 15 and 23. The following insecticides were applied by air: Radiant® at 10 oz/acre on July 1, 8, and 30; Lannate® at 3 pt/acre on July 17 and 23.

Urea ammonium nitrate solution (URAN) was applied through the drip tape five times from May 26 to June 28, supplying a total of 105 lb N/acre. Starting on June 19, root tissue and soil solution 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 only if both the root tissue and soil solution analyses concurrently indicated a deficiency (Table 3). Nitrogen was applied only at the fixed amount previously mentioned, because the soil solution tests indicated the soil was supplying ample amounts of N (Table 4). Potassium was deficient in both the soil and the roots on several sampling dates. A total of 197 lb K/acre was applied in 26- to 31-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, 2017.

Nutrient		19-Jun	4-Jul	11-Jul	17-Jul	24-Jul	31-Jul	7-Aug
NO_3-N (ppm)	Sufficiency range	7667	7200	6833	5000	3500	1834	1000
NO_3-N (ppm)		7325	6868	5773	4847	4903	6090	5218
P (%)	0.32 - 0.7	0.45	0.52	0.44	0.52	0.34	0.27	0.33
K (%)	2.7 - 6.0	2.20	2.58	2.40	1.97	1.48	1.88	0.96
S (%)	0.24 - 0.85	0.84	0.96	1.09	0.98	0.76	0.90	0.99
Ca (%)	0.4 - 1.2	0.61	0.67	0.74	0.85	1.10	0.94	1.18
Mg (%)	0.3 - 0.6	0.39	0.38	0.37	0.36	0.41	0.40	0.41
Zn (ppm)	25 - 50	55	52	48	39	32	32	31
Mn (ppm)	35 - 100	193	183	160	144	139	118	83
Cu (ppm)	6 - 20	24	18	14	12	10	10	12
B (ppm)	19 - 60	30	29	33	41	32	23	25

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, 2017.

Nutrient	Critical level, lb/ac or g/ac	19-Jun	4-Jul	11-Jul	17-Jul	24-Jul	31-Jul	7-Aug
N	Critical levels	7.8	5.5	4.6	4	3	2	1.5
N		7.7	10.9	14.3	17.1	16.6	18.6	23.7
P	0.7 lb/acre	0.3	0.5	0.6	0.7	1.0	1.4	0.9
K	5 lb/acre	1.5	1.8	2.1	2.6	3.0	3.7	4.5
S	1 lb/acre	1.6	2.1	2.6	3.2	3.8	3.9	2.5
Ca	3 lb/acre	10.0	8.8	8.6	6.9	5.6	5.8	4.7
Mg	2 lb/acre	6.4	7.3	6.6	7.7	8.3	9.2	7.2
Zn	28 g/acre	6	15	18	24	30	39	39
Mn	28 g/acre	9	27	21	27	30	36	42
Cu	12 g/acre	3	9	15	18	21	24	24

Table 3. Nutrients applied through the drip irrigation system, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Date	N	K
	------ lb/acre -------	
26-May	30	
5-Jun	15	
15-Jun	15	
20-Jun	30	31
28-Jun	15	
6-Jul		31
11-Jul		26
18-Jul		31
26-Jul		26
1-Aug		26
9-Aug		26
total	105	197

Table 4. Soil available N (NO_3 + NH_4) in the top foot of soil, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Date	Available soil N, lb/acre
19-Jun	54
4-Jul	76
11-Jul	100
17-Jul	120
24-Jul	116
31-Jul	130
7-Aug	166

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 5 and irrigations ended September 5.

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 26 and ending August 18. After August 18 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 furthest 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 in each plot using digital thermometers (Hanna Instruments, Limena, Italy) read twice weekly at 4 p.m. from July through August.

Onions were evaluated for maturity, severity of symptoms of iris yellow spot virus (IYSV), and bolting on August 8. 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 25 to cure in the field. Onions from the middle two double rows in each split plot were topped by hand and bagged on October 2. The bags were put into storage on October 11. 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 1.

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 15, 2017 and January 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 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. 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 2017 were close to the 24-year average, until July (Fig. 1). July had higher than average growing degree-days (Fig. 2).

Surface soil and bulb temperatures for the check treatment onions were on average 35°F and 13°F higher, respectively, than ambient air temperature for the corresponding measurements (Table 5). On average, the artificial heat treatment resulted in the highest and straw mulch resulted in the lowest surface soil temperatures. On average, the artificial heat treatment resulted in the highest 4-inch depth soil temperature and the highest bulb temperatures, with the other treatments having relatively similar 4-inch soil and bulb temperatures as the check.

There was a statistically significant interaction between treatment and variety only for colossal bulb yield. For Joaquin, straw mulch and kaolinite treatments resulted in the highest colossal bulb yield and artificial heat resulted in the lowest colossal bulb yield. The differences in colossal yield among treatments for Granero were not statistically significant. Averaged over heat treatments, Joaquin had higher yields than Granero. Averaged over the two varieties, artificial heat resulted in the lowest total, marketable, and colossal bulb yield. Total and marketable bulb yields for the other treatments were not statistically different. Averaged over the two varieties, straw mulch and kaolinite treatments resulted in the highest colossal bulb yield, and artificial heat resulted in the lowest colossal bulb yield.

For Joaquin, marketable and colossal bulb yields decreased with increasing bulb and soil temperature (Fig. 4 and 6). For Granero, marketable yield decreased with increasing bulb and soil temperature (Fig. 5 and 7).

Straw mulch and kaolinite resulted in among the lowest percentage of tops down on August 16 (Table 6). Artificial heat resulted in the highest percentage of leaf dryness and straw mulch resulted in the lowest percentage of leaf dryness on August 16.

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 16.4 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 heat treatment (17.8 cb) was slightly higher than the check and kaolinite treatments. The average SWT in June and July in the straw mulch treatment (15.5 cb) was slightly lower than the check and kaolinite 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).

Most of the internal decomposition was found in bulbs having incomplete scales, regardless of the presence or absence of dry scales (Table 7). The total amount of internal decomposition in this trial in November ranged from 0% for Granero with straw mulch to 10% for Granero submitted to artificial heat (Table 7). In January, the total amount of internal decomposition ranged from 0.8% for Granero with straw mulch to 13.9% for Joaquin submitted to artificial heat. Averaged over treatments and varieties, the total amount of internal decomposition in January (5.1%) was higher than in November (3.3%). In November, most of the internal decomposition was due to neck rot and black mold, averaging 1.4 and 1.5%, respectively (Table 8). In January most of the internal decomposition was due to neck rot, which increased to 3.9% while black mold decreased slightly to 1.3%. There was very little internal decomposition caused by bacterial rot and *Fusarium proliferatum* in this trial.

Averaged over varieties and dates, bulbs submitted to artificial heat had the highest percentage of bulbs with internal rot. The kaolinite and straw mulch treatments were among the treatments with the lowest percentage of bulbs with internal rot. Averaged over varieties and dates, bulbs submitted to artificial heat had the highest percentage of bulbs with black mold. The kaolinite and straw mulch treatments were among the treatments with the lowest percentage of bulbs with black mold. There was no statistically significant difference in percentage of bulbs with neck rot between treatments, but there was a trend for the heat treatment to result in higher neck rot and for the straw mulch and kaolinite treatments to result in lower neck rot. Averaged over the two varieties, bulb internal decomposition increased with increasing bulb and soil temperature (Figs. 8 and 9).

The results of this trial in 2017 are similar to the results of the 2016 trial (Shock et al. 2017), when straw mulch resulted in the highest supercolossal and colossal bulb yields. In 2016, artificial heat was among the treatments with the lowest colossal bulb yield. In contrast to 2017, bulb yield and size for the kaolinite treatment were not different from the check treatment in 2016. In 2016, internal decomposition was lower, averaging 1.4% over all treatments compared to 3.3% in 2017. In 2016, there were no statistically significant differences in internal decomposition between treatments, but the heat treatments had a later start and a much shorter duration in 2016.

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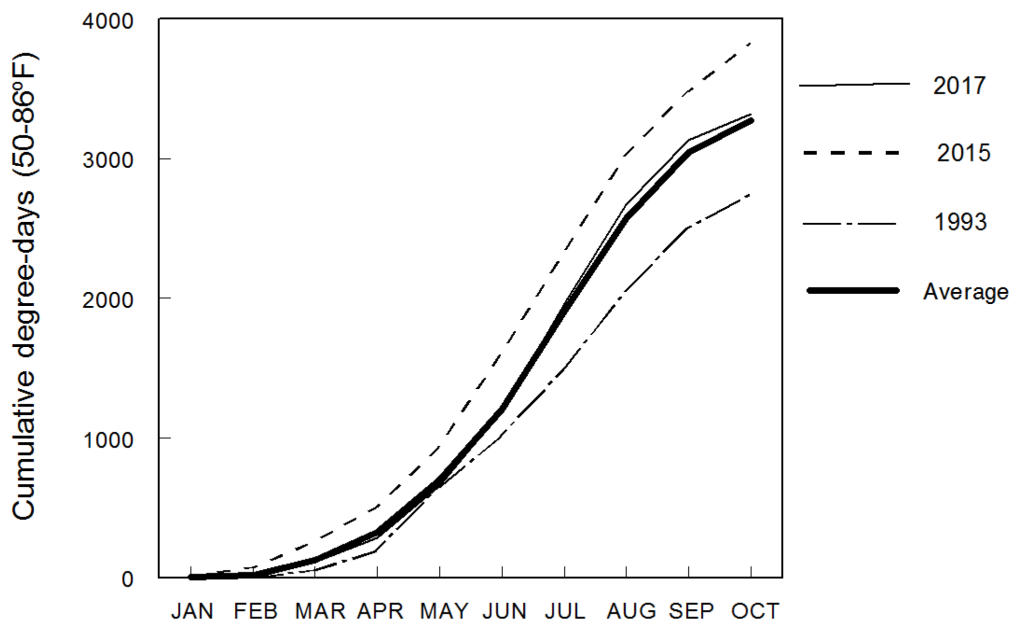

Figure 1. Cumulative growing degree-days (50-86°F) for 2015-2017 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

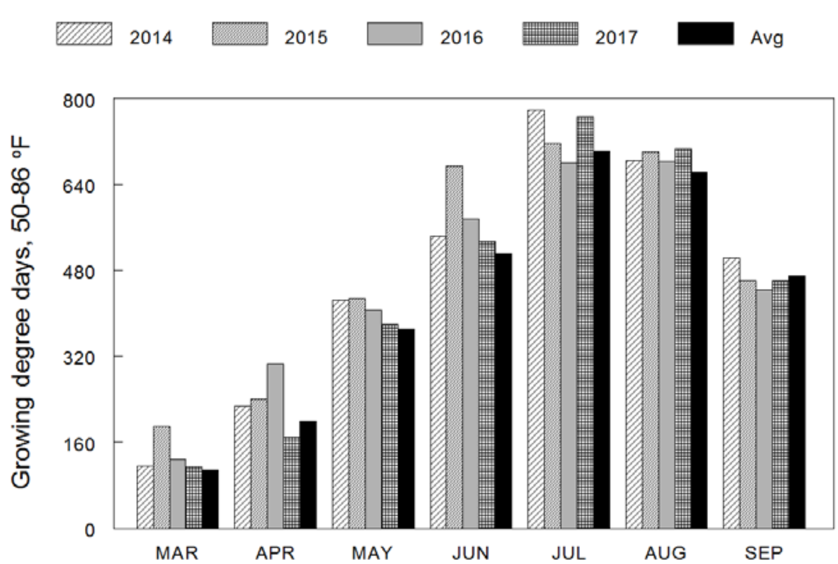

Figure 2. Monthly growing degree-days (50-86°F) for 2014-2017 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

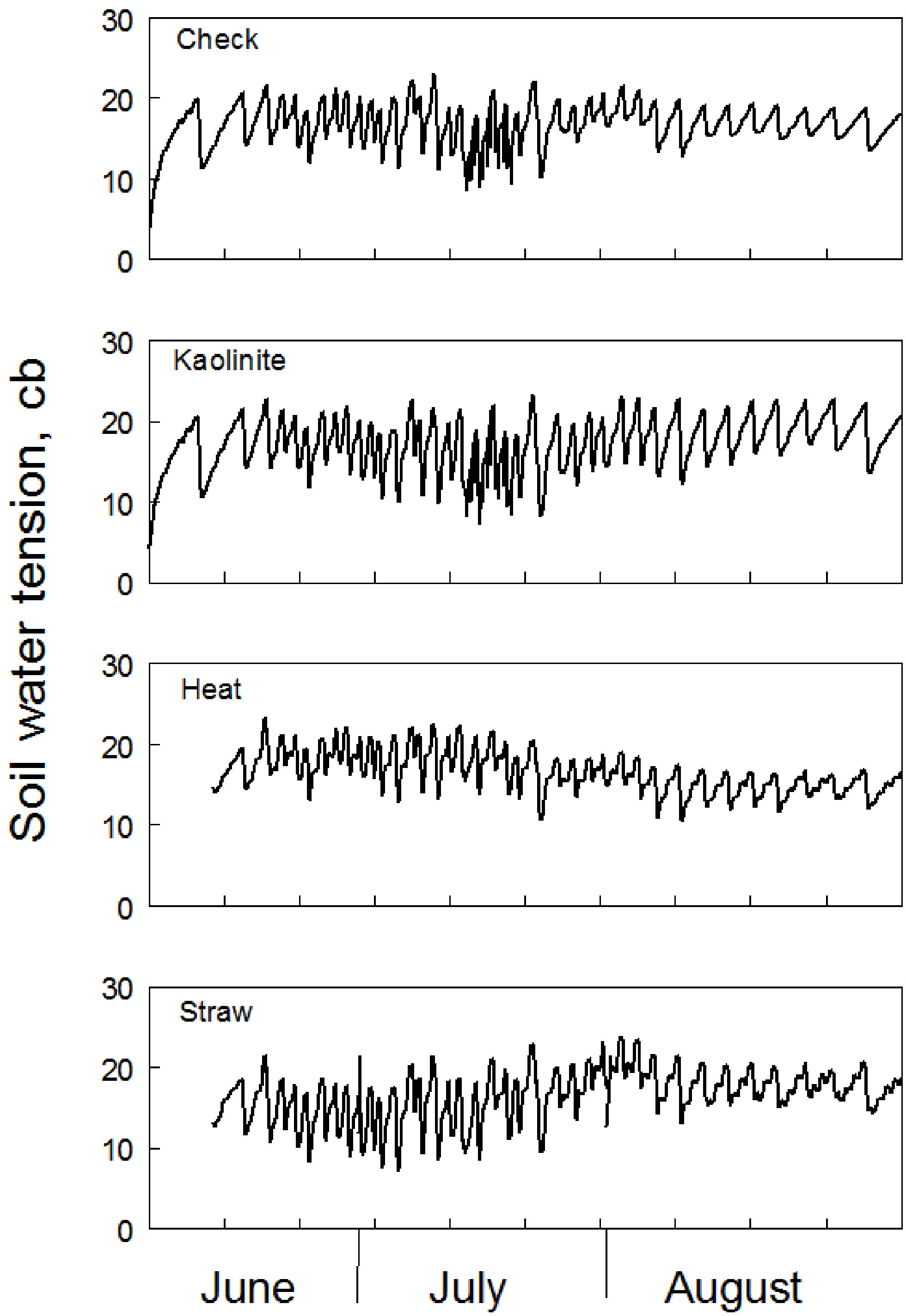

Figure 3. Soil water tension over time for four treatments. Average soil water tension in June and July was 16.6 cb, 16.4 cb, 17.8 cb, and 15.5 cb for the check, kaolinite, artificial heat, and straw mulch treatments, respectively. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Table 5. 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, 2017.

	Ambient air									
	26-Jun	6-Jul	14-Jul	20-Jul	28-Jul	4-Aug	11-Aug	18-Aug	Average	
	89	93	92	89	89	91	89	86	91	
	Soil surface									Soil 4-inch depth
	26-Jun	6-Jul	14-Jul	20-Jul	28-Jul	4-Aug	11-Aug	18-Aug	Average	Average
Check	101.0	128.6	132.3	134.7	125.4	129.6	124.1	135.3	126.4	76.6
Heat	103.4	149.0	142.5	136.0	135.6	142.7	138.7	143.7	136.5	82.5
Kaolinite	103.2	128.3	127.6	125.9	124.4	123.2	118.5	130.9	122.7	76.6
Straw	100.6	118.8	119.7	125.7	117.5	125.8	115.4	117.7	117.6	74.9
LSD (0.05)	NS	14.0	6.9	7.0	7.4	7.7	8.9	7.0	4.0	2.2
	Bulb									
	26-Jun	6-Jul	14-Jul	20-Jul	28-Jul	4-Aug	11-Aug	18-Aug	Average	
Check	91.2	105.1	108.6	103.7	104.2	105.2	105.0	109.2	104.0	
Heat	95.0	111.4	116.3	109.4	112.9	112.7	115.4	117.2	111.3	
Kaolinite	91.9	104.6	103.4	101.1	102.3	101.7	102.8	109.1	102.1	
Straw	92.6	101.7	99.8	100.8	101.9	105.9	105.9	111.4	102.5	
LSD (0.05)	NS[a]	3.2	8.6	4.1	4.4	3.7	2.7	4.3	2.5	

[a]Not significant.

Table 6. Yield and grade of two varieties of onions submitted to four temperature treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety	Treatment	Total yield	Marketable yield by grade: 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	Split root	Tops down	Leaf dryness
		cwt/acre								#/50 lb	%					
Joaquin	Check	1065.2	1056.6	38.5	217.0	768.5	32.5	7.0	0.0	30.6	0.0	0.0	0.0	0.0	46.0	9.0
	Heat	862.3	841.1	32.5	140.1	612.1	56.3	9.2	0.7	27.9	0.9	0.0	0.9	0.1	60.0	12.0
	Kaolinite	1088.2	1074.2	35.3	290.8	727.1	21.0	7.1	0.0	31.4	0.4	0.0	0.4	0.0	26.0	8.0
	Straw	1110.3	1103.5	44.8	297.3	738.8	22.6	4.0	0.0	32.2	0.1	0.0	0.1	0.0	28.0	6.0
	average	1031.5	1018.8	37.8	236.3	711.6	33.1	6.8	0.2	30.5	0.4	0.0	0.4	0.0	40.0	8.8
Granero	Check	988.8	974.7	17.5	168.5	755.1	33.5	7.7	0.0	31.1	0.3	0.0	0.3	0.1	82.0	12.0
	Heat	871.8	852.9	12.7	169.2	645.6	25.4	4.9	0.0	31.1	1.1	0.0	1.1	0.1	78.0	16.0
	Kaolinite	1034.8	1021.6	14.8	162.7	811.7	32.3	7.4	0.0	29.2	0.1	0.0	0.1	0.1	70.0	12.0
	Straw	1053.4	1041.6	16.4	185.5	809.7	30.1	7.0	0.0	32.9	0.3	0.0	0.3	0.0	72.0	9.0
	average	987.2	972.7	15.4	171.5	755.5	30.3	6.7	0.0	31.1	0.4	0.0	0.4	0.1	75.5	12.3
Average	Check	1027.0	1015.6	28.0	192.8	761.8	33.0	7.3	0.0	30.8	0.2	0.0	0.2	0.0	64.0	10.5
	Heat	866.1	845.8	24.6	151.7	625.5	44.0	7.5	0.4	29.2	1.0	0.0	1.0	0.1	69.0	14.0
	Kaolinite	1059.1	1045.5	24.1	220.9	773.3	27.2	7.3	0.0	30.3	0.2	0.0	0.2	0.1	48.0	10.0
	Straw	1081.9	1072.6	30.6	241.4	774.2	26.3	5.5	0.0	32.5	0.2	0.0	0.2	0.0	50.0	7.5
	average	1008.5	994.9	26.8	201.7	733.7	32.6	6.9	0.1	30.7	0.4	0.0	0.4	0.1	57.8	10.5
LSD (0.05)																
Treatment		81.0	81.0	NS	27.0	78.7	NS	NS	NS	NS	0.4	NS	0.4	0.1	18.0	2.9
Variety		27.6	29.0	10.6	28.6	34.1	NS	NS	NS	NS	NS	NS	NS	NS	8.6	1.5
Treatment X variety		NS[a]	NS	NS	57.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[a]Not significant.

Table 7. Internal defects on November 15, 2017 and January 29, 2018 for two varieties of onions submitted to four treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. Continued on next page.

November

		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	63.3	0.0	63.3	28.7	8.0	36.7	100	0.0	0.0	0.0	2.0	0.7	2.7	2.7
	Heat	59.3	0.0	59.3	21.3	19.3	40.7	100	0.7	0.0	0.7	4.7	3.3	8.0	8.7
	Kaolinite	66.0	1.3	67.3	30.0	2.7	32.7	100	0.0	0.0	0.0	0.7	0.0	0.7	0.7
	Straw	60.7	0.7	61.3	29.2	9.9	39.1	100	0.0	0.0	0.0	0.0	1.3	1.3	1.3
	average	62.3	0.5	62.8	27.3	10.0	37.3	100	0.2	0.0	0.2	1.8	1.3	3.2	3.3
Granero	Check	31.3	0.0	31.3	53.9	16.3	70.1	100	0.0	0.0	0.0	0.0	1.9	1.9	1.9
	Heat	38.0	0.0	38.0	43.9	18.0	61.9	100	0.0	0.0	0.0	5.5	4.7	10.1	10.1
	Kaolinite	35.3	0.0	35.3	56.2	8.6	64.9	100	0.0	0.0	0.0	0.7	0.0	0.7	0.7
	Straw	39.3	0.7	40.0	54.0	6.0	60.0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	average	36.0	0.2	36.2	52.0	12.2	64.2	100	0.0	0.0	0.0	1.5	1.7	3.2	3.2
Average	Check	47.3	0.0	47.3	41.3	12.1	53.4	100	0.0	0.0	0.0	1.0	1.3	2.3	2.3
	Heat	48.7	0.0	48.7	32.6	18.7	51.3	100	0.3	0.0	0.3	5.1	4.0	9.1	9.4
	Kaolinite	50.7	0.7	51.3	43.1	5.7	48.8	100	0.0	0.0	0.0	0.7	0.0	0.7	0.7
	Straw	50.0	0.7	50.7	41.6	7.9	49.6	100	0.0	0.0	0.0	0.0	0.7	0.7	0.7
	average	49.2	0.3	49.5	39.7	11.1	50.8	100	0.1	0.0	0.1	1.7	1.5	3.2	3.3

January

		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	36.0	0.0	36.0	32.8	31.2	64.0	100.0	0.0	0.0	0.0	2.4	2.4	4.8	4.8
	Heat	24.8	0.8	25.6	40.7	33.7	74.4	100.0	0.0	0.0	0.0	12.3	1.6	13.9	13.9
	Kaolinite	36.0	0.8	36.8	34.4	28.8	63.2	100.0	0.0	0.0	0.0	2.4	0.0	2.4	2.4
	Straw	41.6	1.6	43.2	27.2	29.6	56.8	100.0	0.0	0.0	0.0	0.8	0.8	1.6	1.6
	average	34.6	0.8	35.4	33.8	30.8	64.6	100.0	0.0	0.0	0.0	4.5	1.2	5.7	5.7
Granero	Check	6.4	0.0	6.4	32.0	61.6	93.6	100.0	0.0	0.0	0.0	3.2	2.4	5.6	5.6
	Heat	8.0	0.0	8.0	24.0	68.0	92.0	100.0	0.0	0.0	0.0	7.2	2.4	9.6	9.6
	Kaolinite	8.0	0.0	8.0	17.0	74.9	91.9	100.0	0.0	0.0	0.0	0.8	1.7	2.5	2.5
	Straw	4.8	0.0	4.8	36.3	58.7	95.0	100.0	0.0	0.0	0.0	0.8	0.0	0.8	0.8
	average	6.8	0.0	6.8	27.3	65.8	93.1	100.0	0.0	0.0	0.0	3.0	1.6	4.6	4.6
Average	Check	21.2	0.0	21.2	32.4	46.4	78.8	100.0	0.0	0.0	0.0	2.8	2.4	5.2	5.2
	Heat	16.4	0.4	16.8	32.3	50.9	83.2	100.0	0.0	0.0	0.0	9.8	2.0	11.8	11.8
	Kaolinite	22.0	0.4	22.4	25.7	51.8	77.5	100.0	0.0	0.0	0.0	1.6	0.8	2.4	2.4
	Straw	23.2	0.8	24.0	31.8	44.2	75.9	100.0	0.0	0.0	0.0	0.8	0.4	1.2	1.2
	average	20.7	0.4	21.1	30.5	48.3	78.9	100.0	0.0	0.0	0.0	3.7	1.4	5.1	5.1

Table 7. (Continued) Internal defects averaged over two dates for two varieties of onions submitted to four treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Average		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	49.6	0.0	49.6	30.4	20.0	50.4	100.0	0.0	0.0	0.0	1.2	1.6	2.8	2.8
	Heat	42.0	0.4	42.4	29.5	28.1	57.6	100.0	0.4	0.0	0.4	9.0	2.4	11.4	11.8
	Kaolinite	50.8	1.2	52.0	32.0	16.0	48.0	100.0	0.0	0.0	0.0	1.6	0.0	1.6	1.6
	Straw	51.6	0.8	52.4	27.9	19.9	47.9	100.0	0.0	0.0	0.0	0.4	0.8	1.2	1.2
	average	48.5	0.6	49.1	30.0	21.0	51.0	100.0	0.1	0.0	0.1	3.0	1.2	4.2	4.3
Granero	Check	21.2	0.0	21.2	41.9	37.8	79.7	100.0	0.0	0.0	0.0	1.6	2.4	4.0	4.0
	Heat	23.6	0.0	23.6	33.2	43.2	76.4	100.0	0.0	0.0	0.0	6.9	4.0	10.9	10.9
	Kaolinite	20.4	0.0	20.4	38.6	41.0	79.7	100.0	0.0	0.0	0.0	0.8	0.8	1.6	1.6
	Straw	22.8	0.4	23.2	43.8	33.0	76.7	100.0	0.0	0.0	0.0	0.4	0.0	0.4	0.4
	average	22.0	0.1	22.1	39.4	38.7	78.1	100.0	0.0	0.0	0.0	2.4	1.8	4.2	4.2
Average	Check	35.4	0.0	35.4	36.2	28.9	65.0	100.0	0.0	0.0	0.0	1.4	2.0	3.4	3.4
	Heat	32.8	0.2	33.0	31.3	35.6	67.0	100.0	0.2	0.0	0.2	7.9	3.2	11.1	11.3
	Kaolinite	35.6	0.6	36.2	35.3	28.5	63.8	100.0	0.0	0.0	0.0	1.2	0.4	1.6	1.6
	Straw	37.2	0.6	37.8	35.8	26.5	62.3	100.0	0.0	0.0	0.0	0.4	0.4	0.8	0.8
LSD(0.05)															
Treatment		NS[a]	NS	NS	NS	NS	NS		NS	NS	NS	NS	1.8	6.5	6.8
Variety		9.9	NS	9.9	8.4	7.8	6.4		NS	NS	NS	NS	NS	NS	NS
Date		8.0	NS	7.1	NS	5.6	6.4		NS	NS	NS	1.2	NS	1.2	1.2
Treatment X variety		NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS
Treatment X date		NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	1.7	NS	NS
Trt. X var. X date		NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS
Variety X date		NS	NS	NS	14.3	8.0	NS		NS	NS	NS	NS	NS	NS	NS

[a]Not significant.

Table 8. Internal decomposition by disease type on November 15, 2017 and January 29, 2018 for two varieties of onions submitted to four treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. Continued on next page.

November					
Variety	Treatment	Bacterial rot	*Fusarium proliferatum*	Neck rot	Black mold
			--------------- % ---------------		
Joaquin	Check	0.0	0.0	0.0	0.7
	Heat	0.0	0.0	6.4	2.7
	Kaolinite	0.0	0.0	0.8	0.0
	Straw	0.0	0.0	0.0	0.6
	average	0.0	0.0	1.8	1.0
Granero	Check	0.0	0.0	0.0	1.9
	Heat	1.6	0.0	4.2	5.3
	Kaolinite	0.0	0.0	0.0	0.7
	Straw	0.0	0.0	0.0	0.0
	average	0.4	0.0	1.0	2.0
Average	Check	0.0	0.0	0.0	1.3
	Heat	0.8	0.0	5.3	4.0
	Kaolinite	0.0	0.0	0.4	0.3
	Straw	0.0	0.0	0.0	0.3
	average	0.2	0.0	1.4	1.5

January					
Variety	Treatment	Bacterial rot	*Fusarium proliferatum*	Neck rot	Black mold
			--------------- % ---------------		
Joaquin	Check	0.0	0.0	2.4	2.0
	Heat	0.0	0.0	12.3	2.9
	Kaolinite	0.0	0.0	2.4	0.0
	Straw	0.0	0.0	0.8	0.7
	average	0.0	0.0	4.5	1.4
Granero	Check	0.0	0.8	4.8	0.0
	Heat	0.0	0.0	7.2	3.3
	Kaolinite	0.0	0.0	0.8	1.4
	Straw	0.0	0.0	0.8	0.0
	average	0.0	0.2	3.4	1.2
Average	Check	0.0	0.4	3.6	1.0
	Heat	0.0	0.0	9.8	3.1
	Kaolinite	0.0	0.0	1.6	0.7
	Straw	0.0	0.0	0.8	0.3
	average	0.0	0.1	3.9	1.3

Table 8. (Continued) Internal decomposition by disease type averaged over two dates for two varieties of onions submitted to four treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Average Variety	Treatment	Bacterial rot	*Fusarium proliferatum*	Neck rot	Black mold
		--------------- % ---------------			
Joaquin	Check	0.0	0.0	1.2	1.3
	Heat	0.0	0.0	9.4	2.8
	Kaolinite	0.0	0.0	1.6	0.0
	Straw	0.0	0.0	0.4	0.7
	average	0.0	0.0	3.1	1.2
Granero	Check	0.0	0.4	2.4	1.0
	Heat	0.8	0.0	5.7	4.3
	Kaolinite	0.0	0.0	0.4	1.0
	Straw	0.0	0.0	0.4	0.0
	average	0.2	0.1	2.2	1.6
Average	Check	0.0	0.2	1.8	1.2
	Heat	0.4	0.0	7.5	3.6
	Kaolinite	0.0	0.0	1.0	0.5
	Straw	0.0	0.0	0.4	0.3
LSD(0.05)					
Treatment		NS	NS	NS	1.9
Variety		NS	NS	NS	NS
Date		NS	NS	1.3	NS
Treatment X variety		NS	NS	NS	NS
Treatment X date		NS	NS	NS	NS
Trt. X var. X date		NS	NS	NS	NS
Variety X date		NS	NS	NS	NS

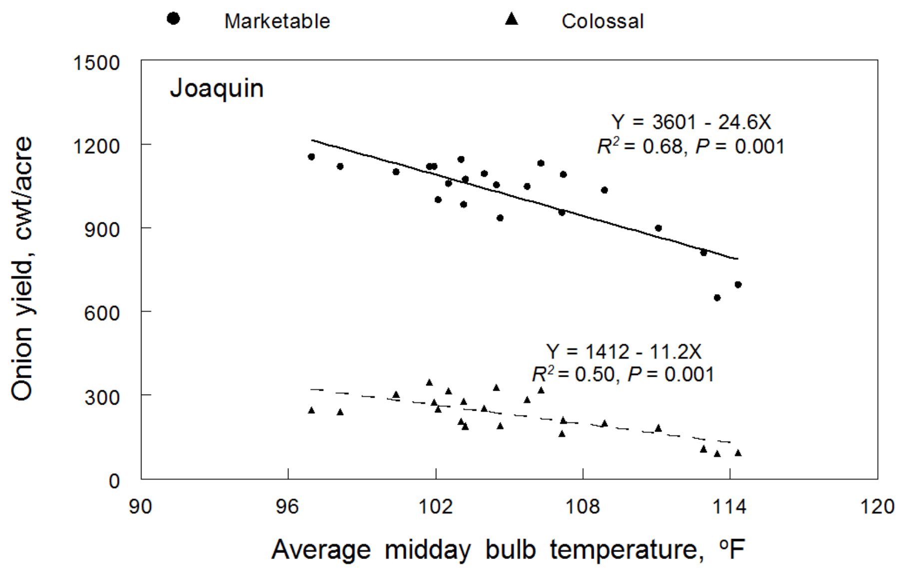

Figure 4. Onion yield response to average midday bulb temperature for Joaquin. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

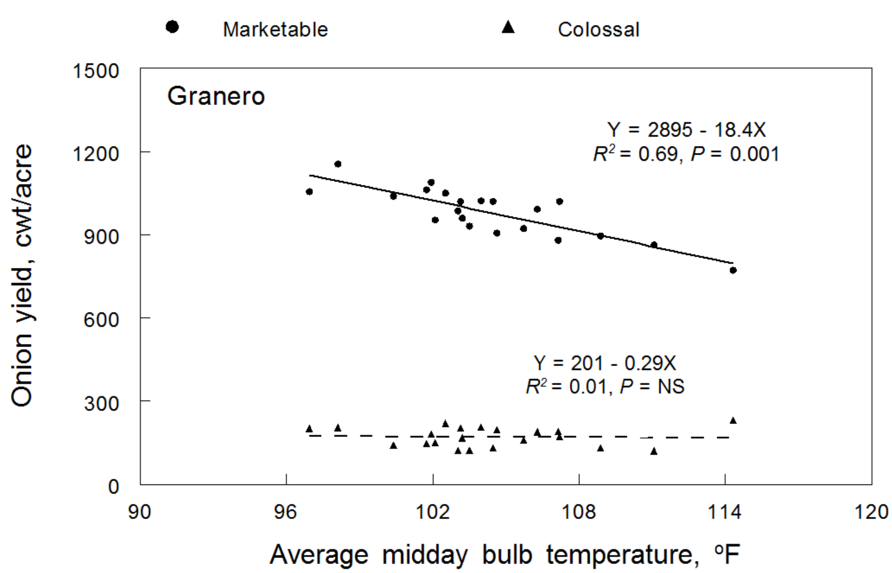

Figure 5. Onion yield response to average midday bulb temperature for Granero. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

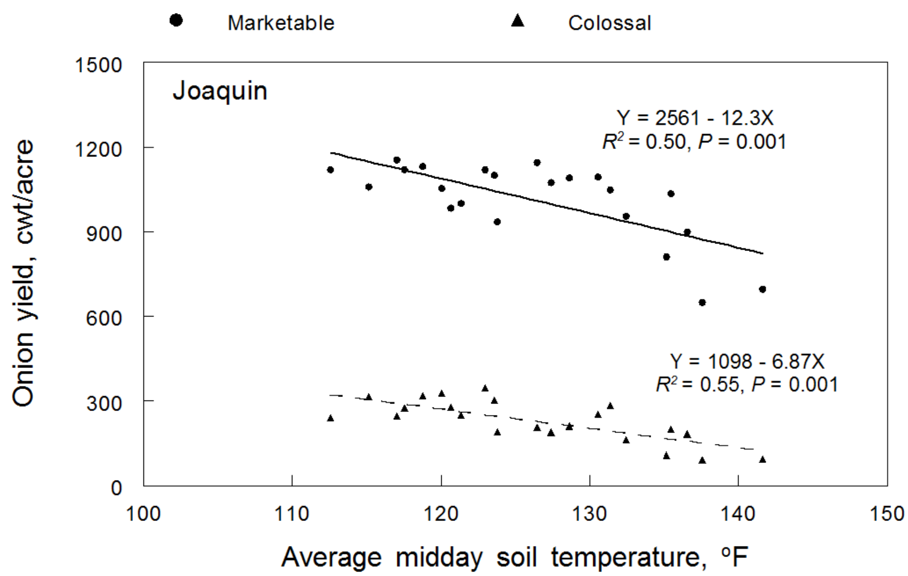

Figure 6. Onion yield response to average midday soil temperature for Joaquin. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

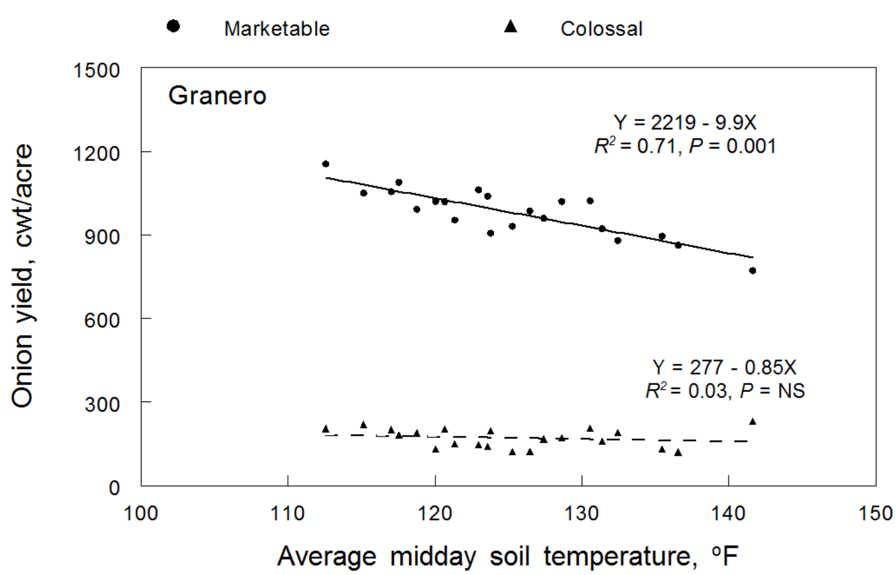

Figure 7. Onion yield response to average midday soil temperature for Granero. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

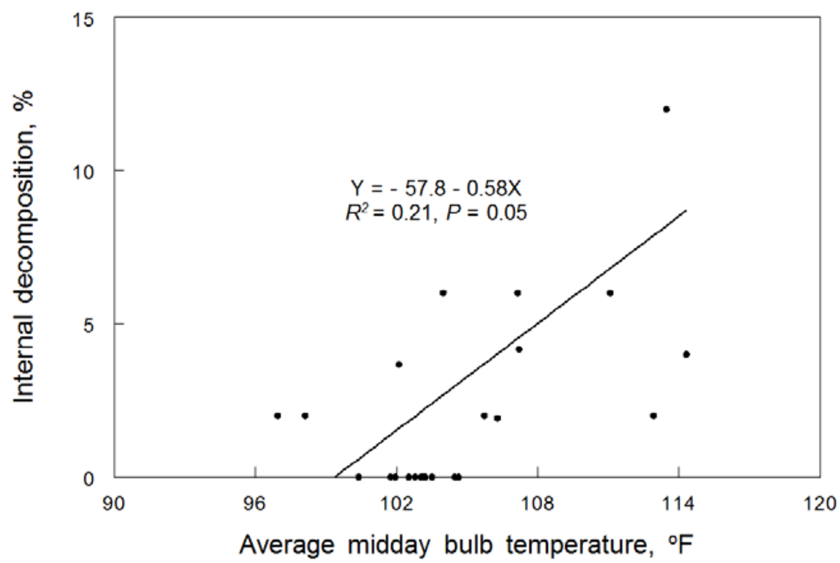

Figure 8. Onion internal decomposition out of storage on November 15 in response to average midday bulb temperature averaged over two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

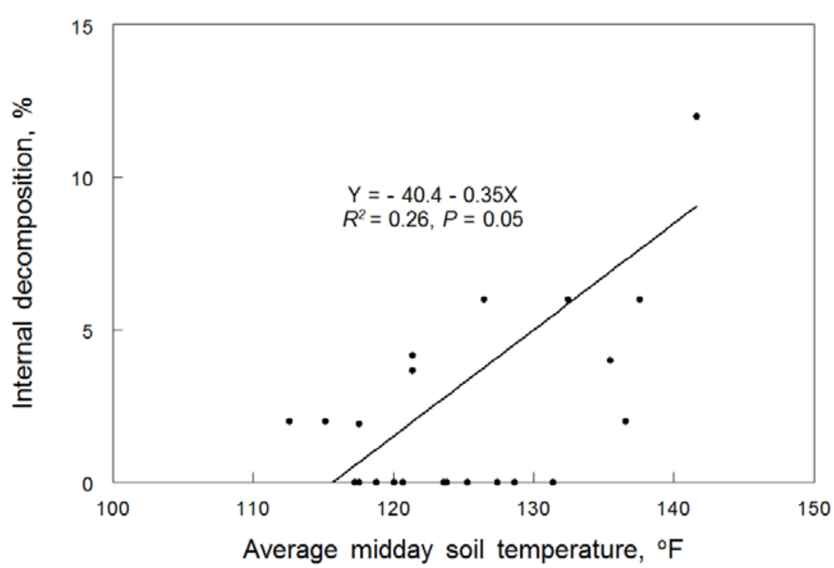

Figure 9. Onion internal decomposition out of storage on November 15 in response to average midday soil temperature averaged over two varieties. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

TIMING OF THE OCCURRENCE OF INTERNAL QUALITY PROBLEMS IN ONION BULBS

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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 the neck or become dehydrated, resulting in small 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 2017 on an Owyhee silt loam previously planted to wheat. A soil analysis taken in the fall of 2016 showed that the top foot of soil had a pH of 8.1, 3.0% organic matter, 9 ppm nitrate, 3 ppm ammonium, 50 ppm phosphorus (P), 341 ppm potassium (K), 16 ppm sulfur (S), 2927 ppm calcium (Ca), 502 ppm magnesium (Mg), 269 ppm sodium, 2.2 ppm zinc (Zn), 5 ppm manganese (Mn), 0.6 ppm copper (Cu), 4 ppm iron, and 0.5 ppm boron (B). In the fall of 2016, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. Based on a soil analysis, 22 lb P/acre, 42 lb K/acre, 200 lb S/acre, 2 lb Zn/acre, 2 lb Mn/acre, and 1 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 April 5 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 20. On May 9, alleys 4 ft wide were cut between plots, leaving plots 23 ft long. On May 25, 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: Prowl® H_2O at 0.83 lb ai/acre (2 pt/acre) and Poast® at 0.25 lb ai/acre (16 oz/acre) on May 4; GoalTender® at 0.09 lb ai/acre (4 oz/acre) and Buctril® at 16 oz/acre on May 15; and Prowl H_2O at 0.31 lb ai/acre (0.75 pt/acre) and Poast at 0.5 lb ai/acre (32 oz/acre) on June 4.

For thrips control, the following insecticides were applied by ground: Movento® at 5 oz/acre on May 26; Movento at 5 oz/acre and Aza-Direct® at 12 oz/acre on June 2; Agri-Mek® SC at 3.5 oz/acre on June 15 and 23. The following insecticides were applied by air: Radiant® at 10 oz/acre on July 1, 8, and 30; Lannate® at 3 pt/acre on July 17 and 23.

Urea ammonium nitrate solution (URAN) was applied through the drip tape five times from May 26 to June 28, totaling 105 lb N/acre. Starting on June 19, root tissue and soil solution samples were taken every week from field borders and analyzed for nutrients by Western Laboratories, Inc., Parma Idaho (Tables 1 and 2). Nutrients were applied through the drip tape only if both the root tissue and soil solution analyses concurrently indicated a deficiency (Table 3). Nitrogen was applied at the fixed amount previously mentioned, but was limited to 105 lb/acre, because the soil solution test indicated the soil was supplying the crop with ample amounts of N. Ample supplies of soil N are also indicated by the amounts of total available soil N during the season (Table 4). Potassium was deficient in both the soil and the roots on several sampling dates. A total of 197 lb K/acre was applied in 25-lb increments during the 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 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 5 and irrigations ended September 5.

Onions in each plot were evaluated weekly in the field starting July 7 and ending September 15. After harvest, the onions from each plot were evaluated out of storage monthly starting in mid-November. Five consecutive bulbs from each single row in the four-double-row 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.

Table 1. Onion root tissue sufficiency levels and nutrient content, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Nutrient		19-Jun	4-Jul	11-Jul	17-Jul	24-Jul	31-Jul	7-Aug
NO_3-N (ppm)	Sufficiency range	7667	7200	6833	5000	3500	1834	1000
NO_3-N (ppm)		7325	6868	5773	4847	4903	6090	5218
P (%)	0.32 - 0.7	0.45	0.52	0.44	0.52	0.34	0.27	0.33
K (%)	2.7 - 6.0	2.20	2.58	2.40	1.97	1.48	1.88	0.96
S (%)	0.24 - 0.85	0.84	0.96	1.09	0.98	0.76	0.90	0.99
Ca (%)	0.4 - 1.2	0.61	0.67	0.74	0.85	1.10	0.94	1.18
Mg (%)	0.3 - 0.6	0.39	0.38	0.37	0.36	0.41	0.40	0.41
Zn (ppm)	25 - 50	55	52	48	39	32	32	31
Mn (ppm)	35 - 100	193	183	160	144	139	118	83
Cu (ppm)	6 - 20	24	18	14	12	10	10	12
B (ppm)	19 - 60	30	29	33	41	32	23	25

Table 2. Soil solution critical levels and weekly analyses. Data represent the amount of each plant nutrient per day that the soil can potentially supply to the crop. Numbers following each nutrient are the critical levels. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Nutrient	Critical level, lb/ac or g/ac	19-Jun	4-Jul	11-Jul	17-Jul	24-Jul	31-Jul	7-Aug
N	Critical level	7.8	5.5	4.6	4	3	2	1.5
N		7.7	10.9	14.3	17.1	16.6	18.6	23.7
P	0.7 lb/acre	0.3	0.5	0.6	0.7	1.0	1.4	0.9
K	5 lb/acre	1.5	1.8	2.1	2.6	3.0	3.7	4.5
S	1 lb/acre	1.6	2.1	2.6	3.2	3.8	3.9	2.5
Ca	3 lb/acre	10.0	8.8	8.6	6.9	5.6	5.8	4.7
Mg	2 lb/acre	6.4	7.3	6.6	7.7	8.3	9.2	7.2
Zn	28 g/acre	6	15	18	24	30	39	39
Mn	28 g/acre	9	27	21	27	30	36	42
Cu	12 g/acre	3	9	15	18	21	24	24

Table 3. Nutrients applied through the drip irrigation system to the onion variety trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Date	N	K
	------ lb/acre -------	
26-May	30	
5-Jun	15	
15-Jun	15	
20-Jun	30	31
28-Jun	15	
6-Jul		31
11-Jul		26
18-Jul		31
26-Jul		26
1-Aug		26
9-Aug		26
total	105	197

Table 4. Soil available N (NO_3 + NH_4) in the top foot of soil, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Date	Available soil N, lb/acre
19-Jun	54
4-Jul	76
11-Jul	100
17-Jul	120
24-Jul	116
31-Jul	130
7-Aug	166

The onions were lifted on September 25 to cure in the field. Onions from each plot were topped by hand and bagged on October 2. The bags were moved into storage on October 11. 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 2017 were close to the 24-year average, until July (Fig. 1), which had higher than average growing degree-days (Fig. 2).

On July 7, 2017 the bulbs had an average of 12 leaves, were 1.8 inches in diameter (Table 5), and had no symptoms of incomplete scale or decomposition (Table 6). The average number of leaves peaked at 17 and the average diameter peaked at close to 4 inches.

Both dry scales and incomplete scales were detected starting in late July (Table 6). The percentage of bulbs with incomplete scales or dry scales increased over time until the November evaluation for both varieties. Between the November and the January evaluations, the percentage of bulbs with incomplete scales and dry scales did not increase. Bulbs with internal decomposition were first found on August 25. Averaged over the two varieties, the percentage of bulbs with internal decomposition increased over time until September 15, reaching 9.5%. Evaluated out of storage in November and January, bulbs with internal decomposition decreased to 3.3 and 3.8%, respectively. Most of the internal decomposition was found in bulbs with incomplete scales. Of the bulbs with internal decomposition, 94.7% had incomplete or dry scales and only 5.3% had neither. Averaged over dates, Granero had a higher percentage of bulbs with incomplete scales and internal decomposition.

Most of the internal decomposition in this trial in 2017 was caused by black mold (Table 7). There was very little internal decomposition caused by bacteria, *Fusarium proliferatum*, or botrytis neck rot. For both varieties, black mold was first detected in late August and increased until September 15, just before harvest. At the November and January evaluations, the internal decomposition caused by black mold decreased. The internal decomposition caused by black mold decreased from 7% in September to 1% in January for Joaquin and from 10% in September to 5.5% in January for Granero.

In 2016, incomplete scales were first detected in early September and internal decomposition was first detected in December, later than in 2017 (Table 8). In 2016, most of the internal decomposition was due to bacterial rot and neck rot, with very little *Fusarium proliferatum* (Table 9). No internal decomposition due to black mold was detected in 2016.

Acknowledgements

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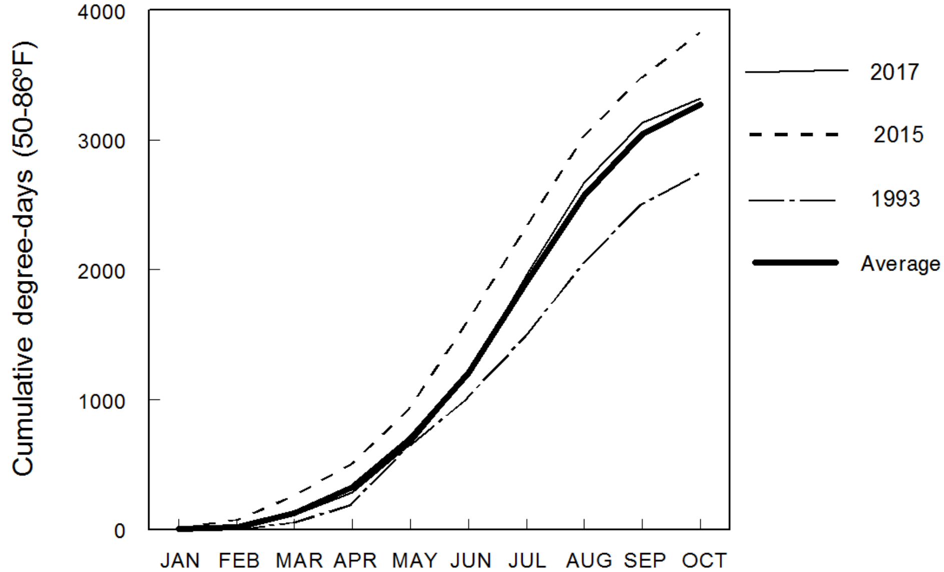

Figure 1. Cumulative growing degree-days (50-86°F) for 2015-2017 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

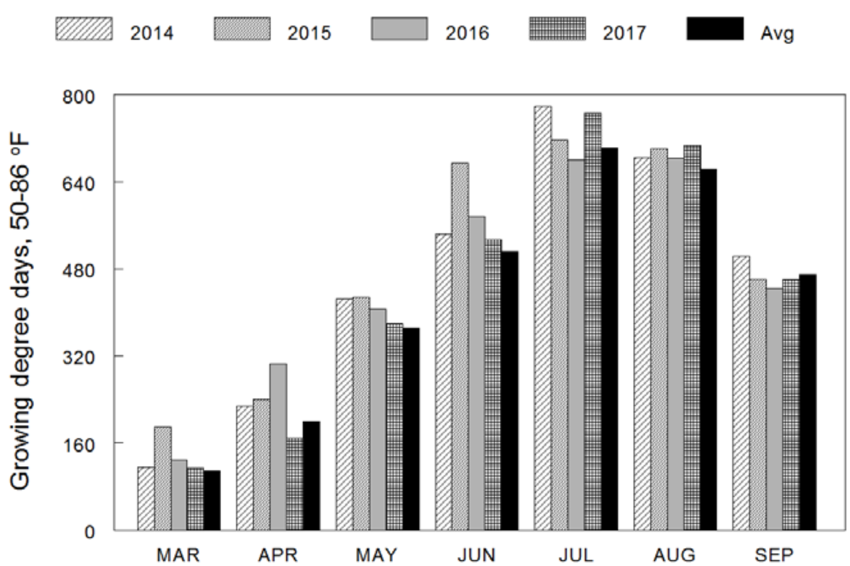

Figure 2. Monthly growing degree-days (50-86°F) for 2014-2017 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Table 5. Number of leaves and bulb diameter over time for onion bulbs evaluated for internal defects, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety	Date	No. of leaves	Bulb diameter, inch
Joaquin	7-Jul	12.0	1.8
	14-Jul	13.3	2.8
	21-Jul	13.1	2.5
	28-Jul	14.2	3.0
	11-Aug	15.1	3.4
	18-Aug	14.9	3.4
	25-Aug	15.7	3.5
	1-Sep	16.0	3.5
	8-Sep	17.2	3.7
	15-Sep		3.6
Granero	7-Jul	11.9	1.8
	14-Jul	12.6	2.9
	21-Jul	13.2	2.4
	28-Jul	15.2	3.2
	11-Aug	14.7	3.3
	18-Aug	14.6	3.3
	25-Aug	15.4	3.4
	1-Sep	15.9	3.5
	8-Sep	16.5	3.4
	15-Sep		3.4
Average	7-Jul	12.0	1.8
	14-Jul	13.0	2.8
	21-Jul	13.2	2.4
	28-Jul	14.7	3.1
	11-Aug	14.9	3.3
	18-Aug	14.8	3.3
	25-Aug	15.5	3.4
	1-Sep	15.9	3.5
	8-Sep	16.8	3.6
	15-Sep		3.5
LSD (0.05)	Variety	NS	NS
	Date	0.94	0.2
	Variety X date	NS	NS

Table 6. Internal defects over time for two onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. 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	7-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
	14-Jul	99.0	0.0	99.0	0.0	1.0	1.0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	21-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
	28-Jul	97.5	2.5	100.0	0.0	0.0	0.0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11-Aug	88.5	6.0	94.5	1.0	4.5	5.5	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	18-Aug	86.5	6.0	92.5	0.0	7.5	7.5	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	25-Aug	77.5	4.0	81.5	1.0	17.5	18.5	100	0.0	0.0	0.0	0.0	2.5	2.5	2.5
	1-Sep	56.0	21.0	77.0	2.0	21.0	23.0	100	0.0	0.0	0.0	0.0	2.0	2.0	2.0
	8-Sep	61.5	22.5	84.0	0.0	16.0	16.0	100	1.0	0.5	1.5	0.0	3.0	3.0	4.5
	15-Sep	65.5	15.5	81.0	0.0	19.0	19.0	100	0.5	0.5	1.0	0.0	7.0	7.0	8.0
	21-Nov	36.8	2.0	38.8	32.0	29.2	61.2	100	0.0	0.0	0.0	0.0	1.2	1.2	1.2
	29-Jan	33.5	8.0	41.5	21.5	37.0	58.5	100	0.0	0.0	0.0	0.5	0.5	1.0	1.0
	Average	75.0	7.3	82.3	5.0	12.7	17.7	100	0.1	0.1	0.2	0.0	1.3	1.4	1.6
Granero	7-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
	14-Jul	98.0	0.0	98.0	0.0	2.0	2.0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	21-Jul	96.5	0.5	97.0	2.5	0.5	3.0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	28-Jul	92.0	7.0	99.0	1.0	0.0	1.0	100	0.0	0.0	0.0	1.0	0.0	1.0	1.0
	11-Aug	49.0	12.5	61.5	5.0	33.5	38.5	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	18-Aug	59.0	9.5	68.5	2.0	29.5	31.5	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	25-Aug	46.5	15.5	62.0	0.5	37.5	38.0	100	0.0	0.0	0.0	0.0	2.5	2.5	2.5
	1-Sep	32.0	17.0	49.0	1.5	49.5	51.0	100	0.0	0.0	0.0	0.0	4.5	4.5	4.5
	8-Sep	23.0	27.0	50.0	0.5	49.5	50.0	100	0.0	0.0	0.0	0.5	9.5	10.0	10.0
	15-Sep	29.5	9.0	38.5	1.0	60.5	61.5	100	0.0	0.0	0.0	0.0	11.0	11.0	11.0
	21-Nov	15.5	1.0	16.5	36.5	47.0	83.5	100	0.0	0.0	0.0	0.0	5.5	5.5	5.5
	29-Jan	3.0	6.0	9.0	22.5	68.5	91.0	100	0.0	0.5	0.5	0.5	5.5	6.0	6.5
	Average	53.7	8.8	62.4	6.1	31.5	37.6	100	0.0	0.0	0.0	0.2	3.2	3.4	3.4

Table 6. (Continued) Internal defects over time averaged over two onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

		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	7-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
	14-Jul	98.5	0.0	98.5	0.0	1.5	1.5	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	21-Jul	97.3	0.3	97.5	2.3	0.3	2.5	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	28-Jul	94.8	4.8	99.5	0.5	0.0	0.5	100	0.0	0.0	0.0	0.5	0.0	0.5	0.5
	11-Aug	68.8	9.3	78.0	3.0	19.0	22.0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	18-Aug	72.8	7.8	80.5	1.0	18.5	19.5	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	25-Aug	62.0	9.8	71.8	0.8	27.5	28.3	100	0.0	0.0	0.0	0.0	2.5	2.5	2.5
	1-Sep	44.0	19.0	63.0	1.8	35.3	37.0	100	0.0	0.0	0.0	0.0	3.3	3.3	3.3
	8-Sep	42.3	24.8	67.0	0.3	32.8	33.0	100	0.5	0.3	0.8	0.3	6.3	6.5	7.3
	15-Sep	47.5	12.3	59.8	0.5	39.8	40.3	100	0.3	0.3	0.5	0.0	9.0	9.0	9.5
	21-Nov	26.2	1.5	27.7	34.3	38.1	72.3	100	0.0	0.0	0.0	0.0	3.3	3.3	3.3
	29-Jan	18.3	7.0	25.3	22.0	52.8	74.8	100	0.0	0.3	0.3	0.5	3.0	3.5	3.8
LSD (0.05)															
Variety		4.7	NS	5.3	NS	3.7	5.3		NS	NS	NS	0.9	0.7	0.9	1.0
Date		6.3	5.2	6.6	3.8	6.1	6.5		NS	NS	NS	2	2.2	2.4	2.3
Var. X date		8.9	NS	9.4	NS	8.6	9.4		NS	NS	NS	NS	3.1	3.4	NS

Table 7. Internal decomposition over time by disease for two onion varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety	Date	Bacterial rot	*Fusarium proliferatum*	Neck rot	Black mold
		--------------- % ---------------			
Joaquin	7-Jul	0.0	0.0	0.0	0.0
	14-Jul	0.0	0.0	0.0	0.0
	21-Jul	0.0	0.0	0.0	0.0
	28-Jul	0.0	0.0	0.0	0.0
	11-Aug	0.0	0.0	0.0	0.0
	18-Aug	0.0	0.0	0.0	0.0
	25-Aug	0.0	0.0	0.0	2.5
	1-Sep	0.0	0.0	0.0	2.0
	8-Sep	0.5	0.0	0.5	3.5
	15-Sep	0.5	0.5	0.0	7.0
	21-Nov	0.0	0.0	0.0	1.2
	29-Jan	0.0	0.0	0.0	1.0
	Average	0.1	0.0	0.0	1.4
Granero	7-Jul	0.0	0.0	0.0	0.0
	14-Jul	0.0	0.0	0.0	0.0
	21-Jul	0.0	0.0	0.0	0.0
	28-Jul	1.0	0.0	0.0	0.0
	11-Aug	0.0	0.0	0.0	0.0
	18-Aug	0.0	0.0	0.0	0.0
	25-Aug	0.0	0.0	0.0	2.5
	1-Sep	0.0	0.0	0.0	4.5
	8-Sep	0.0	1.0	0.0	9.0
	15-Sep	0.0	1.0	0.0	10.0
	21-Nov	0.0	0.0	0.0	5.5
	29-Jan	1.0	0.0	0.0	5.5
	Average	0.2	0.2	0.0	3.1
Average	7-Jul	0.0	0.0	0.0	0.0
	14-Jul	0.0	0.0	0.0	0.0
	21-Jul	0.0	0.0	0.0	0.0
	28-Jul	0.5	0.0	0.0	0.0
	11-Aug	0.0	0.0	0.0	0.0
	18-Aug	0.0	0.0	0.0	0.0
	25-Aug	0.0	0.0	0.0	2.5
	1-Sep	0.0	0.0	0.0	3.3
	8-Sep	0.3	0.5	0.3	6.3
	15-Sep	0.3	0.8	0.0	8.5
	21-Nov	0.0	0.0	0.0	3.3
	29-Jan	0.5	0.0	0.0	3.3
LSD (0.05)					
Variety		NS	NS	NS	0.9
Date		NS	NS	NS	2.1
Var. X date		NS	NS	NS	3.0

Table 8. Internal defects over time for two onion varieties in 2016, Malheur Experiment Station, Oregon State University, Ontario, OR, 2016. 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	7-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
	13-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
	21-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
	28-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
	3-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
	11-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
	17-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
	26-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
	1-Sep	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
	9-Sep	94.0	0.0	94.0	6.0	0.0	6.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3-Nov	32.5	5.0	37.5	29.5	33.0	62.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	16-Dec	38.0	0.0	38.0	38.0	24.0	62.0	100.0	0.0	0.0	0.0	0.5	0.0	0.5	0.5
	15-Feb	47.0	0.0	47.0	46.5	6.5	53.0	100.0	0.0	0.0	0.0	2.5	0.0	2.5	2.5
	Average	85.5	0.4	85.9	9.2	4.9	14.1	100.0	0.0	0.0	0.0	0.2	0.0	0.2	0.2
Granero	7-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
	13-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
	21-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
	28-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
	3-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
	11-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
	17-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
	26-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
	1-Sep	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
	9-Sep	70.0	0.0	70.0	30.0	0.0	30.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3-Nov	27.0	7.0	34.0	26.0	40.0	66.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	16-Dec	31.0	0.0	31.0	32.5	36.0	68.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	15-Feb	32.5	0.5	33.0	52.0	14.0	66.0	100.0	0.0	0.0	0.0	1.5	0.0	1.5	1.5
	Average	81.5	0.6	82.1	10.8	6.9	17.8	100.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1

Table 8. (Continued) Internal defects over time averaged over two onion varieties in 2016, Malheur Experiment Station, Oregon State University, Ontario, OR, 2016.

		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	7-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
	13-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
	21-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
	28-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
	3-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
	11-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
	17-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
	26-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
	1-Sep	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
	9-Sep	82.0	0.0	82.0	18.0	0.0	18.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3-Nov	29.8	6.0	35.8	27.8	36.5	64.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	16-Dec	34.5	0.0	34.5	35.3	30.0	65.3	100.0	0.0	0.0	0.0	0.3	0.0	0.3	0.3
	15-Feb	39.8	0.3	40.0	49.3	10.3	59.5	100.0	0.0	0.0	0.0	2.0	0.0	2.0	2.0
LSD (0.05)															
Variety		NS	NS	NS	NS	1.7	NS		NS	NS	NS	NS	NS	NS	NS
Date		4.1	0.9	3.8	3.0	2.9	3.6		NS	NS	NS	0.4	NS	0.4	0.4
Var. X date		5.8	NS	5.3	4.3	4.0	5.1		NS	NS	NS	NS	NS	NS	NS

Table 9. Internal decomposition over time for two onion varieties in 2016, Malheur Experiment Station, Oregon State University, Ontario, OR, 2016.

Variety	Date	Bacterial rot	*Fusarium proliferatum*	Neck rot
			--------------- % ---------------	
Joaquin	7-Jul	0.0	0.0	0.0
	13-Jul	0.0	0.0	0.0
	21-Jul	0.0	0.0	0.0
	28-Jul	0.0	0.0	0.0
	3-Aug	0.0	0.0	0.0
	11-Aug	0.0	0.0	0.0
	17-Aug	0.0	0.0	0.0
	26-Aug	0.0	0.0	0.0
	1-Sep	0.0	0.0	0.0
	9-Sep	0.0	0.0	0.0
	3-Nov	0.0	0.0	0.0
	16-Dec	0.0	0.0	0.5
	15-Feb	1.5	0.0	1.0
	Average	0.1	0.0	0.1
Granero	7-Jul	0.0	0.0	0.0
	13-Jul	0.0	0.0	0.0
	21-Jul	0.0	0.0	0.0
	28-Jul	0.0	0.0	0.0
	3-Aug	0.0	0.0	0.0
	11-Aug	0.0	0.0	0.0
	17-Aug	0.0	0.0	0.0
	26-Aug	0.0	0.0	0.0
	1-Sep	0.0	0.0	0.0
	9-Sep	0.0	0.0	0.0
	3-Nov	0.0	0.5	0.0
	16-Dec	0.5	0.5	0.0
	15-Feb	1.0	0.0	0.5
	Average	0.1	0.1	0.0
Average	7-Jul	0.0	0.0	0.0
	13-Jul	0.0	0.0	0.0
	21-Jul	0.0	0.0	0.0
	28-Jul	0.0	0.0	0.0
	3-Aug	0.0	0.0	0.0
	11-Aug	0.0	0.0	0.0
	17-Aug	0.0	0.0	0.0
	26-Aug	0.0	0.0	0.0
	1-Sep	0.0	0.0	0.0
	9-Sep	0.0	0.0	0.0
	3-Nov	0.0	0.3	0.0
	16-Dec	0.3	0.3	0.3
	15-Feb	1.3	0.0	0.8
LSD (0.05)				
Variety		NS	NS	NS
Date		0.4	NS	NS
Var. X date		NS	NS	NS

EVALUATION OF CHLORINE AND DIATOMACEOUS EARTH FOR CONTROL OF INTERNAL DECAY IN ONION BULBS

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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, especially by bacterial diseases and *Fusarium proliferatum*. Unlike neck rot or plate rot, this internal decomposition is difficult to detect externally, resulting in onion bulb quality control issues in marketing. The internal decomposition is thought to possibly be associated with one or more scales that do not finish forming completely into the neck, resulting in small gaps close to the neck that may be associated with dry scales extending into the bulb from the neck. Incomplete scales could provide an opening for pathogenic organisms to infect the bulb interior in the field prior to harvest. Dry scales could provide a path for pathogenic organisms into the bulb in the field prior to harvest. Another potential route of entry for pathogenic organisms could be on bulb mites entering the bulb during bulb maturation and curing, prior to harvest. Dry bulb mites have been found to cause damage to and induce *Fusarium proliferatum* decay of stored garlic (Jepson and Putnam 2008). Dry bulb mites can infect cultivated members of the genus *Allium*, including onion, garlic, and leeks.

Chlorine has been found to be effective in controlling pathogenic microorganisms that infect horticultural produce after harvest (Praeger et al. 2016). Diatomaceous earth has been found to be effective in controlling stored grain mites (Wakil et al. 2010). This trial tested chlorine and diatomaceous earth for control of internal decay of onion.

Materials and Methods

Onions were grown in 2017 on an Owyhee silt loam previously planted to wheat. A soil analysis taken in the fall of 2016 showed that the top foot of soil had a pH of 8.2, 3.7% organic matter, 4 ppm nitrate, 3 ppm ammonium, 15 ppm phosphorus (P), 395 ppm potassium (K), 9 ppm sulfur (S), 3774 ppm calcium, 549 ppm magnesium (Mg), 208 ppm sodium, 0.6 ppm zinc (Zn), 17 ppm manganese (Mn), 0.4 ppm copper (Cu), 47 ppm iron, and 0.5 ppm boron (B). In the fall of 2016, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. Based on a soil analysis, 55 lb of P/acre, 200 lb of S/acre, 9 lb of Zn/acre, 1 lb Cu/acre, and 1 lb of B/acre were broadcast before plowing. After plowing, the field was fumigated with K-Pam® at 15 gal/acre and bedded at 22 inches.

Seed of variety Vaquero (Nunhems Seed Co., Parma, ID) was planted on April 4 in double rows spaced 3 inches apart at 150,000 seeds/acre. Each double row was planted on beds spaced 22 inches apart. 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 20. On May 2, 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.

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: Prowl® H_2O at 0.83 lb ai/acre (2 pt/acre) and Poast® at 0.25 lb ai/acre (16 oz/acre) on May 4; GoalTender® at 0.09 lb ai/acre (4 oz/acre) and Buctril® at 16 oz/acre on May 15; and Prowl H_2O at 0.31 lb ai/acre (0.75 pt/acre) and Poast at 0.5 lb ai/acre (32 oz/acre) on June 4.

For thrips control, the following insecticides were applied by ground: Movento® at 5 oz/acre on May 26; Movento at 5 oz/acre and Aza-Direct® at 12 oz/acre on June 2; Agri-Mek® SC at 3.5 oz/acre on June 15 and 23. The following insecticides were applied by air: Radiant® at 10 oz/acre on July 1, 8, and 30; Lannate® at 3 pt/acre on July 17 and 23.

Urea ammonium nitrate solution (URAN) was applied through the drip tape weekly starting May 1 and ending June 28, totaling 120 lb nitrogen (N)/acre. Starting on May 26, root tissue and soil solution samples were taken every week and analyzed for nutrients by Western Laboratories, Inc., Parma Idaho (Tables 1 and 2). Nutrients were applied through the drip tape only if both the root tissue and soil solution analyses concurrently indicated a deficiency (Table 3). Nitrogen was applied at the fixed amount previously mentioned, but was limited to 120 lb/acre, because the soil solution test indicated the soil was supplying the crop with adequate amounts of N after June 27. The amounts of total available soil N went above the critical level of 80 lb N/acre (Sullivan et al. 2001) starting July 11 (Table 4).

Table 1. Onion root tissue sufficiency ranges and nutrient content in the onion variety trial, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Nutrient		26-May	12-Jun	19-Jun	27-Jun	4-Jul	11-Jul	17-Jul	24-Jul	31-Jul	7-Aug
NO_3-N (ppm)	Sufficiency range	8500	7667	7000	6000	5000	4338	3000	2000	1834	1000
NO_3-N (ppm)		3743	4431	3988	4378	5472	6782	5746	5134	3944	3704
P (%)	0.32 - 0.7	0.34	0.27	0.39	0.47	0.52	0.58	0.5	0.48	0.43	0.62
K (%)	2.7 - 6.0	2.81	3.11	3.74	4.44	4.37	4.09	3.18	2.93	2.03	2.32
S (%)	0.24 - 0.85	0.72	0.7	0.95	0.99	0.81	0.96	0.77	0.74	0.72	0.91
Ca (%)	0.4 - 1.2	1.03	0.92	0.72	0.83	1	1.15	1.03	0.84	1.01	1.12
Mg (%)	0.3 - 0.6	0.4	0.35	0.33	0.33	0.3	0.37	0.34	0.38	0.4	0.47
Zn (ppm)	25 - 50	44	33	41	31	37	34	35	32	31	27
Mn (ppm)	35 - 100	124	114	131	109	116	120	115	97	76	90
Cu (ppm)	6 - 20	17	14	20	15	14	11	9	8	9	7
B (ppm)	19 - 60	22	20	25	19	22	25	31	35	42	33

Table 2. Soil solution weekly analyses and critical levels. Data represent the amount of each plant nutrient per day that the soil can potentially supply to the crop. Numbers following each nutrient are the critical levels. Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

	Critical level	Sample date									
Nutrient	lb/ac or g/ac	26-May	12-Jun	19-Jun	27-Jun	4-Jul	11-Jul	17-Jul	24-Jul	31-Jul	7-Aug
N	Critical level	8.6	7.8	7	6	5	4.6	4	3	2	2
N		5.4	4.6	4	6.6	10.9	12.9	13.1	16	16	14.6
P	0.7 lb/acre	1	1.3	0.7	0.8	1.1	1.3	1.5	1.1	1.2	1
K	5 lb/acre	5	5.1	4.3	5.3	4.3	5.3	6	6.9	5.2	6.5
S	1 lb/acre	4.1	3.1	2.1	2	2.4	3	3.7	4.4	5.1	3.9
Ca	3 lb/acre	9.5	7.8	10.5	8.8	7.8	6.9	6.8	5.9	5.2	5.1
Mg	2 lb/acre	17.9	14	8.3	8	6.8	7.5	7.8	8.3	8.8	7.5
Zn	28 g/acre	27	33	27	33	42	51	63	72	75	66
Mn	28 g/acre	24	18	9	15	27	30	33	30	36	39
Cu	12 g/acre	6	9	6	12	15	18	15	18	21	24

Table 3. Nutrients applied through the drip irrigation system, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Date	N	P	K
	------- lb/acre --------		
1-May	30		
26-May	15		11
2-Jun	15	5	
9-Jun	15		
13-Jun	15		
22-Jun	15		
28-Jun	15		
Total	120	5	11

Table 4. Soil available N (NO_3 + NH_4) in the top foot of soil, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Date	Available soil N, lb/acre
26-May	38
12-Jun	32
19-Jun	28
27-Jun	46
4-Jul	76
11-Jul	90
17-Jul	92
24-Jul	112
31-Jul	112
7-Aug	102

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 10 and irrigations ended on September 5.

A field of onions was divided into plots that were 23 ft long by 4 double rows wide with 4-ft alleys between plots. The experimental design was a randomized complete block with four treatments (Table 5) and six replicates. A bleach solution was made by dissolving granular calcium hypochlorite ($Ca(ClO)_2$, 49% Cl) in water to make a 100-ppm Cl concentration. The solution was broadcast at 44.5 gal/acre. The diatomaceous earth was broadcast at 37 lb/acre in 148 gal water/acre. Both solutions were broadcast over the four onion double rows on September 5, 15, and October 3. For treatment 3, which received both solutions, the bleach was applied prior to the diatomaceous earth.

The onions were lifted to cure in the field on September 22, prior to the last diatomaceous earth and bleach applications. Onions from the middle two rows in each plot were topped by hand and bagged on October 5. The bags were put in storage on October 11. The storage shed was ventilated and the temperature was slowly decreased to maintain air temperature as close to 34°F as possible. Onions were evaluated out of storage on December 12, 2017.

Two hundred bulbs from each plot were cut longitudinally and each bulb was evaluated for the presence of incomplete scales, dry scales, and internal decay from bacteria, *Fusarium proliferatum,* black mold, or neck rot. 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 a small dry scale inside the bulb either near the top of the neck or lower down on the scale.

Table 5. Treatments applied to onions for reduction of internal decay.

Treatment	Bleach ($Ca(ClO)_2$)	Diatomaceous earth
1	no	no
2	yes	no
3	yes	yes
4	no	yes

Results and Discussion

Averaged over all treatments, total yield was 1040 cwt/acre.

The percentage of bulbs with complete scales averaged 29.6% (Table 6); 70.4% of bulbs had incomplete scales. The total percentage of bulbs with internal decay averaged only 1.5% on December 12. The percentage of bulbs with both internal rot and complete scales averaged 0.1%. The percentage of bulbs with internal rot and incomplete scales averaged 1.4%. Averaged over all treatments, the percentages of bulbs with bacterial rot, *Fusarium proliferatum*, black mold, and neck rot were 0.4, 0.05, 0.8, and 0.3%, respectively.

The treatment of bulbs with both chlorine and diatomaceous earth resulted in a significantly higher percentage of bulbs with complete scales and in the lowest percentage of bulbs with incomplete scales (Table 2). The treatment with diatomaceous earth increased the total amount of internal rot, increased the total amount of internal rot caused by black mold (data not shown), and was among the treatments having the highest percentage of bulbs with incomplete scales. Chlorine had no significant effect in this trial.

This trial was a repeat of a similar trial in 2016 trial (Shock et al. 2017). In 2016 the incidence of internal decay was low and the results were inconclusive. The chlorine and diatomaceous earth treatments were designed to help control *Fusarium proliferatum*, which was not a factor in either 2016 or 2017.

Conclusions

Most of the internal decay occurred in bulbs with incomplete scales. The amount of internal decay was very low in this trial. Treatment of bulbs with diatomaceous earth or chlorine, either alone or in combination, did not reduce the amount of internal decay in this trial.

Acknowledgements

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Table 6. The proportions of Vaquero onion bulbs with complete scales, incomplete scales, dry scale, and internal rot in response to chlorine (Cl) and diatomaceous earth (D.E.) applied alone or in combination, Malheur Experiment Station, Oregon State University, Ontario, OR, December 12, 2017.

		All bulbs							Diseased bulbs						
		Complete scales			Incomplete scales			Total	Complete scales			Incomplete scales			Total
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	
		%													
Check		24.0	5.5	29.4	36.6	34.0	70.6	100	0.0	0.0	0.0	0.0	0.5	0.5	0.5
Cl		24.9	3.1	27.9	31.3	40.7	72.1	100	0.2	0.0	0.2	0.0	1.0	1.0	1.1
D.E.		18.7	4.0	22.7	33.4	43.9	77.3	100	0.0	0.1	0.1	0.0	2.3	2.3	2.4
Cl, D.E.		32.1	6.2	38.3	31.4	30.2	61.7	100	0.1	0.0	0.1	0.3	1.7	2.0	2.1
Average		24.9	4.7	29.6	33.2	37.2	70.4	100	0.1	0.0	0.1	0.1	1.4	1.4	1.5
Cl	no	21.3	4.7	26.1	35.0	39.0	73.9	100	0.0	0.0	0.0	0.0	1.4	1.4	1.4
	yes	28.5	4.7	33.1	31.4	35.5	66.9	100	0.1	0.0	0.1	0.2	1.3	1.5	1.6
	average	24.9	4.7	29.6	33.2	37.2	70.4	100	0.1	0.0	0.1	0.1	1.4	1.4	1.5
D.E.	no	24.4	4.3	28.7	33.9	37.4	71.3	100	0.1	0.0	0.1	0.0	0.7	0.7	0.8
	yes	25.4	5.1	30.5	32.4	37.1	69.5	100	0.0	0.0	0.1	0.2	2.0	2.1	2.2
	average	24.9	4.7	29.6	33.2	37.2	70.4	100	0.1	0.0	0.1	0.1	1.4	1.4	1.5
LSD (0.05)															
Cl		NS	NS	NS	NS	NS	NS		NS	NS	NS	0.1	NS	NS	NS
D.E.		NS	NS	NS	NS	NS	NS		NS	NS	NS	0.1	1.3	1.3	1.4
Cl X D.E.		4.6	NS	7.8	NS	5.6	7.8		NS	NS	NS	0.2	NS	NS	NS

ONION RESPONSE TO VARIOUS OUTLOOK® HERBICIDE RATES APPLIED THROUGH IRRIGATION DRIP WITH AND WITHOUT FERTILIZER

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017

Introduction

Application of dimethenamid-p (Outlook®) through irrigation drips to control yellow nutsedge in dry bulb onion grown in the Treasure Valley of eastern Oregon and southwestern Idaho was approved in 2016. Section 24C Special Local Need (SLN) No. OR-160004 allows applications of Outlook through irrigation drips 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 the irrigation drip 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 are allowed without going over 21 fl oz/acre/season. Applications through the irrigation drip are allowed starting when onions are at the 2-leaf but not after the 6-leaf stage. The current registration restricts the applications through the irrigation drip 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 and liquid fertilizer applied through the irrigation drips. The study was conducted with onion variety 'Vaquero' and URAN fertilizer was used.

Materials and Methods

A field study was conducted at the Malheur Experiment Station, Ontario, Oregon in 2017 to evaluate the response of onion variety 'Vaquero' to mixtures of Outlook herbicide plus nitrogen (N) fertilizer applied through the irrigation drip. Herbicide/fertilizer solution applications were initiated when onion plants were at the 2-leaf stage. Onion seeds of variety Vaquero were planted on April 7 in double rows spaced 3 inches apart with 4-inch seed spacing within each row. Each double row was planted on beds spaced 22 inches apart. Immediately after planting, onion rows received a 7-inch band of Lorsban® at 3.7 oz/1000 ft of row 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 randomized complete blocks with four replicates. 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 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) on June 4 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 June 1. Sequential applications on a weekly or biweekly schedule continued through June 22 (Tables 1 and 2). The first fertilizer application to supply 30 lb N/acre was injected on May 4 to the entire study in order to correct soil nutrient deficiencies attributed to uncharacteristically high moisture from previous winter snow and spring precipitation. The final URAN fertilizer to supply 50 lb N/acre was applied on July 10.

Treatments for Outlook plus URAN fertilizer to supply 20 lb N/acre were applied on June 1, 8, 15, and 22. Treatments receiving standalone Outlook solution were fertilized using URAN solution to supply 20 lb N/acre the day after the Outlook plus fertilizer treatments. On July 20, 10 plants were identified randomly from each plot and measured from the ground to the tip of the longest fully extended leaf to determine the average plant height. All other operations including insect control followed recommended local production practices.

Plant tops were flailed and onion bulbs were lifted on September 6 and 7, respectively. Bulbs were hand-harvested from the two center beds on September 11 and graded on September 22. Bulbs were graded for yield and quality based on USDA standards as follows: bulbs without blemishes (U.S. No. 1), split bulbs (U.S. 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 >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 May 3, 2017. Evaluations on July 20 (60 days after emergence) indicated a variable onion plant stand across treatments but there was no effect on plant height (Table 1). Differences in plant stand were attributed to wet conditions during spring from uncharacteristically high snow amounts during winter and high precipitation in spring. Plant stand ranged from 102,423 to 109,466 plants/acre across Outlook treatments applied through the irrigation drip compared to 107,344 plants/acre for the grower standard and 109,607 plants/acre for the hand-weeded check.

Rotten bulb amounts were similar across herbicide treatments and ranged from 0 to 5.6 cwt/acre (Table 2). Yield for various onion categories varied widely across herbicide treatments. Marketable bulb yield for plants treated with the weekly sequential application of Outlook at 7 fl oz/acre with and without fertilizer was 1067.5 and 1036.6 cwt/acre, respectively. Similar yield was also recorded for plants treated with weekly sequential application of Outlook at 6, 5, 5, 5 fl oz/acre mixed with fertilizer (1080.8 cwt/acre) and 1015.5 cwt/acre for Outlook without fertilizer.

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 (927.3 cwt/acre) or mixed with fertilizer (934 cwt/acre) compared to 1131.7 cwt/acre for the hand-weeded check. Marketable yield for the grower standard and hand-weeded check was similar to Outlook applied sequentially at 7 fl oz/acre or 6, 5, 5, 5 fl oz/acre on a weekly schedule.

These results indicated no adverse effects when Outlook was applied through the irrigation drip with or without URAN fertilizer solution to onion variety Vaquero starting at the 2-leaf stage. The study will be repeated in 2018 to confirm these results. The 2 years of data will be used to solicit changes to the SLN label to allow mixing Outlook with liquid fertilizer in applications made through irrigation drips in the Treasure Valley of eastern Oregon and southwestern Idaho.

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Table 1. Onion plant stand and height on July 20 and number of harvested bulbs in response to various Outlook (dimethenamid-p) herbicide treatments applied with and without liquid fertilizer through the irrigation drip at the Malheur Experiment Station, Ontario, OR, 2017.

					Plant				Marketable				
	With	Rate[a]	Timing[b]	Plant stand	height	<2¼ in[c]	US No. 2	Plate rot	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
Treatment	fertilizer	fl oz/acre		No./acre	cm	---------- Number of bulbs/acre[c] ----------							
Outlook	Yes	7	A = 2 leaf	109,466 ab	84.2 ab	297 a	148 b	1,780 ab	4,599 ab	57,121 ab	30,266 ab	8,012 ab	99,998 a
Outlook	Yes	7	14 days after A										
Outlook	Yes	7	21 days after A										
Outlook	No	7	A = 2 leaf	102,324 c	87.1 a	593 a	1039 a	1,484 b	2,819 ab	42,878 b	35,459 ab	8,012 ab	89,167 b
Outlook	No	7	7 days after A										
Outlook	No	7	14 D after A										
Outlook	Yes	6	A = 2 leaf	107,344 abc	84.3 ab	445 a	445 ab	1,929 ab	3,116 ab	52,521 ab	32,789 ab	8,754 ab	97,179 ab
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	103,738 bc	83.6 ab	445 a	445 ab	1,039 b	3,412 ab	51,631 ab	29,376 ab	8,605 ab	93,025 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	110,597 a	83.6 ab	297 a	445 ab	4,006 a	5,935 ab	64,984 a	22,997 b	3,412 b	97,328 ab
Outlook	Yes	21	14 days after A										
Outlook	No	21	A = 2 leaf	106,284 abc	82.8 b	0 a	445 ab	3,116 ab	9,199 a	52,373 ab	25,816 b	6,528 ab	93,915 ab
Outlook	No	21	14 days after A										
Outlook-Grower standard		21	A = 2 leaf-broadcast	107,344 abc	87.0 a	445 a	1,039 a	2,522 ab	2,671 ab	39,762 b	42,729 a	11,572 a	96,734 ab
Hand-weeded check				109,607 ab	85.1 ab	1,039 a	1187 a	3,412 ab	2,374 b	43,916 b	38,427 ab	11,869 a	96,586 ab
LSD (*P* = 0.05)				6,390.1	3.90	1,082.7	860.4	2,498.9	6,635.5	17,562.0	15,458.0	6,009.3	8,479.7

[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 (Jun 1, 2017); B = 7 days after A (Jun 8, 2017); C = 14 days after A (Jun 15, 2017); D = 21 days after A (Jun 15, 2017); E = 28 days after A (Jun 22, 2017).
[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. 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). Marketable yield consists of U.S. No.1 bulbs >2¼ inches.

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

									Marketable				
	With	Rate[a]	Timing[b]	Plant stand	Plant height	Plate rot	US No. 2	<2¼ in[c]	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
Treatment	fertilizer	fl oz/acre		No./acre	cm	cwt/acre[c]							
Outlook	Yes	7	A = 2 leaf	109,466 ab	84.2 ab	2.3a	0.4 b	3.2 abc	18.3a	514.3 ab	401.0 abc	133.9ab	1,067.5 ab
Outlook	Yes	7	14 days after A										
Outlook	Yes	7	21 days after A										
Outlook	No	7	A = 2 leaf	102,324 c	87.1 a	3.7a	7.4 ab	2.7 bc	11.2a	421.5 ab	471.2 abc	132.7ab	1,036.6 ab
Outlook	No	7	7 days after A										
Outlook	No	7	14 days after A										
Outlook	Yes	6	A = 2 leaf	107,344 abc	84.3 ab	2.0a	5.1 ab	3.1 abc	12.0a	493.1 ab	433.2 abc	142.5ab	1,080.8 ab
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	103,738 bc	83.6 ab	1.9a	3.4 ab	1.4 c	13.3a	475.9 ab	382.6 abc	142.7ab	1,014.5 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	110,597 a	83.6 ab	2.4a	3.1 ab	6.8 a	23.7a	552.0 a	299.6 c	58.7b	934.0 b
Outlook	Yes	21	14 days after A										
Outlook	No	21	A = 2 leaf	106,284 abc	82.8 b	0.0a	2.9 ab	5.1 abc	35.1a	442.5 ab	341.8 bc	108.0ab	927.3 b
Outlook	No	21	14 days after A										
Outlook-Grower standard		21	A = 2 leaf-broadcast	107,344 abc	87.0 a	3.7a	9.7 a	3.5 abc	10.6a	380.6 b	568.8 a	186.9a	1,146.9 a
Hand-weeded check				109,607 ab	85.1 ab	5.6	10.1 a	5.6 ab	9.8a	411.9 b	513.1 ab	196.9a	1,131.7 a
LSD (*P* = 0.05)				6,390.1	3.9	NS	8.9	3.9	26.5	134.2	211.2	98.8	177.4

[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 (Jun 1, 2017); B = 7 days after A (Jun 8, 2017); C = 14 days after A (Jun 15, 2017); D = 21 days after A (Jun 15, 2017); E = 28 days after A (Jun 22, 2017).

[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. 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). Marketable yield consists of U.S. No.1 bulbs >2¼ inches.

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

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017

Introduction

Application of dimethenamid-p (Outlook®) herbicide through drip irrigation systems to control yellow nutsedge in onion in the Treasure Valley of eastern Oregon and southwestern Idaho was authorized in 2016. The section 24C Special Local Need (SLN) registration is allowed only on yellow onions. 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 labels still limit 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 irrigation drip 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 that is needed in order to allow the use of Outlook through the irrigation drips to red and white onions. The study included six red varieties and four white varieties.

Materials and Methods

A field study was conducted at the Malheur Experiment Station, Ontario, Oregon in 2017 to evaluate the response of six red and four white onion varieties to various Outlook herbicide rates applied through irrigation drips. Seeds of red varieties 'Red Wing', 'Red Carpet', 'Red Devil', 'Salsa', SV4643NT, and 'Purple Haze'; as well as white varieties 'Antarctica', 'White Cloud', SV4058NU, and 'Brundage' were planted on April 10, 2017 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. On April 17 each onion row received a 7-inch band of Lorsban® at 3.7 oz/1000 ft of row 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 19. 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 31, June 7, 13, and 22 (Tables 1-4). On July 20, 10 plants were identified randomly from each plot and measured from the ground to the tip of the longest fully extended leaf to determine the average plant height. Fertilizer was applied through irrigation drip on May 8 (30 lb nitrogen (N)/acre), June 22, July 7, and 11 (50 lb N/acre each). All other operations followed recommended local production practices.

Plant tops were flailed and onion bulbs were lifted on September 6 and 7, respectively. Bulbs were hand-harvested from the two center beds on September 11 and graded on September 22. Bulbs were graded for yield and quality based on USDA standards as follows: bulbs without blemishes (U.S. No. 1), split bulbs (U.S. 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 >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 May 3, 2017. Data analysis indicated differences attributed to varietal differences but not herbicide rates and there was no interaction between variety and herbicide rates. Therefore, the data presented herein are averaged across herbicide rates (or across varieties to illustrate lack of herbicide effects).

Evaluations on July 20 (78 days after onion emergence) indicated variations in plant height that were attributed to variety difference and not herbicide or the interaction of herbicide by variety (Table 1). The average plant height for red varieties was 29.2 inches compared to 31.8 for white varieties. Plant stand on July 20 ranged from 73,853 to 114,345 plants/acre for reds and 68,040 to 100,766 plants/acre for whites. Differences in the number of harvested bulbs for each category varied widely for the red and white varieties. The variations were not attributed to herbicide rates or the interaction of herbicide by variety.

Data averaged across varieties revealed differences in the number of plants and height as well as the number of harvested bulbs attributable to variety difference, with no negative effects from any of the herbicide rates or the interaction of herbicide by varieties (Table 2).

Differences in onion yield for various bulb categories were also attributed to variety differences (Table 3). Onion bulb yield averages across varieties confirmed differences were due to varieties and there were no negative effects from herbicide rates (Table 4).

These results demonstrated that red and white onion varieties evaluated in this study were not negatively affected by any of the Outlook herbicide rates tested.

The study will be repeated in 2018 to confirm these results followed by a request to include red and white onions on the Outlook SLN labels in eastern Oregon and southwestern Idaho to apply Outlook through the irrigation drips to control yellow nutsedge in onions.

The current SLN label allowing the application of Outlook through the irrigation drips 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

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 supported by Formula Grant nos. 2017-31100-06041 and 2017-31200-06041 from the USDA National Institute of Food and Agriculture.

Table 1. Onion plant stand and plant height (July 20), and number of harvested bulbs for six red and four white onion varieties averaged across various Outlook[a] (dimethenamid-p) herbicide rates applied through the irrigation drip at the Malheur Experiment Station, Ontario, OR, 2017. The average across herbicide rates includes the untreated hand-weeded control treatment.

							Marketable				
Type[a]	Variety	Plant stand	Plant height	<2¼ in	U.S No. 2	Plate Rot	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		No./acre	inches	Number of bulbs/acre[b]							
Red	Red Wing	114,345	29.7	15,298	231	165	29,014	70,325	659	0	99,998
Red	Red Carpet	98,129	29.7	15,067	659	198	30,036	51,137	1,616	66	82,854
Red	Red Devil	79,201	30.2	10,979	264	1,286	30,827	35,641	264	33	66,764
Red	Salsa	77,638	26.6	16,947	4,121	3,495	21,892	29,310	758	33	51,994
Red	SV4643NT	88,555	30.2	16,518	2,341	923	27,365	38,443	1,418	33	67,259
Red	Purple Haze	73,853	29.0	9,528	330	1,121	27,530	36,564	264	0	64,357
Average		88,620	29.2	14,056	1,324	1,198	27,777	43,570	830	28	72,204
White	Antarctica	100,766	33.8	2,143	1,187	429	6,001	73,128	19,254	1,220	99,602
White	White Cloud	90,704	30.4	3,495	6,660	6,627	5,836	52,554	15,133	1,714	75,238
White	SV4058NU	99,423	31.9	2,769	1,121	1,451	10,847	72,369	11,144	593	94,954
White	Brundage	68,040	31.1	3,825	1,484	725	10,023	44,477	6,825	429	61,753
Average		89,733	31.8	3,058	2,613	2,308	8,177	60,632	13,089	989	82,887
LSD (0.05) Variety		19,349	2.0	NS	2,256	2,095	17,441	40,182	6,358	792	28,078
LSD (0.05) Herbicide		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD (0.05) Var x Herbicide		NS	NS	NS	NS	NS	NS	NS	NS	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]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. 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). Marketable yield consists of U.S. No.1 bulbs >2¼ inches.

Table 2. Onion plant stand and plant height (July 20), and number of harvested bulbs in response to various Outlook[a] (dimethenamid-p) herbicide treatments applied through the irrigation drip at the Malheur Experiment Station, Ontario, OR 2017. The number of bulbs are averaged across six red and four white onion varieties.

Treatment	Rate[a]	Timing[b]	Plant population	Plant height	<2¼ in	US No. 2	Plate rot	Marketable[c] 2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
	fl oz/acre		No./acre	inches	Number of bulbs /acre[c]							
Outlook	11	2 leaves = A	89,459	30.4	8,289	2,097	1,365	18,377	52,917	6,667	475	78,436
Outlook	10	14 days after A										
Outlook	7	2 leaves = A	87,847	30.4	9,772	1,780	1,899	20,079	51,117	5,440	475	77,110
Outlook	7	7 days after A										
Outlook	7	14 days after A										
Outlook	6	2 leaves = A	90,587	30.1	10,208	1,187	1,286	22,215	51,374	3,996	178	77,763
Outlook	5	7 days after A										
Outlook	5	14 days after A										
Outlook	5	21 days after A										
Outlook	21	2 leaves = A	91,349	30.0	10,821	2,038	2,156	22,690	47,952	5,302	415	76,359
Outlook	21	14 days after A										
Outlook	21	2-leaf broadcast	86,645	30.3	9,950	1,899	1,622	17,646	49,435	6,014	495	73,589
Hand-weeded			88,506	30.4	8,902	2,038	1,523	18,615	49,574	6,983	435	75,607
LSD (0.05) herbicide			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD (0.05) varieties			19,349	2.0	NS	2,256	2,095	17,441	NS	6,358	792	28,078
LSD (0.05) herbicide x variety			NS	NS	NS	NS	NS	NS	NS	NS	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 31, 2017); B = 7 days after A (Jun 7, 2017); C = 14 days after A (Jun 13, 2017); D = 21 days after A (Jun 21, 2017).
[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. 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). Marketable yield consists of U.S. No.1 bulbs >2¼ inches.

Table 3. Onion plant stand (July 20), and harvested bulb yield for six red and four white onion varieties averaged across various Outlook[a] (dimethenamid-p) herbicide rates applied through the irrigation drip at the Malheur Experiment Station, Ontario, OR, 2017. The average across herbicide rates includes the untreated hand-weeded check treatment.

			Unmarketable			Marketable				
Type	Variety	Plant stand	<2¼ in	US No.2	Plate Rot	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
		No./acre	---------- cwt/acre[b] ----------							
Red	Red Wing	114,345	27.7	1.3	0.6	106.3	481.3	6.8	0.0	594.4
Red	Red Carpet	98,129	30.8	4.6	0.7	106.2	365.6	16.7	0.7	489.2
Red	Red Devil	79,201	23.1	1.3	4.9	115.7	231.8	3.2	0.4	351.0
Red	Salsa	77,638	30.0	20.8	7.7	77.4	210.6	9.2	0.6	297.9
Red	SV4643NT	88,555	30.6	18.4	3.4	95.4	280.5	16.9	0.5	393.3
Red	Purple Haze	73,853	19.8	1.2	5.5	103.7	229.6	3.1	0.0	336.4
Average		88,620	27	7.9	3.8	100.8	299.9	9.3	0.4	410.4
White	Antarctica	100,766	4.3	11.3	4.9	24.3	646.5	234.8	18.2	923.7
White	White Cloud	90,704	5.5	45.4	55.6	22.4	462.3	199.0	29.0	712.7
White	SV4058NU	99,423	5.7	6.2	10.0	42.4	590.0	136.7	9.0	778.1
White	Brundage	68,040	6.3	7.8	4.4	37.3	355.6	82.5	6.2	481.6
Average		89,733	5.5	17.7	18.7	31.6	513.6	163.3	15.6	724.0
LSD (0.05) variety		19,349	NS	17.7	15.4	55.5	NS	81.6	13.2	311.5
LSD (0.05) herbicide		NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD (0.05) var x herbicide		NS	NS	NS	NS	NS	NS	NS	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]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. 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). Marketable yield consists of U.S. No.1 bulbs >2¼ inches.

Table 4. Onion plant stand on July 20 and harvested bulb yield averaged across six red and four white onion varieties various in response to Outlook[a] (dimethenamid-p) herbicide treatments applied through the irrigation drip at the Malheur Experiment Station, Ontario, OR, 2017.

				Unmarketable			Marketable				
Treatment	Rate[a]	Timing[b]	Plant stand	<2¼ in[c]	US No. 2	Plate Rot	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
	fl oz/acre		No./acre	cwt/acre[c]							
Outlook	11	2 leaves = A	89,459	15.5	13.6	7.6	69.7	414.4	82.7	7.5	574.3
Outlook	10	14 days after A									
Outlook	7	2 leaves = A	87,847	19.0	11.2	12.2	73.7	388.5	67.5	7.4	537.1
Outlook	7	7 days after A									
Outlook	7	14 days after A									
Outlook	6	2 leaves = A	90,587	20.1	8.3	8.5	81.6	390.6	49.1	2.9	524.3
Outlook	5	7 days after A									
Outlook	5	14 days after A									
Outlook	5	21 days after A									
Outlook	21	2 leaves = A	91,349	20.7	11.7	11.2	83.3	362.4	63.5	6.4	515.5
Outlook	21	14 days after A									
Outlook	21	2-leaf broadcast	86,645	18.3	12.0	10.1	62.2	378.0	74.9	7.7	522.7
Hand-weeded check			88,506	16.7	14.2	8.8	68.3	378.3	87.6	6.8	541.0
LSD (0.05) herbicide			NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD (0.05) varieties			19,349	NS	17.7	15.4	55.5	NS	81.6	13.2	311.5
LSD (0.05) herbicide x varieties			NS	NS	NS	NS	NS	NS	NS	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 31, 2017); B = 7 days after A (Jun 7, 2017); C = 14 days after A (Jun 13, 2017); D = 21 days after A (Jun 21, 2017).
[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. 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). Marketable yield consists of U.S. No.1 bulbs >2¼ inches.

ONION RESPONSE TO CHATEAU® AND FIERCE® HERBICIDES APPLIED LATE PRE-EMERGENCE ON MINERAL SOIL

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017

Introduction

Weed control in marketable onions is essential in order to minimize yield losses from weed competition and realize acceptable bulb size. Weed control in onions is difficult compared to many crops because of the lack of a complete crop canopy and limited herbicide options. The herbicide Chateau® (flumioxazin) is also marketed as Valor® by Valent Corporation to manage weeds in various specialty crops. Initially it was evaluated for suitability as a postemergence weed control in direct-seeded onions, but injury proved to be too high for the company to proceed with registration in the Treasure Valley. Currently there are labels for Chateau use to control weeds in onions in Michigan and New York. This trial was initiated to evaluate the potential use of Chateau as a late pre-emergence-applied product similar to the timing of Prowl® H_2O in onions grown in the Treasure Valley of eastern Oregon and southwestern Idaho.

Materials and Methods

A field study was conducted at the Malheur Experiment Station, Ontario, Oregon in 2017 to evaluate the response of onion variety 'Vaquero' to Chateau (flumioxazin) and Fierce® (premix of Chateau plus Zidua® (pyroxasulfone)), when applied late pre-emergence at reduced rates. Onion seeds of variety Vaquero were planted on April 7, 2017 in double rows spaced 3 inches apart with 4-inch seed spacing within each row. Each double row was planted on beds spaced 22 inches apart. Immediately after planting, onion rows received a 7-inch band of Lorsban® at 3.7 oz/1000 ft of row (chlorpyrifos at 0.206 lb ai/acre) and the soil surface was rolled. The soil was an Owyhee silt loam with a pH 7.2 and 1.83% organic matter.

The study had a randomized complete block design with three replicates. Individual plots were 7.33 ft wide (4 beds) by 27 ft long. Plots for respective treatments (except untreated check plots) were treated with pendimethalin (Prowl H_2O) at 2.0 pt/acre (0.95 lb ai/acre) or Chateau or Fierce late pre-emergence on April 19 (Table 1). 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) was made when onion seedlings were at the 2-leaf stage on May 23 and at the 4- to 6-leaf stages on June 5. The study plots were sprayed with Poast® herbicide at 1.5 pt/acre (sethoxydim at 0.287 lb ai/acre) on June 4 to control grassy weeds.

The plants were fertilized on May 4 (30 lb nitrogen (N)/acre), June 16 (50 lb N/acre), July 3 and 14 (50 lb N/acre each date). On June 23, all weeds within the two center rows were counted and plots hand weeded. All other operations including insect control followed recommended local production practices.

Plant tops were flailed and onion bulbs were lifted on September 6 and 7, respectively. Bulbs were hand-harvested from the two center beds on September 13 and graded on September 25. Bulbs were graded for yield and quality based on USDA standards as follows: bulbs without blemishes (U.S. No. 1), split bulbs (U.S. 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 >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 May 3, 2017. Generally, the plant population was low during the 2017 cropping season, possibly due to uncharacteristically high moisture from winter snow and spring precipitation. Evaluations on May 23 (34 days after application of late pre-emergence treatments) indicated plant injury ranging from 10 to 15% for plants growing in plots treated with Chateau or Fierce (Table 1). Common lambsquarters control ranged from 90 to 98% for Chateau and Fierce treatments compared to 94 to 97% for plots treated with Prowl H_2O. A similar trend was observed for redroot pigweed, kochia, hairy nightshade, and barnyardgrass.

Evaluations on May 30 (41 days after late pre-emergence and 7 days after postemergence treatments) indicated onion injury in plots treated with Chateau and Fierce ranging from 5 to 10% compared to 0% for those treated with Prowl H_2O (Table 2). Control for common lambsquarters, redroot pigweed, kochia, and hairy nightshade was still high, ranging from 80 to 79% compared to 100% for plots treated with Prowl H_2O. However, weed control in plots treated with Prowl H_2O late pre-emergence followed by Chateau at 0.5 oz/acre when onions were at the 2- and 4-leaf stage was ≤23% for common lambsquarters, redroot pigweed, kochia, and hairy nightshade. These results suggested that Chateau would not be a good choice as a standalone product to control weeds postemergence.

Average number of weeds in the two center rows on June 20 (31 days after late pre-emergence and 7 days after postemergence treatments) is presented in Table 3. Common lambsquarters control ranged from 2 to 14 plants for plots treated with Chateau or Fierce late pre-emergence compared to 18 plants for Chateau applied postemergence and 1 to 5 plants for plots treated with Prowl H_2O. Generally, plots treated with Chateau or Fierce late pre-emergence had fewer weeds compared to plots treated with Prowl H_2O at the same timing.

Plant stand on May 30 and marketable onion yield is presented in Table 4. Counts on May 30 indicated reduced plant stand in plots treated with Fierce at 1.25 oz/acre (0.0594 lb ai/acre) and Chateau at 1 oz/acre (0.032 lb ai/acre), which was 80,960 and 83,600 plants/acre, respectively. Yield for US. No. 2 onions was similar across treatments ranging from 0 to 5.5 cwt/acre. Yield for bulbs exhibiting plate rot was higher in plots treated with Chateau or Fierce late pre-emergence. Total marketable yield was similar across herbicide treatments and ranged from 862.2 to 988.4 cwt/acre compared to 1002.6 cwt/acre for the grower standard.

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 supported by Formula Grant nos. 2017-31100-06041 and 2017-31200-06041 from the USDA National Institute of Food and Agriculture.

Table 1. Onion response and weed control on May 23 (34 days after late pre-emergence treatments) to application of various herbicides at the Malheur Experiment Station, Ontario, OR, 2017.

Treatment	Rate[a]	Timing[b]	Onion injury	Weed control[c] Common lambsquarters	Redroot pigweed	Kochia	Hairy nightshade	Common barnyardgrass
			%					
Untreated check	per acre		0 d	0 d	0 e	0 d	0 c	0 b
Chateau	0.5 oz	LPRE	10 ab	90 c	95 d	92 c	94 ab	97 a
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Chateau	1.0 oz	LPRE	13 a	98 a	99 a	99 a	99 a	98 a
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Fierce (Chateau + Zidua)	1.25 oz	LPRE	15 a	97 ab	98 abc	98 ab	98 ab	98 a
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Prowl H_2O	2.0 pt	LPRE	3 cd	96 ab	96 cd	93 c	94 ab	96 a
Fierce (Chateau + Zidua)	1.25 oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Prowl H_2O	2.0 pt	LPRE	3 cd	97 ab	99 ab	99 ab	96 ab	94 a
Fierce (Chateau + Zidua)	1.5 oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Prowl H_2O	2.0 pt	LPRE	5 bcd	94 b	97 bcd	92 c	93 b	96 a
Chateau	0.5 oz	2-leaf						
Chateau	0.5 oz	4-6 leaf						
Prowl H_2O (Grower standard)	2.0 pt	LPRE	7 bc	96 ab	98 abc	95 bc	95 ab	98 a
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
LSD (P = 0.05)			5.8	3.4	2.3	4.2	5.2	4.0
Standard Deviation			3.3	1.9	1.3	2.4	3.0	2.3
CV			46.53	2.32	1.52	2.86	3.54	2.7

[a]Chateau 0.5 oz/acre = flumioxazin 0.016 lb/acre; Buctril 12 fl oz/acre = bromoxynil 0.188 lb ai/acre; GoalTender 4 fl oz/acre = oxyfluorfen 0.125 lb ai/acre; Fierce 1.25 oz/acre = flumioxazin 0.0262 + pyroxasulfone 0.0332 lb ai/acre; Prowl H_2O 2 pt/acre = pendimethalin 0.95 lb ai/acre.

[b]Timing LPRE-late pre-emergence (75% of seeds have germinated but no emergence); 2-leaf = onion seedlings at 2-leaf stage; 4-6 leaf = onion seedling at 4- to 6-leaf stage.

[c]Means within a column followed by same letter do not significantly differ (P = 0.05, LSD).

Table 2. Onion response and weed control on May 30 (41 days after late pre-emergence) and 7 days after postemergence application of various herbicides at the Malheur Experiment Station, Ontario, OR, 2017.

Treatment	Rate[a]	Timing[b]	Onion injury	Weed control[c] Common lambsquarters	Redroot pigweed	Kochia	Hairy nightshade	Common barnyardgrass
	per acre		%					
Untreated check			0.0 c	0 e	0 d	0 e	0 e	0 f
Chateau	0.5 oz	LPRE	5.0 b	93 b	97 a	95 b	95 b	80 b
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Chateau	1.0 oz	LPRE	10.0 a	97 ab	97 a	95 b	97 b	20 e
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Fierce (Chateau + Zidua)	1.25 oz	LPRE	6.7 b	97 ab	97 a	97 ab	95 b	72 d
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Prowl H_2O	2.0 pt	LPRE	0.0 c	85 c	87 b	78 c	80 c	77 c
Fierce (Chateau + Zidua)	1.25 oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Prowl H_2O	2.0 pt	LPRE	5.0 b	96 ab	97 a	97 ab	97 b	80 b
Fierce (Chateau + Zidua)	1.5 oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Prowl H_2O	2.0 pt	LPRE	0.0 c	22 d	23 c	22 d	22 d	2 f
Chateau	0.5 oz	2-leaf						
Chateau	0.5 oz	4-6 leaf						
Prowl H_2O (Grower standard)	2.0 pt	LPRE	0.0 c	100 a	100 a	100 a	100 a	100 a
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
LSD (P = 0.05)			1.79	4.7	3.4	4.3	2.4	3
Standard Deviation			1.02	2.7	1.9	2.4	1.4	1.89
CV			30.62	3.62	2.58	3.35	1.9	3.52

[a]Chateau 0.5 oz/acre = flumioxazin 0.016 lb/acre; Buctril 12 fl oz/acre = bromoxynil 0.188 lb ai/acre; GoalTender 4 fl oz/acre = oxyfluorfen 0.125 lb ai/acre; Fierce 1.25 oz/acre = flumioxazin 0.0262 + pyroxasulfone 0.0332 lb ai/acre; Prowl H_2O 2 pt/acre = pendimethalin 0.95 lb ai/acre.
[b]Timing LPRE-late pre-emergence (75% of seeds have germinated but no emergence); 2-leaf = onion seedlings at 2-leaf stage; 4-6 leaf = onion seedling at 4- to 6- leaf stage.
[c]Means within a column followed by same letter do not significantly differ (P=0.05, LSD).

Table 3. Average number of weeds in two center rows (3.67 x 27ft) of the onion plot on June 20 (31 days after late pre-emergence and 14 days after the last postemergence herbicide application) at the Malheur Experiment Station, Ontario, OR, 2017.

			Number of weeds[c]					
Treatment	Rate[a]	Timing[b]	Common lambsquarters	Redroot pigweed	Kochia	Hairy nightshade	Lady's-thumb	Total count
	per acre		number/plot					
Untreated check			694 a	958 a	132 a	1,949 a	1,354 a	5,087 a
Chateau	0.5 oz	LPRE	14 b	14 b	3 b	1 b	22 b	53 b
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Chateau	1.0 oz	LPRE	2 b	1 b	0 b	0 b	2 b	5 b
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Fierce (Chateau + Zidua)	1.25 oz	LPRE	5 b	1 b	1 b	0 b	3 b	10 b
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Prowl H_2O	2.0 pt	LPRE	5 b	22 b	2 b	54 b	27 b	111 b
Fierce (Chateau + Zidua)	1.25 oz	2-Leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Prowl H_2O	2.0 pt	LPRE	8 b	12 b	1 b	63 b	31 b	116 b
Fierce (Chateau + Zidua)	1.5 oz	2-Leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
Prowl H_2O	2.0 pt	LPRE	18 b	58 b	2 b	77 b	29 b	185 b
Chateau	0.5 oz	2-leaf						
Chateau	0.5 oz	4-6 leaf						
Prowl H_2O (Grower standard)	2.0 pt	LPRE	1 b	5 b	1 b	55 b	12 b	73 b
Buctril	12 fl oz	2-leaf						
GoalTender	4 fl oz	2-leaf						
Buctril	12 fl oz	4-6 leaf						
GoalTender	4 fl oz	4-6 leaf						
LSD (P = 0.05)			65.13	457.6	93.7	372.9	99.7	724.8
Standard Deviation			37.19	261.3	53.5	212.9	56.9	413.8
CV			39.83	195.42	299.16	77.44	30.75	58.7

[a]Chateau 0.5 oz/acre = flumioxazin 0.016 lb/acre; Buctril 12 fl oz/acre = bromoxynil 0.188 lb ai/acre; GoalTender 4 fl oz/acre = oxyfluorfen 0.125 lb ai/acre; Fierce 1.25 oz/acre = flumioxazin 0.0262 + pyroxasulfone 0.0332 lb ai/acre; Prowl H_2O 2 pt/acre = pendimethalin 0.95 lb ai/acre.
[b]Timing LPRE-late pre-emergence (75% of seeds have germinated but no emergence); 2-leaf = onion seedlings at 2-leaf stage; 4-6 leaf = onion seedling at 4- to 6-leaf stage.
[c]Means within a column followed by same letter do not significantly differ (P = 0.05, LSD).

Table 4. Onion plant stand and bulb yield in response to Chateau and Fierce herbicides applied late pre-emergence at the Malheur Experiment Station, Ontario, OR, 2017.

				Unmarketable			Marketable yield[d]				
Treatment	Rate[a] per acre	Timing[b]	Plant stand	US No. 2	Plate Rot	<2¼ in[c]	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
			No./acre	cwt/acre [d]							
Untreated check			73,480 d	0.0 a	0.0 b	0.0 b	0.0 c	0.0 d	0.0 b	0.0 c	0.0 b
Chateau	0.5 oz	LPRE	91,520 ab	0.0 a	3.1 ab	2.3 ab	17.7 abc	475.4 ab	376.4 a	57.3 bc	926.8 a
Buctril	12 fl oz	2-leaf									
GoalTender	4 fl oz	2-leaf									
Buctril	12 fl oz	4-6 leaf									
GoalTender	4 fl oz	4-6 leaf									
Chateau	1.0 oz	LPRE	83,600 bc	1.6 a	7.3 a	2.7 ab	9.4 bc	368.1 c	379.6 a	145.4 a	902.5 a
Buctril	12 fl oz	2-leaf									
GoalTender	4 fl oz	2-leaf									
Buctril	12 fl oz	4-6 leaf									
GoalTender	4 fl oz	4-6 leaf									
Fierce (Chateau + Zidua)	1.25 oz	LPRE	80,960 cd	0.0 a	5.0 ab	3.1 ab	18.8 abc	431.6 bc	345.4 a	66.3 bc	862.2 a
Buctril	12 fl oz	2-leaf									
GoalTender	4 fl oz	2-leaf									
Buctril	12 fl oz	4-6 leaf									
GoalTender	4 fl oz	4-6 leaf									
Prowl H_2O	2.0 pt	LPRE	88,733 abc	0.0 a	0.0 b	5.7 ab	22.0 ab	484.7 ab	403.1 a	78.6 ab	988.4 a
Fierce (Chateau + Zidua)	1.25 oz	2-leaf									
Buctril	12 fl oz	4-6 leaf									
GoalTender	4 fl oz	4-6 leaf									
Prowl H_2O	2.0 pt	LPRE	94,013 a	3.3 a	0.8 b	6.3 a	18.1 abc	524.8 a	297.4 a	69.9 bc	910.3 a
Fierce (Chateau + Zidua)	1.5 oz	2-leaf									
Buctril	12 fl oz	4-6 leaf									
GoalTender	4 fl oz	4-6 leaf									
Prowl H_2O	2.0 pt	LPRE	97,093 a	0.0 a	0.0 b	5.5 ab	36.4 a	542.7 a	292.8 a	42.9 bc	914.7 a
Chateau	0.5 oz	2-leaf									
Chateau	0.5 oz	4-6 leaf									
Prowl H_2O (Grower standard)	2.0 pt	LPRE	95,333 a	5.5 a	0.4 b	1.5 ab	24.2 ab	465.1 ab	439.0 a	74.4 b	1,002.6 a
Buctril	12 fl oz	2-leaf									
GoalTender	4 fl oz	2-leaf									
Buctril	12 fl oz	4-6 leaf									
GoalTender	4 fl oz	4-6 leaf									
LSD (P = 0.05)			9,393.7	5.48	5.68	5.71	19.13	88.41	198.22	70.68	200.36
Standard Deviation			5,363.6	3.13	3.24	3.26	10.92	50.48	113.18	40.36	114.40
CV			6.09	240.56	155.7	96.26	59.6	12.27	35.74	60.36	14.06

[a] Means within a column followed by same letter do not significantly differ (P = 0.05, LSD).
[b] Chateau 0.5 oz/acre = flumioxazin 0.016 lb/acre; Buctril 12 fl oz/acre = bromoxynil 0.188 lb ai/acre; GoalTender 4 fl oz/acre = oxyfluorfen 0.125 lb ai/acre; Fierce 1.25 oz/acre = flumioxazin 0.0262 + pyroxasulfone 0.0332 lb ai/acre; Prowl H_2O 2pt/acre = pendimethalin 0.95 lb ai/acre.
[c] Timing LPRE-late pre-emergence (75% of seeds have germinated but no emergence); 2-leaf = onion seedlings at 2-leaf stage; 4-6 leaf = onion seedling at 4- to 6-leaf stage.
[d] 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. 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). Marketable yield consists of U.S. No.1 bulbs >2¼ inches.

ONION RESPONSE TO FOMESAFEN (REFLEX®) HERBICIDE APPLIED AT VARIOUS TIMINGS ON MINERAL SOIL

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017

Introduction

Weed control is an important component of onion production in order to minimize yield losses and realize acceptable marketable bulb size. Weed control in onions is difficult compared to other crops because of the lack of a complete crop canopy and limited herbicide options. The few herbicides registered for use in onion necessitate evaluation of product fitness as they come on the market. Reflex® herbicide would fit well into onion production systems in the Treasure Valley of eastern Oregon and southwestern Oregon because of its ability to suppress yellow nutsedge. The objectives of this study were to evaluate onion tolerance of Reflex herbicide and weed control efficacy under local conditions.

Materials and Methods

A field study was conducted at the Malheur Experiment Station, Ontario, Oregon in 2017 to evaluate the response of onion variety 'Vaquero' to Reflex (fomesafen) herbicide applied at various onion growth stages. Seeds of onion variety Vaquero were planted on April 7, 2017 in double rows spaced 3 inches apart with 4-inch seed spacing within each row. Each double row was planted on beds spaced 22 inches apart. On April 12, onion rows received a 7-inch band of Lorsban® at 3.7 oz/1000 ft of row (chlorpyrifos at 0.206 lb ai/acre) and the soil surface was rolled. The soil was a Greenleaf silt loam with a pH of 7.2 and 1.5% organic matter.

The study had a randomized complete block design with four replicates. Individual plots were 7.33 ft wide (4 beds) by 27 ft long. Plots for respective treatments (except untreated check plots) were treated with pendimethalin (Prowl® H_2O) at 2.0 pt/acre (0.95 lb ai/acre) or Reflex late pre-emergence (LPRE) on April 19 (Table 1). Postemergence treatments were sprayed on May 3 when onion plants were at the 2-leaf stage and on May 23 when plants were at the 4-leaf stage. The study was sprayed with Poast® herbicide at 1.5 pt/acre (sethoxydim at 0.287 lb ai/acre) plus crop oil concentrate at 2.5% v/v on May 10 to control grassy weeds.

Urea ammonium nitrate solution (URAN) to supply 30 lb nitrogen (N)/acre was applied through the drip tape on May 3. The same fertilizer solution was used to supply 50 lb N/acre at each occurrence on June 20, 29, and July 14. All weeds were counted and removed on June 20. All other operations including insect control followed recommended local production practices.

Plant tops were flailed and onion bulbs were lifted on September 6 and 7, respectively. Bulbs were hand-harvested from the two center beds on September 15 and graded on September 27. Bulbs were graded for yield and quality based on USDA standards as follows: bulbs without blemishes (U.S. No. 1), split bulbs (U.S. 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 >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 May 3, 2017. Generally, the plant population was low during the 2017 cropping season, possibly due to uncharacteristically high moisture from winter snow and spring precipitation. Treatments that received Reflex LPRE had the lowest plant stand compared to plots treated with Prowl H_2O (Table 1). Onion plant height was also variable across herbicide treatment, but there was no clear trend, suggesting plant stand may have been influenced by factors other than herbicide treatments. Onion injury was greater for plants in plots sprayed with Reflex LPRE. The injury was characterized by yellowing of the leaves and overall stunting.

Common lambsquarters control on May 23 (35 days after LPRE and 21 days after postemergence application) was ≥91% across herbicide treatments except for Reflex followed by Buctril® alone when onions were at the 2-leaf stage (Table 1). A similar trend was observed for redroot pigweed, kochia, and hairy nightshade control.

Evaluation on May 30 (28 days after postemergence application) revealed high onion injury for plots treated with Reflex at 4 fl oz/acre (LPRE) followed by Reflex at 16 fl oz/acre when onions were at the 2-leaf stage (Table 2). Control for common lambsquarters ranged from 53 to 95%, while control for redroot pigweed ranged from 49 to 98%. Kochia control ranged from 25 to 98% and hairy nightshade control was from 41 to 98% across herbicide treatments.

The number of weeds in the two center rows of each plot on June 26 is presented in Table 3. The most weeds were observed in plots treated LPRE with Reflex at 4 fl oz/acre or Prowl H_2O followed by Reflex.

Three treatment combinations resulted in onion marketable yield similar to the hand-weeded check (Table 4): Prowl H_2O followed by Buctril, Prowl H_2O followed by Reflex at the loop stage followed by Buctril at the 4-leaf stage, and Prowl H_2O followed by Reflex at the 2-leaf stage (Table 4). The lowest yield was observed when Reflex at 4 fl oz/acre was applied LPRE followed by Reflex at 8 fl oz/acre when onions were at the 2-leaf stage.

Results from this study suggest that Reflex may not be a viable candidate as a late pre-emergence-applied product to control weeds in onions. Reflex remains a good candidate for postemergence application to manage weeds in onions. The study will be repeated in 2018 to confirm these results.

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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 supported by Formula Grant nos. 2017-31100-06041 and 2017-31200-06041 from the USDA National Institute of Food and Agriculture.

Table 1. Onion plant stand on May 23 and injury and weed control on May 24 in response to various fomesafen (Reflex) herbicide rates and application timing at the Malheur Experiment Station, Ontario, OR, 2017.

Treatment	Rate[a]	Product rate	Timing[b]	Plant stand	Plant height	Injury	Weed control[c] Common lambsquarters	Redroot pigweed	Kochia	Hairy nightshade
	lb ai/a	per acre			inches	-------------	------------- %	-------------	-------------	-------------
Untreated				79,640ab	29.3 f	0 c	0 c	0 c	0 d	0 c
Hand weeded				94,820a	33.9 a	1 c	100 a	100 a	100 a	100 a
Fomesafen	0.0625	4 fl oz	LPRE	78,100b	33.1 a-d	6 c	48 b	48 b	40 c	46 b
Buctril	0.188	12 fl oz	4-leaf							
Prowl H_2O	0.95	2 pt	LPRE	81,400ab	33.1 a-d	5 c	99 a	99 a	99 ab	100 a
Buctril	0.188	12 fl oz	4-leaf							
Prowl H_2O	0.95	2 pt	LPRE	72,930bc	33.5 abc	8 bc	100 a	100 a	100 a	100 a
Fomesafen	0.0625	4 fl oz	LOOP							
Buctril	0.188	12 fl oz	4-leaf							
Prowl H_2O	0.95	2 pt	LPRE	84,150ab	30.6 def	3 c	96 a	97 a	96 ab	96 a
Fomesafen	0.0625	4 fl oz	2-leaf							
Prowl H_2O	0.95	2 pt	LPRE	82,720ab	32.7 a-e	4 c	97 a	98 a	98 ab	98 a
Fomesafen	0.125	8 fl oz	2-leaf							
Prowl H_2O	0.95	2 pt	LPRE	79,310ab	33.8 ab	5 c	99 a	99 a	99 ab	99 a
Fomesafen	0.25	16 fl oz	2-leaf							
Prowl H_2O	0.95	2 pt	LPRE	68,750bc	31.2 b-f	9 abc	97 a	95 a	78 b	98 a
Buctril	0.188	12 fl oz	2-leaf							
Fomesafen	0.0625	4 fl oz	LPRE	56,760c	30.2 ef	18 ab	94 a	93 a	90 ab	96 a
Fomesafen	0.125	8 fl oz	2-leaf							
Fomesafen	0.0625	4 fl oz	LPRE	77,000b	31.0 c-f	8 bc	91 a	90 a	85 ab	90 a
Fomesafen	0.25	16 fl oz	2-leaf							
Prowl H_2O	0.95	2 pt	LPRE	57,310c	31.7 a-f	19 a	98 a	98 a	98 ab	96 a
Fomesafen	0.0625	4 fl oz	LOOP							
Fomesafen	0.0625	4 fl oz	2-leaf							
Fomesafen	0.0625	4 fl oz	4-Leaf							
LSD (*P* = 0.05)				16,296.9	2.62	10.16	9.81	12.45	22.46	10.61
Standard Deviation				11,286.6	1.81	7.04	6.80	8.62	15.56	7.35
CV				14.84	5.67	100.82	8.02	10.2	19.03	8.64

[a]Fomesafen = Reflex; Prowl H_2O = pendimethalin.
[b]Timing LPRE-late pre-emergence (75% of seeds have germinated but no emergence); 2-leaf = onion seedlings at 2-leaf stage; 4-leaf = onion seedling at 4-leaf stage.
[c]Means within a column followed by same letter do not significantly differ (*P* = 0.05, LSD).

Table 2. Onion injury and weed control on May 30 in response to various Fomesafen (Reflex) rates and application timing at the Malheur Experiment Station, Ontario, OR.

Treatment	Rate[a]	Product rate	Timing[b]	Onion injury	Weed control[c]			
					Common lambsquarters	Redroot pigweed	Kochia	Hairy nightshade
	lb ai/acre	per acre		%				
Untreated				0 c	0 d	0 d	0 f	0 e
Hand weeded				0 c	100 a	100 a	100 a	100 a
Fomesafen Buctril	0.0625 0.188	4 fl oz 12 fl oz	LPRE 4-leaf	10 bc	53 c	49 c	25 e	41 d
Prowl H_2O Buctril	0.95 0.188	2 pt 12 fl oz	LPRE 4-leaf	10 bc	95 ab	97 a	98 ab	95 a
Prowl H_2O Fomesafen Buctril	0.95 0.0625 0.188	2 pt 4 fl oz 12 fl oz	LPRE LOOP 4-leaf	1 c	95 ab	98 a	97 ab	97 a
Prowl H_2O Fomesafen	0.95 0.0625	2 pt 4 fl oz	LPRE 2-leaf	8 bc	76 abc	76 ab	76 bc	75 abc
Prowl H_2O Fomesafen	0.95 0.125	2.0 pt 8 fl oz	LPRE 2-leaf	4 c	93 ab	95 ab	86 ab	87 ab
Prowl H_2O Fomesafen	0.95 0.25	2 pt 16 fl oz	LPRE 2-leaf	5 c	96 ab	98 a	97 ab	97 a
Prowl H_2O Buctril	0.95 0.188	2 pt 12 fl oz	LPRE 2-leaf	4 c	95 ab	95 ab	95 ab	98 a
Fomesafen Fomesafen	0.0625 0.125	4 fl oz 8 fl oz	LPRE 2-leaf	23 ab	61 c	69 bc	41 de	50 cd
Fomesafen Fomesafen	0.0625 0.25	4 fl oz 16 fl oz	LPRE 2-leaf	11 abc	73 bc	75 abc	53 cd	68 bc
Prowl H_2O Fomesafen Fomesafen Fomesafen	0.95 0.0625 0.0625 0.0625	2 pt 4 fl oz 4 fl oz 4 fl oz	LPRE LOOP 2-leaf 4-leaf	28 a	92 ab	97 a	96a b	97 a
LSD (P = 0.05)				17.04	24.58	26.54	23.67	25.18
Standard Deviation				11.80	17.03	18.38	16.39	17.44
CV				138.13	22.03	23.27	22.79	23.17

[a]Fomesafen = Reflex; Prowl H_2O = pendimethalin.
[b]Timing LPRE-late pre-emergence (75% of seeds have germinated but no emergence); 2-leaf = onion seedlings at 2-leaf stage; 4-leaf = onion seedling at 4-leaf stage.
[c]Means within a column followed by same letter do not significantly differ (P = 0.05, LSD).

Table 3. Number of weeds in the two center rows of each plot (3.67 x 27 ft) on June 29, 2017 in response to Fomesafen (Reflex) applied at various timings in direct-seeded onion at the Malheur Experiment Station, Ontario, OR.

Treatment	Rate[a]	Product rate	Timing[b]	Common lambsquarters	Redroot pigweed	Kochia	Hairy nightshade	Total
				Number of weeds[c]				
	lb ai/acre	per acre		Number in 2 center rows				
Untreated				138 a	59 ab	18 a	30 a	244 a
Hand weeded				18 c	9 c	0 d	1 b	28 e
Fomesafen	0.0625	4 fl oz	LPRE	104 ab	32 abc	9 a-d	8 ab	154 bc
Buctril	0.188	12 fl oz	4-leaf					
Prowl H_2O	0.95	2 pt	LPRE	14 c	8 c	3 d	3 b	27 e
Buctril	0.188	12 fl oz	4-leaf					
Prowl H_2O	0.95	2 pt	LPRE	5 c	16 bc	0 d	0 b	22 e
Fomesafen	0.0625	4 fl oz	LOOP					
Buctril	0.188	12 fl oz	4-leaf					
Prowl H_2O	0.95	2 pt	LPRE	58 bc	72 a	8 a-d	31 a	169 abc
Fomesafen	0.0625	4 fl oz	2-leaf					
Prowl H_2O	0.95	2 pt	LPRE	58 bc	23 bc	4 cd	12 ab	97 cde
Fomesafen	0.125	8 fl oz	2-leaf					
Prowl H_2O	0.95	2 pt	LPRE	24 c	3 c	4 cd	0 b	31 e
Fomesafen	0.25	16 fl oz	2-leaf					
Prowl H_2O	0.95	2 pt	LPRE	7 c	14 c	0 d	0 b	20 e
Buctril	0.188	12 fl oz	2-leaf					
Fomesafen	0.0625	4 fl oz	LPRE	155 a	24 bc	15 ab	4 b	198 ab
Fomesafen	0.125	8 fl oz	2-leaf					
Fomesafen	0.0625	4 fl oz	LPRE	99 ab	11 c	14 abc	8 ab	131 bcd
Fomesafen	0.25	16 fl oz	2-leaf					
Prowl H_2O	0.95	2 pt	LPRE	46 bc	3 c	7 bcd	0 b	55 de
Fomesafen	0.0625	4 fl oz	LOOP					
Fomesafen	0.0625	4 fl oz	2-leaf					
Fomesafen	0.0625	4 fl oz	4-leaf					
LSD (*P* = 0.05)				72.7	45.9	9.5	23.6	86.3
Standard Deviation				50.3	31.8	6.6	16.3	59.8
CV				83.31	139.17	97.15	201.73	60.93

[a]Fomesafen = Reflex; Prowl H_2O = pendimethalin.
[b]Timing LPRE-late pre-emergence (75% of seeds have germinated but no emergence); 2-leaf = onion seedlings at 2-leaf stage; 4-leaf = onion seedling at 4-leaf stage.
[c]Means within a column followed by same letter do not significantly differ (*P* = 0.05, LSD).

Table 4. Onion bulb yield in response to Fomesafen (Reflex) herbicide applied at various growth stages at the Malheur Experiment Station, Ontario, OR, 2017.

				Unmarketable			Marketable[c]				
Treatment	Rate[a]	Product rate	Timing[b]	Plate rot	US No. 2	<2¼ in	2¼-3 in	3-4 in	4-4¼ in	>4¼ in	Total
	lb ai/acre	per acre		---- cwt/acre[d] ----							
Untreated				0.0 b	0.0 b	0.0 e	0.0 e	0.0 f	0.0 e	0.0 e	0.0 g
Hand weeded				6.5 a	2.3 b	7.2 bcd	15.2 cde	404.4 ab	379.1 a	152.1 a	950.7 a
Fomesafen	0.0625	4 fl oz	LPRE	2.5 ab	5.0 b	5.2 cde	25.3 bcd	380.5 abc	228.6 bcd	73.5 bcd	707.9 b-e
Buctril	0.188	12 fl oz	4-leaf								
Prowl H_2O	0.95	2 pt	LPRE	0.9 ab	2.3 b	4.2 de	14.6 cde	358.5 abc	384.2 a	87.1 abc	844.5 ab
Buctril	0.188	12 fl oz	4-leaf								
Prowl H_2O	0.95	2 pt	LPRE	1.1 ab	5.4 b	2.7 de	9.1 de	305.1 cde	376.6 a	116.5 ab	807.3 ab
Fomesafen	0.0625	4 fl oz	LOOP								
Buctril	0.188	12 fl oz	4-leaf								
Prowl H_2O	0.95	2 pt	LPRE	1.8 ab	2.4 b	16.2 a	55.1 a	295.6 cde	152.2 cd	45.6 cde	548.5 def
Fomesafen	0.0625	4 fl oz	2-leaf								
Prowl H_2O	0.95	2.0 pt	LPRE	1.5 ab	1.0 b	11.1 abc	31.9 bc	423.3 a	217.7 bcd	50.8 b-e	723.8 bcd
Fomesafen	0.125	8 fl oz	2-leaf								
Prowl H_2O	0.95	2 pt	LPRE	4.7 ab	6.5 b	5.3 cde	22.6 bcd	321.2 bcd	312.4 ab	116.0 ab	772.2 abc
Fomesafen	0.25	16 fl oz	2-leaf								
Prowl H_2O	0.95	2 pt	LPRE	1.4 ab	8.8 b	7.4 bcd	22.1 b-e	285.3 cde	201.1 bcd	80.9 bcd	589.4 cde
Buctril	0.188	12 fl oz	2-leaf								
Fomesafen	0.0625	4 fl oz	LPRE	0.6 b	1.8 b	13.4 ab	32.2 bc	207.7 e	85.0 de	37.4 cde	362.4 f
Fomesafen	0.125	8 fl oz	2-leaf								
Fomesafen	0.0625	4 fl oz	LPRE	3.2 ab	3.1 b	11.7 abc	40.4 ab	321.9 bcd	116.3 cde	20.4 de	499.1 ef
Fomesafen	0.25	16 fl oz	2-leaf								
Prowl H_2O	0.95	2 pt	LPRE	2.8 ab	114.4 a	2.7 de	16.9 cde	234.0 de	245.8 abc	86.4 a-d	583.0 cde
Fomesafen	0.0625	4 fl oz	LOOP								
Fomesafen	0.0625	4 fl oz	2-leaf								
Fomesafen	0.0625	4 fl oz	4-leaf								
LSD (*P* = 0.05)				5.56	90.81	6.64	22.31	98.67	144.52	66.58	216.45
Standard Deviation				3.85	62.89	4.60	15.45	68.33	100.09	46.11	149.90
CV				170.15	493.26	63.29	64.94	23.18	44.5	63.84	24.35

[a]Fomesafen = Reflex; Prowl H_2O = pendimethalin.

[b]Timing LPRE-late pre-emergence (75% of seeds have germinated but no emergence); 2-leaf = onion seedlings at 2-leaf stage; 4-leaf = onion seedling at 4-leaf stage.

[c]Means within a column followed by same letter do not significantly differ (*P* = 0.05, LSD).

[d]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. 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). Marketable yield consists of U.S. No.1 bulbs >2¼ inches.

SURFACE WATER QUALITY IN TREASURE VALLEY IRRIGATION CANALS IN RELATION TO FSMA STANDARDS FOR WATER TESTING – 2017

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

Introduction

The Produce Safety Rule of the Food Safety Modernization Act (FSMA) that regulates the production and harvesting of fresh produce begins to go into effect in 2018. Standards for determining the microbial quality of agricultural water are still under consideration by the Food and Drug Administration (FDA). As of this writing, the FDA is considering extending the compliance dates and potentially revising the standards to simplify them (https://www.fda.gov/Food/GuidanceRegulation/FSMA/ucm546089.htm).

A major concern with the water testing provisions is how extensive the microbial testing for agricultural water will need to be. The current draft version of the agricultural water standards would require the establishment of water quality profiles for each source of agricultural water used during the growing of onions or other covered produce. Agricultural water is defined by the FDA as water that is directly applied to growing produce, which includes irrigation water and water used for pesticide applications. Separate water quality profiles would be required when there is “known or reasonably foreseeable hazard” that would lead to a change in water quality. This condition could result in very fine scale water testing, with individual farms having multiple water profiles depending on layout of their fields and the sources of their spray water.

Under the current draft rules, growers would be required to establish water quality profiles based on 20 water samples. If the geometric mean of the most recent 20 samples exceeds 126 colony forming units of generic *E. coli* per 100 ml of water (CFU/100 ml) and the statistical threshold value of those samples exceeds 410 CFU/100 ml of water, growers would be required to take some type of mitigation measure. The most practical mitigation measure for onion growers would be to allow for a microbial die-off period before harvest. The draft rules would allow a die-off rate of 0.5 log per day for up to 4 days following the last irrigation.

Although each farm would be required to maintain their own water quality profiles, there are provisions in the FSMA rules for sharing of water test results and for allowing third parties to collect water samples.

The FDA has indicated that testing could be done at larger geographic scales rather than a farm-by-farm or field-by-field basis if it can be scientifically demonstrated that data collected at those broader scales reliably characterize water quality. Such a region-wide data collection program could significantly reduce the burden on individual growers to collect water samples.

Potential Impact

The FDA has indicated that some form of water quality monitoring will be required for compliance with the produce safety rules of FSMA. Field configurations and the complexity of irrigation systems in the Treasure Valley could mean individual farms would need significant numbers of separate water quality profiles.

Developing a regional approach that samples water at broad geographic levels and that shares data among farms would significantly reduce the cost and time investment for individual growers.

In this study, water quality profiles were developed over a 2-year period for multiple sites along three major canals that provide irrigation water to a large proportion of onion fields in the Treasure Valley. These were the Old Owyhee Ditch in Malheur County, the Owyhee Irrigation District's "Shoestring" Canal in Malheur County, and the Farmers' Coop Canal in Canyon County, Idaho. The Shoestring Canal is supplied by water from the Owyhee Reservoir, water pumped from the Snake River and return flows. The Old Owyhee Ditch is supplied from the Owyhee River, Owyhee Reservoir, the Snake River, and return flows from other canal systems. The Farmers' Coop Canal is supplied by a diversion from the Boise River, which itself flows through agricultural areas. The data (n = 20 samples from each of 48 sites) were then used to generate other profiles based on different geographic parameters.

Materials and Methods

For each canal, four sampling "zones" with four sample sites within each zone were established (n = 16 sites per canal). Sample sites within zones were separated by 1 km (0.62 miles), and there was approximately 7 km (4.5 miles) between zones. These distances covered almost all of the lengths of each canal used for irrigation, with the intent to characterize water quality throughout each system. To comply with the proposed FSMA standards, sites were sampled a total of 20 times over 2 years (2016 and 2017). Canals were sampled from late July to early September to satisfy the FDA requirement that samples are collected as "close to harvest as practicable".

In addition to locating the sample sites, all places where water returned into each canal from drains or other inlets were identified and mapped.

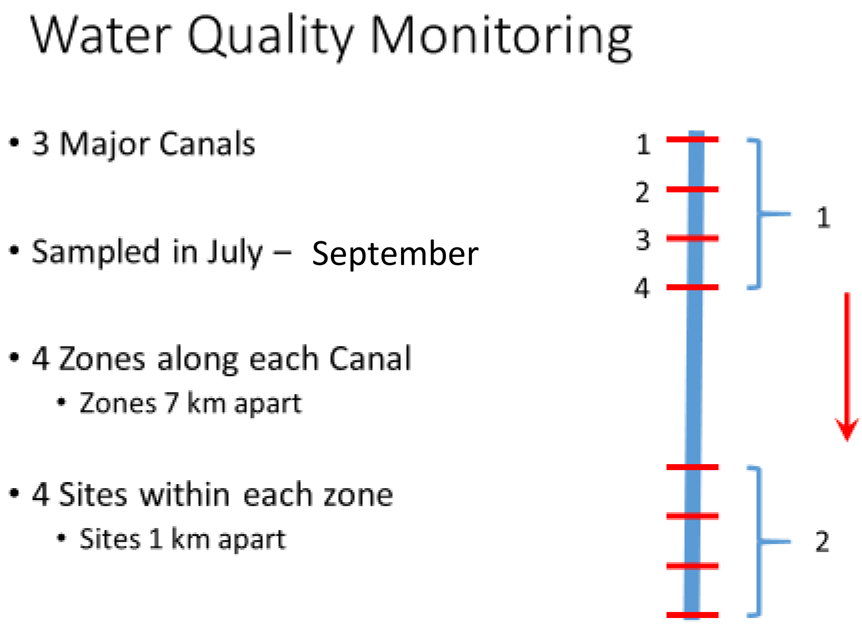

Figure 1. Schematic of water monitoring plan showing the arrangement of sampling sites within sampling zones.

Water quality profiles were developed for each canal to determine how variable results were among sites within and among zones. The water quality profiles were recalculated with the FDA die-off provisions (0.5 log per day die-off over 4 days). This 2-log reduction translates into a final level 1% of the original level.

Water quality profiles based on the actual sample data were expected to be highly variable with a large proportion potentially not within the FSMA thresholds (GM $\leq$ 126, STV $\leq$ 410 CFU/100 ml) (GM = geometric mean, STV = statistical threshold value). However, when recalculated with the die-off allowance (log(CFU) – 2), all sites were expected to be well within standards.

RESULTS

The sampling sites encompassed nearly the entire length of each canal. We mapped several hundred return points in the systems. The runoff from these points may potentially lead to increases in the bacterial load of the water in each canal. In general, the canals had different water quality characteristics.

Each canal flows through intensive agricultural areas with numerous return flow points. Even with these similarities, each canal had different patterns and levels of generic *E. coli* levels (Fig. 2). Canal 3 had the overall highest generic *E. coli* levels and the most variable data. Upstream sites on Canal 3 had low mean *E. coli* levels, but its downstream sites had the highest levels (Fig. 2). These patterns led to significant differences among the sampling zones on Canals 2 and 3; however, there were no differences among the sampling zones on Canal 1.

Although there were differences in water quality profiles among the different zones on Canals 2 and 3, there were no significant differences in profiles within each of the zones. This same pattern held for Canal 1. In fact, there were no differences in the profiles within or among zones. This finding suggests that sampling over larger geographic areas (e.g., 2-6 miles among testing locations) would be as representative of water quality as field-by-field sampling.

The majority of profiles for each of the canals had GM > 126 MPN / 100 or STV > 410 MPN / 100 ml or both, and thus exceeded the proposed FSMA standards (Figs. 3 and 4). However, after the 4-day die-off period, all profile sampling sites were well within the proposed FSMA standards. All of the sampling sites had profiles within the proposed standards within just 1-2 days of die-off.

Importantly, there was little variation among sample sites within each zone (Figs. 2 and 3). With the die-off provisions, large-scale geographic testing of water should adequately characterize the quality of different canal systems (Fig. 4). These results raise the potential that FSMA-related water testing could be done on a regional basis and growers can share water testing results. This could reduce some of the water testing burdens and costs on individual growers.

With Idaho-Eastern Oregon Onion Committee and grower association approval, information will be communicated to FDA to determine if broader scale monitoring would be an acceptable approach.

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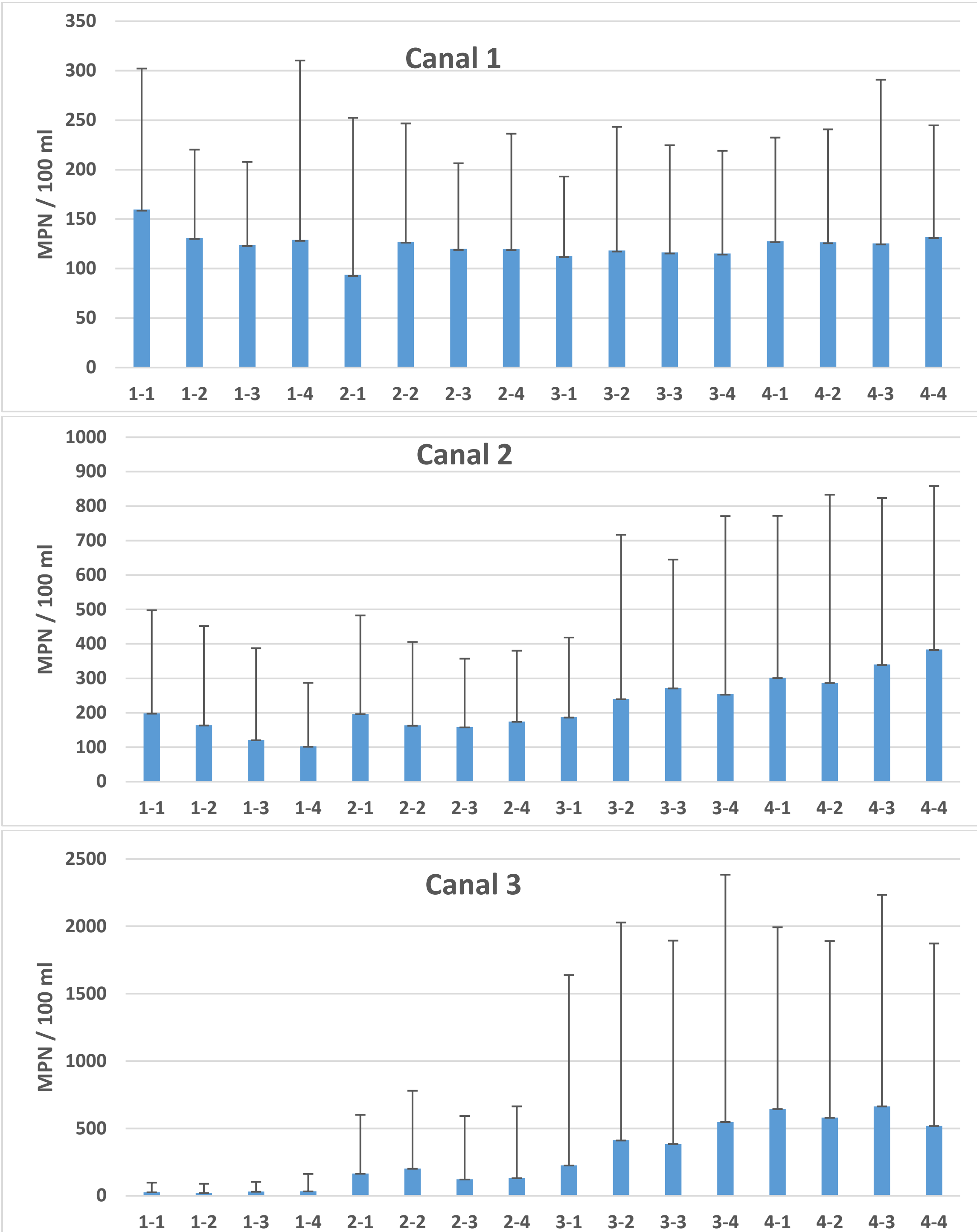

Figure 2. Water quality profiles for each sampling site along different canals. The first number in the site ID refers to the sampling zone (1 = upstream, 4 = downstream). The second reference number refers to site within zone (1 = most upstream, 4 = most downstream). Bars represent the geometric mean (GM); lines above bars represent the statistical threshold value (STV) for each site's profile. Note the different scales on each graph.

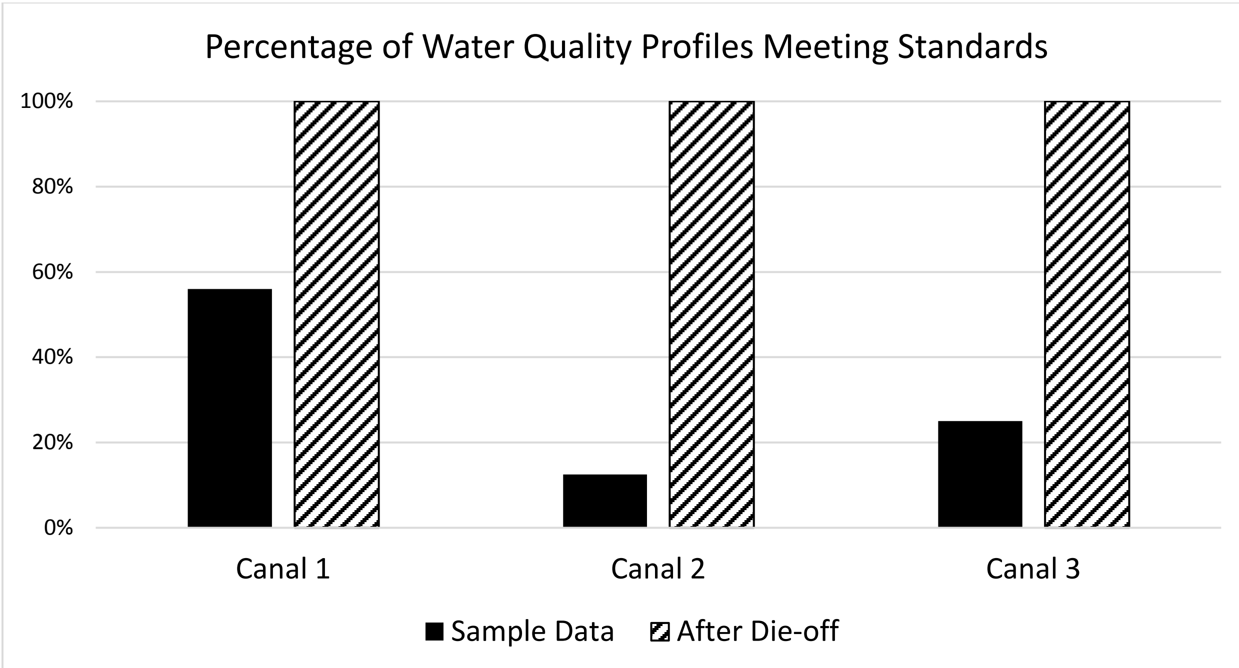

Figure 3. Percentage of water quality profiles that were within the proposed FSMA standards. All profiles were within the standards after allowing for die-off (hatched bars). Initial profiles based on the actual data show that only 13-56% of the profiles were within the proposed FSMA standards.

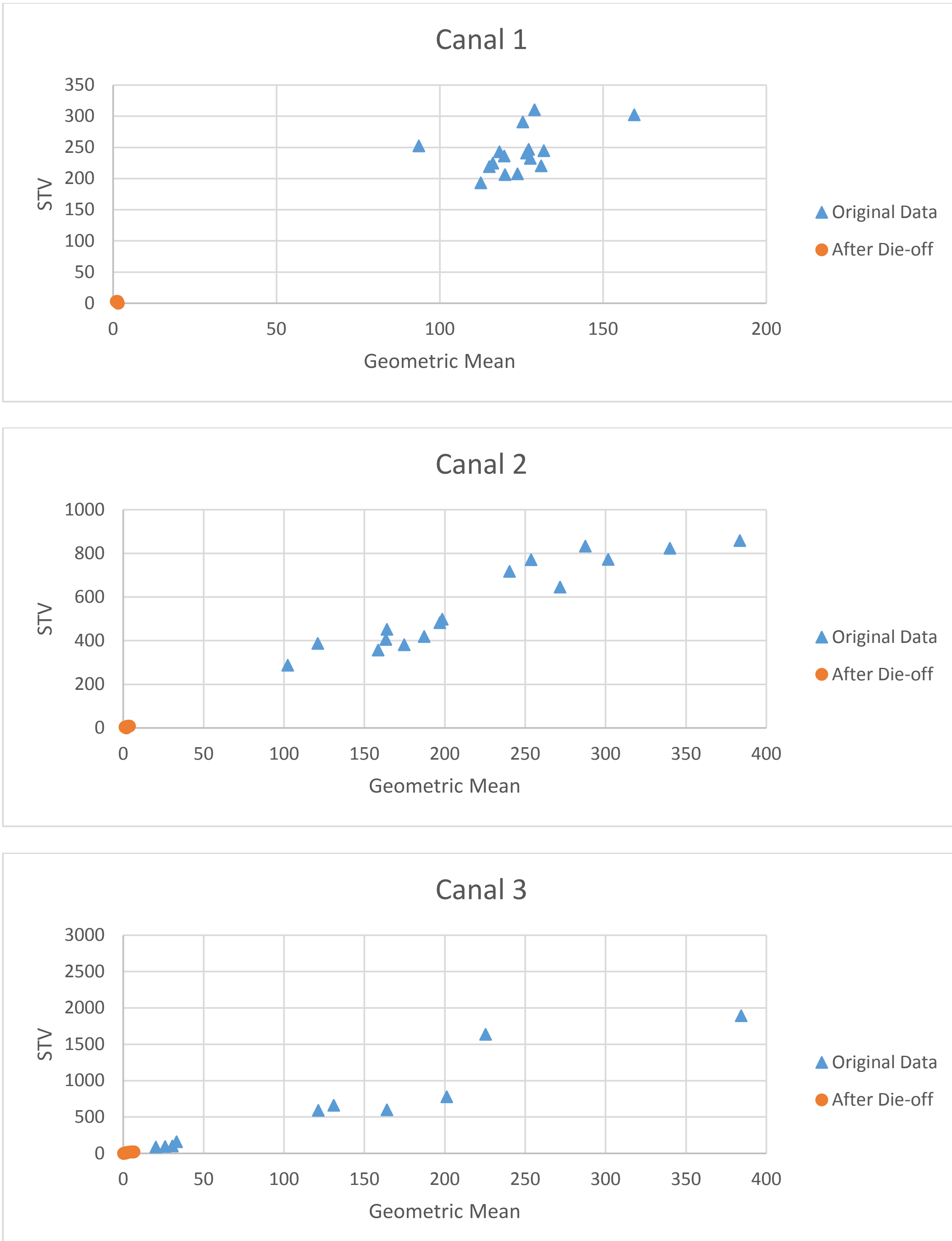

Figure 4. Water quality profiles based on original sample data (triangles) and after a 4-day die-off allowance (circles). Profiles with geometric mean (GM) $\leq$ 126 and statistical threshold value (STV) $\leq$ 410 meet the proposed FSMA standards. All profiles met the standard after the die-off period.

THRIPS AND IRIS YELLOW SPOT VIRUS MANAGEMENT IN THE TREASURE VALLEY

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Objectives

1. Evaluate different treatment sequences of insecticides for thrips and Iris yellow spot management.
2. Evaluate new application methods for thrips and Iris yellow spot management.

Introduction

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.

Production practices for onions continue to evolve in the Treasure Valley. Today, the majority of onions are grown under drip irrigation, and with the expanding use of drip irrigation, it is important to evaluate insecticides that can be applied through drip systems.

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 24 different treatment regimens (Table 1). Applications in this trial were made on a 7-day interval. Treatment programs with experimental or unregistered insecticides are not shown.

A second trial was designed to compare treatment regimens in which products were applied by drip application versus corresponding foliar applications. This trial included 12 different treatment regimens, in which applications were made on an approximate 10-day interval (Table 2). Treatment programs with experimental or unregistered insecticides are not shown.

Materials and Methods

Cultural Practices

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.

Foliar Insecticide and Adjuvant Trial Applications

Insecticides were applied weekly from June 2 to July 21, according to the schedule and rates listed in Table 1. Certain programs had two additional treatments at the end of the season (July 28 and August 4). Insecticides were applied with a CO_2 backpack sprayer using a 4-nozzle boom with 11004 nozzles at 30 psi and 35 gal/acre.

Drip Insecticide Trial Applications

Drip applications began after 1 hour of water was applied at the beginning of an 8-hour set (1 hour water, 6 hour insecticide injection, 1 hour water). Foliar applications of insecticides for this trial were made with a CO_2 backpack sprayer, as described above. Applications in this trial were made on a 10-day schedule, beginning on June 6 and continuing until August 11. A total of 7 applications were made in this trial.

Data Collection

Weekly thrips counts were made, starting on May 4 (before applications began). 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. Each treatment plot was 4 double rows wide by 23 ft long.

Onions in each plot were evaluated visually for severity of symptoms of iris yellow spot virus (IYSV) and thrips feeding damage on August 3 in the foliar trial and August 14 in 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 follows:

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, topped by hand, bagged and placed in storage. The onions from each plot were graded on November 3 for the drip trial and November 6 for the foliar trial. 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 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).

Table 1. Treatments used in the foliar thrips trial. Applications were made weekly from June 2 to July 21, for up to eight applications. Treatment 17 included two additional late season applications (July 28 [I] and August 4 [J]). Treatment programs with experimental or unregistered products are not included in the table or the results. Malheur Experiment Station, Ontario, OR, 2017. Continued on next page.

Trt	Treatment Name	Formulation Type*	Rate	Application Timing**	Application Description	pH
1	Untreated Check				Control	
2	MOVENTO	SC	5 fl oz/acre	AB	Standard Treatment	pH 6.5
	MSO	SL	0.5 % vol/vol	AB		
	AGRI-MEK	SC	3.5 fl oz/acre	CD		pH 7
	MSO	SL	0.5 % vol/vol	CD		
	RADIANT	SC	8 fl oz/acre	EF		pH 7
	DYNE-AMIC	SL	0.7 pt/acre	EF		
	LANNATE LV	L	3 pt/acre	GH		pH 5
	NIS	SL	0.25 % vol/vol	GH		
3	AZA-DIRECT	EC	12 fl oz/acre	ABC	Delayed use of Movento	pH 6
	M-PEDE	SL	2 % vol/vol	ABDFG	No Lannate	
	MOVENTO	SC	5 fl oz/acre	CD		pH 6.5
	MSO	SL	0.5 % vol/vol	D		
	AGRI-MEK	SC	3.5 fl oz/acre	H		pH 7
	MSO	SL	0.5 % vol/vol	H		
	RADIANT	SC	8 fl oz/acre	FG		pH 7
	CAPTIVA	EC	11 fl oz/acre	E		pH 7
	CAPTIVA	EC	7 fl oz/acre	H		
4	RADIANT	SC	8 fl oz/acre	B	Radiant as adulticide with	pH 7
	MOVENTO	SC	5 fl oz/acre	BD	Movento. Delayed start of	pH 6.5
	MSO	SL	0.5 % vol/vol	BD	applications.	
	AZA-DIRECT	EC	16 fl oz/acre	D		pH 6
	M-PEDE	SL	2 % vol/vol	FH		
	LANNATE LV	L	3 pt/acre	FH		
	NIS	SL	0.25 % vol/vol	FH		
5	RADIANT	SC	8 fl oz/acre	A	Radiant as adulticide with	pH 7
	MOVENTO	SC	5 fl oz/acre	AC	Movento. Early season start	pH 6.5
	MSO	SL	0.5 % vol/vol	AC		
	AZA-DIRECT	EC	16 fl oz/acre	C		pH 6
	M-PEDE	SL	2 % vol/vol	EG		
	LANNATE LV	L	3 pt/acre	EG		pH 5
12	MINECTO PRO	SC	10.0 fl oz/acre	AB	Minecto Pro substituted for	pH 6.5
	NIS	SL	0.25 % vol/vol	AB	Agri-Mek, beginning of season	
	MOVENTO	SC	5.0 fl oz/acre	CD		pH 7
	NIS	SL	0.25 % vol/vol	CD		
	RADIANT	SC	8.0 fl oz/acre	EF		pH 7
	NIS	SL	0.25 % vol/vol	EF		
	LANNATE LV	L	3.0 pt/acre	GH		pH 5
	NIS	SL	0.25 % vol/vol	GH		
13	MINECTO PRO	SC	10.0 fl oz/acre	AB	Minecto Pro substituted for	pH 6.5
	NIS	SL	0.25 % vol/vol	AB	Agri-Mek, beginning of season	
	MOVENTO	SC	5.0 fl oz/acre	EF	Earlier use of Radiant	pH 7
	NIS	SL	0.25 % vol/vol	EF		
	RADIANT	SC	8.0 fl oz/acre	CD		pH 7
	NIS	SL	0.25 % vol/vol	CD		
	LANNATE LV	L	3.0 pt/acre	GH		pH 5
	NIS	SL	0.25 % vol/vol	GH		
14	MOVENTO	SC	5.0 fl oz/acre	AB	Minecto Pro substituted for	pH 7
	NIS	SL	0.25 % vol/vol	AB	Agri-Mek, later season	
	LANNATE LV	L	3.0 pt/acre	CD		pH 5
	NIS	SL	0.25 % vol/vol	CD		
	MINECTO PRO	SC	10.0 fl oz/acre	EF		pH 6.5
	NIS	SL	0.25 % vol/vol	EF		
	RADIANT	SC	8.0 fl oz/acre	GH		pH 7
	NIS	SL	0.25 % vol/vol	GH		

* Formulation Type: EC = Emulsifiable Concentrate, L = Liquid, SC = Soluble Concentrate, SL = Soluble Liquid,
**Application Timing: June 2 = A, June 9 = B, June 16 = C, June 23 = D, June 30 = E, July 7 = F, July 14 = G, July 21 = H, July 28 = I, and August 4 = J.

Table 1. Continued. Treatments used in the foliar thrips trial. Applications were made weekly from June 2 to July 21, for up to eight applications. Some treatments included fewer than eight applications. Treatment 17 included two additional late season applications (July 28 [I] and August 4 [J]). Treatment programs with experimental or unregistered products are not included in the table or the results. *Malheur Experiment Station, Ontario, OR, 2017.*

Trt	Treatment Name	Formulation Type*	Rate		Application Timing**	Application Description	pH
15	RADIANT	SC	8.0	fl oz/acre	AB		pH 7
	NIS	SL	0.25	% vol/vol	AB		
	LANNATE LV	L	3.0	pt/acre	CD		pH 5
	NIS	SL	0.25	% vol/vol	CD		
	MINECTO PRO	SC	10.0	fl oz/acre	EF	Minecto Pro substituted for	pH 6.5
	NIS	SL	0.25	% vol/vol	EF	Agri-Mek, later season	
	MOVENTO	SC	5.0	fl oz/acre	GH		pH 7
	NIS	SL	0.25	% vol/vol	GH		
16	MOVENTO	SC	5.0	fl oz/acre	AB		pH 7
	NIS	SL	0.25	% vol/vol	AB		
	MINECTO PRO	SC	10.0	fl oz/acre	CD	Minecto Pro substituted for	pH 6.5
	NIS	SL	0.25	% vol/vol	CD	Agri-Mek	
	RADIANT	SC	8.0	fl oz/acre	EF		pH 7
	NIS	SL	0.25	% vol/vol	EF		
	LANNATE LV	L	3.0	pt/acre	GH		pH 5
	NIS	SL	0.25	% vol/vol	GH		
17	MOVENTO	SC	5.0	fl oz/acre	AB		pH 7
	NIS	SL	0.25	% vol/vol	AB		
	MINECTO PRO	SC	10.0	fl oz/acre	CD	Minecto Pro substituted for	pH 6.5
	NIS	SL	0.25	% vol/vol	CD	Agri-Mek, early season	
	RADIANT	SC	8.0	fl oz/acre	EF		pH 7
	NIS	SL	0.25	% vol/vol	EF	Agri-Mek used later for longer	
	AGRI-MEK	SC	3.5	fl oz/acre	GH	Spray season	pH 7
	MSO	SL	0.5	% vol/vol	GH		
	LANNATE LV	L	3.0	pt/acre	IJ		pH 5
	NIS	SL	0.25	% vol/vol	IJ		
22	MOVENTO	SC	5	fl oz/acre	AB	Movento with different adjuvant	pH 6.5
	DYNE-AMIC	SL	0.7	pt/acre	AB		
	AGRI-MEK	SC	3.5	fl oz/acre	CD		pH 7
	MSO	SL	0.5	% vol/vol	CD		
	RADIANT	SC	8	fl oz/acre	EF		pH 7
	DYNE-AMIC	SL	0.7	pt/acre	EF		
	LANNATE LV	L	3	pt/acre	GH		pH 5
	NIS	SL	0.25	% vol/vol	GH		
23	MOVENTO HL	SC	2.5	fl oz/acre	AB	New Movento formulation	pH 6.5
	DYNE-AMIC	SL	0.7	pt/acre	AB		
	AGRI-MEK	SC	3.5	fl oz/acre	CD		pH 7
	MSO	SL	0.5	% vol/vol	CD		
	RADIANT	SC	8	fl oz/acre	EF		pH 7
	DYNE-AMIC	SL	0.7	pt/acre	EF		
	LANNATE LV	L	3	pt/acre	GH		pH 5
	NIS	SL	0.25	% vol/vol	GH		
24	MOVENTO HL	SC	2.5	fl oz/acre	AB	New Movento formulation and	pH 6.5
	DYNE-AMIC	SL	0.7	pt/acre	AB	Exirel substituted for Agri-Mek	
	EXIREL	SC	13.5	fl oz/acre	CD		pH 7
	DYNE-AMIC	SL	0.7	pt/acre	CD		
	RADIANT	SC	8	fl oz/acre	EF		pH 7
	DYNE-AMIC	SL	0.7	pt/acre	EF		
	LANNATE LV	L	3	pt/acre	GH		pH 5
	NIS	SL	0.25	% vol/vol	GH		

* Formulation Type: EC = Emulsifiable Concentrate, L = Liquid, SC = Soluble Concentrate, SL = Soluble Liquid,
**Application Timing: June 2 = A, June 9 = B, June 16 = C, June 23 = D, June 30 = E, July 7 = F, July 14 = G, July 21 = H, July 28 = I, and August 4 = J.

Table 2. Treatments used in the drip thrips trial. Seven applications were made approximately 10 days apart from June 6 to August 11. Malheur Experiment Station, Ontario, OR, 2017.

Trt No.	Treatment Name	Formulation Type	Rate	Appl Code	Application Description
1	Untreated Check				Untreated Control
2	VERIMARK	SC	10.3 fl oz/acre	AB	Verimark by drip substituted for Movento (Complement To Treatment 5)
	AGRI-MEK	SC	3.5 fl oz/acre	CD	
	MSO	SL	0.5 % vol/vol	CD	
	RADIANT	SC	8 fl oz/acre	EF	
	DYNE-AMIC	SL	0.7 pt/acre	EF	
	LANNATE LV	L	3 pt/acre	G	
	NIS	SL	0.5 % vol/vol	G	
3	VERIMARK	SC	10.3 fl oz/acre	CD	Verimark by drip after Movento (Complement to Treatment 8)
	MOVENTO	SC	5 fl oz/acre	AB	
	MSO	SL	0.5 % vol/vol	AB	
	RADIANT	SC	8 fl oz/acre	EF	
	DYNE-AMIC	SL	0.7 pt/acre	EF	
	AGRI-MEK	SC	3 pt/acre	G	
	MSO	SL	0.5 % vol/vol	G	
4	MOVENTO	SC	5 fl oz/acre	AB	Standard
	MSO	SL	0.5 % vol/vol	AB	
	AGRI-MEK	SC	3.5 fl oz/acre	CD	
	MSO	SL	0.5 % vol/vol	CD	
	RADIANT	SC	8 fl oz/acre	EF	
	DYNE-AMIC	SL	0.7 pt/acre	EF	
	LANNATE LV	L	3 pt/acre	G	
	MSO	SL	0.5 % vol/vol	G	
5	EXIREL	SE	13.5 fl oz/acre	AB	Exirel substituted for Movento (Complement to Treatment 2)
	MSO	SL	0.5 % vol/vol	AB	
	AGRI-MEK	SC	3.5 fl oz/acre	CD	
	MSO	SL	0.5 % vol/vol	CD	
	RADIANT	SC	8 fl oz/acre	EF	
	DYNE-AMIC	SL	0.7 pt/acre	EF	
	LANNATE LV	L	3 pt/acre	G	
	MSO	SL	0.5 % vol/vol	G	
8	MOVENTO	SC	5 fl oz/acre	AB	Exirel after Movento (Complement to Treatment 3)
	MSO	SL	0.5 % vol/vol	AB	
	EXIREL	SE	13.5 fl oz/acre	CD	
	MSO	SL	0.5 % vol/vol	CD	
	RADIANT	SC	8 fl oz/acre	EF	
	DYNE-AMIC	SL	0.7 pt/acre	EF	
	AGRI-MEK	SC	3.5 fl oz/acre	G	
	MSO	SL	0.5 % vol/vol	G	
10	AZA-DIRECT	EC	32 fl oz/acre	AB	Azadirect by drip before Movento (Complement to Treatment 11)
	MOVENTO	SC	5 fl oz/acre	CD	
	MSO	SL	0.5 % vol/vol	CD	
	VERIMARK	SC	10.3 fl oz/acre	EF	
	AGRI-MEK	SC	3.5 fl oz/acre	G	
	MSO	SL	0.5 % vol/vol	G	
11	AZA-DIRECT	EC	12 fl oz/acre	AB	Azadirect + M-Pede before Movento (Complement to Treatment 10)
	M-PEDE	SL	2 % vol/vol	AB	
	MOVENTO	SC	5 fl oz/acre	CD	
	MSO	SL	0.5 % vol/vol	CD	
	EXIREL	SE	13.5 fl oz/acre	EF	
	MSO	SL	0.5 % vol/vol	EF	
	AGRI-MEK	SC	3.5 fl oz/acre	G	
	MSO	SL	0.5 % vol/vol	G	
12	AZA-DIRECT	EC	32 fl oz/acre	AB	Azadirect and Verimark by drip
	VERIMARK	SC	10.3 fl oz/acre	CD	
	RADIANT	SC	8 fl oz/acre	EF	
	DYNE-AMIC	SL	0.7 pt/acre	EF	
	AGRI-MEK	SC	3.5 fl oz/acre	G	
	MSO	SL	0.5 % vol/vol	G	

* Formulation Type: EC = Emulsifiable Concentrate, L = Liquid, SC = Soluble Concentrate, SE = Suspo-emulsion, SL = Soluble Liquid,

**Application Timing: June 6 = A, June 16 = B, June 30 = C, July 10 = D, July 21 = E, July 31 = F, and August 11 = G

Results and Conclusions

Foliar Application Trial

Thrips began to colonize onions in late May and reached the threshold level for the trial (4 thrips per plant) by May 30. Applications in the foliar trial began on June 2, [A] June 9 [B], June 16 [C], June 23 [D], June 30 [E], July 7 [F], July 14 [G] and July 21 [H]. Treatment program 17 had two additional applications: July 28 [I] and August 4 [J]. Thrips populations began to peak in late June and early July, which has been the typical pattern in the Ontario/Cairo Junction area. However, populations rapidly collapsed soon after although populations of immature thrips rebounded in mid-July before collapsing at the end of July. As is typical, most thrips on onions throughout the season were immatures (~75%). Because of the ability of adults to move from plant to plant and recolonize treated areas, we typically do not see large differences in adult populations among insecticide treatments in field station trials.

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 in Figs. 1-2). As reported previously, Movento does not show good activity until after a second application is made, but it does provide residual control of larvae for 2-3 weeks after a second application.

The effect of Movento was enhanced by combining it with an adulticide (e.g., Treatment 4, Movento + Radiant). In situations where applications need to begin earlier in the spring than late May-early June, applying Movento later in the season (by 1-2 weeks) rather than at the start of the spray season may also make better use of its activity against the large populations of immature thrips that occur during peak abundance in late June-early July. It is important to combine Movento with an adulticide with this type of use pattern so that dispersing adults do not cause excessive damage. The cool, wet spring of 2017 delayed thrips populations development, which minimized the need for applications to begin much earlier in the spring.

Minecto® Pro, which includes abamectin, the active ingredient in Agri-Mek, and cyantraniliprole, the active ingredient in Exirel® and Verimark®, provided slightly better control than Agri-Mek itself. For resistance management, it would be best to not use either Agri-Mek, or Exirel/Verimark if Minecto Pro is used.

Radiant remains the most effective insecticide in trials. It has good activity against adult and immature thrips. Because of this activity, it is a good option for use during peak thrips abundance (Figs. 1 and 2).

In many of the treatment programs in the foliar trial, thrips numbers increased during mid- to late July after dropping to low levels in early July (Figs. 1 and 2). This pattern contrasts with the pattern in the drip trial (Figs. 3 and 4), where populations decreased sharply by mid-July and remained low through the remainder of the season. One possible contributing factor relates to timing and different insecticides in the trial. In the foliar trial, most treatment programs included late season use of Lannate (7^{th} and 8^{th} applications). With the 10-day application interval in the drip trial, most programs included the use of Radiant in mid- to late July. There are concerns regarding the efficacy of Lannate, and growers should avoid overuse of Lannate and consider using other products during periods of peak thrips abundance.

Treatment program 3, which did not include Lannate, provided good late season control of thrips. This program also started applications of Movento 1 week later than the standard program (Treatment 2).

Onion yields in programs with insecticides were higher than in the untreated check. The average yield for all of the insecticide programs was more than 62% higher than in the untreated check. Yields were low, reflecting the late planting and high temperatures during the season that affected plant growth. It also may reflect the late season thrips pressure. Treatment programs 3, 8, 15, 17, and 22 had size profiles weighted to larger size classes than other treatments (Fig. 5). Treatment program 3 included later use of Movento and Radiant than the standard program and did not include Lannate. Program 15 included Lannate but used it earlier in the season and included Minecto Pro later in the season.

Drip Application Trial

In the drip application trial, applications were made on an approximately 10-day interval from June 6 to August 11. Application dates were June 6 [A], June 16 [B], June 30 [C], July 10 [D], July 21 [E], July 31 [F] and August 11 [G]. The drip trial included the standard foliar applications of Movento, Agri-Mek, Radiant, and Lannate for comparison (Treatment 4 in this trial).

The foliar standard performed well and gave good season-long management of thrips (Figs. 3 and 4).

Exirel, the foliar version of cyantraniliprole, and Verimark, the drip version of cyantraniliprole, performed well. Their use at the beginning of the season followed by foliar applications of Movento gave good control and allowed Movento to continue to control immature thrips through the peak abundance time.

Foliar applications of Aza-Direct® (12 fl oz/acre) gave better control of thrips than drip applications of Aza-Direct (32 fl oz/acre).

In terms of onion yield, there were no statistical differences in marketable yields among the treatments (Fig. 6). However, size profiles were weighted toward larger sizes in Treatments 2, 4, 10, and 12. Treatment 2 used Verimark by drip as a substitute for Movento. Treatment 4 was the standard foliar program of Movento (2X), Agri-Mek (2x), Radiant (2X), and Lannate (1X). Treatments 10 and 12 included drip applications of Aza-Direct. Treatment program 2 started with drip applications of Verimark and had significantly higher yields of colossal and supercolossal bulbs (36% of marketable yield) compared with the other treatments (Fig. 6). This is similar to results from our 2016 trial.

Although drip applications of Aza-Direct did not give as good thrips management as foliar applications, the drip programs had the highest yields and larger size profiles than other treatments, with total marketable yields 5-7% higher than the standard program (Fig. 6). Colossal and supercolossal bulbs made up 28-34% of the marketable yield in the Aza-Direct by drip treatments (Treatments 10 and 12).

Again, the longer application windows in the drip trial probably contributed to the larger yields than in the foliar trial, where applications ended July 21.

Acknowledgments

We appreciate the technical assistance of Ian Trenkel, Allison Simmons, Hannah Rose, Megan Travis, and Kelsey Alexander. The project was supported by the Idaho-Eastern Oregon Onion Committee, Bayer, Gowan, Syngenta, Simplot, Dow, DuPont, Nichino. Oregon State University, and the Malheur County Education Service District.

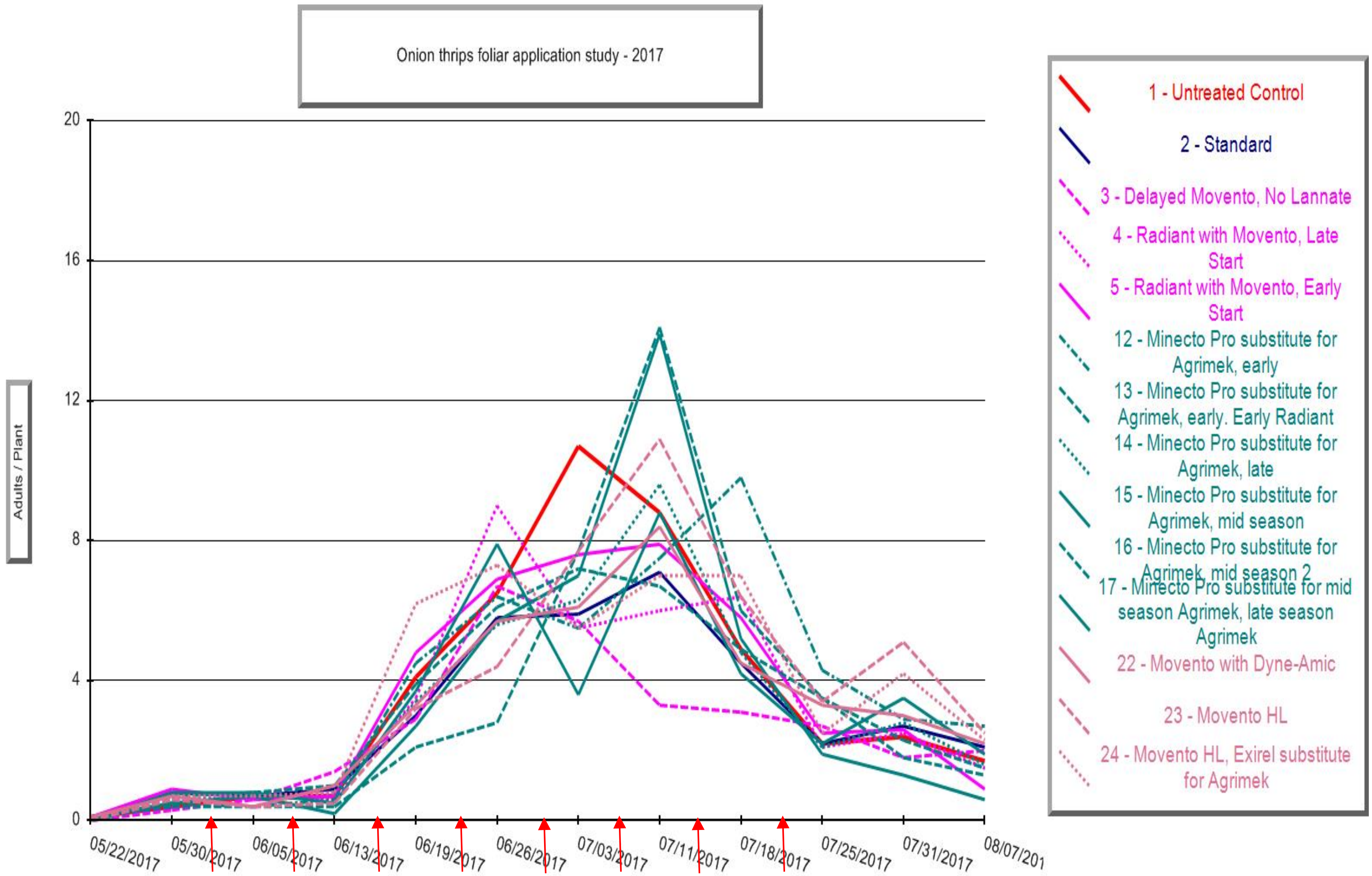

Figure 1. Average adult thrips per onion plant in the foliar thrips trial. Arrows on the date axis mark when applications were made. Malheur Experiment Station, Ontario, OR 2017.

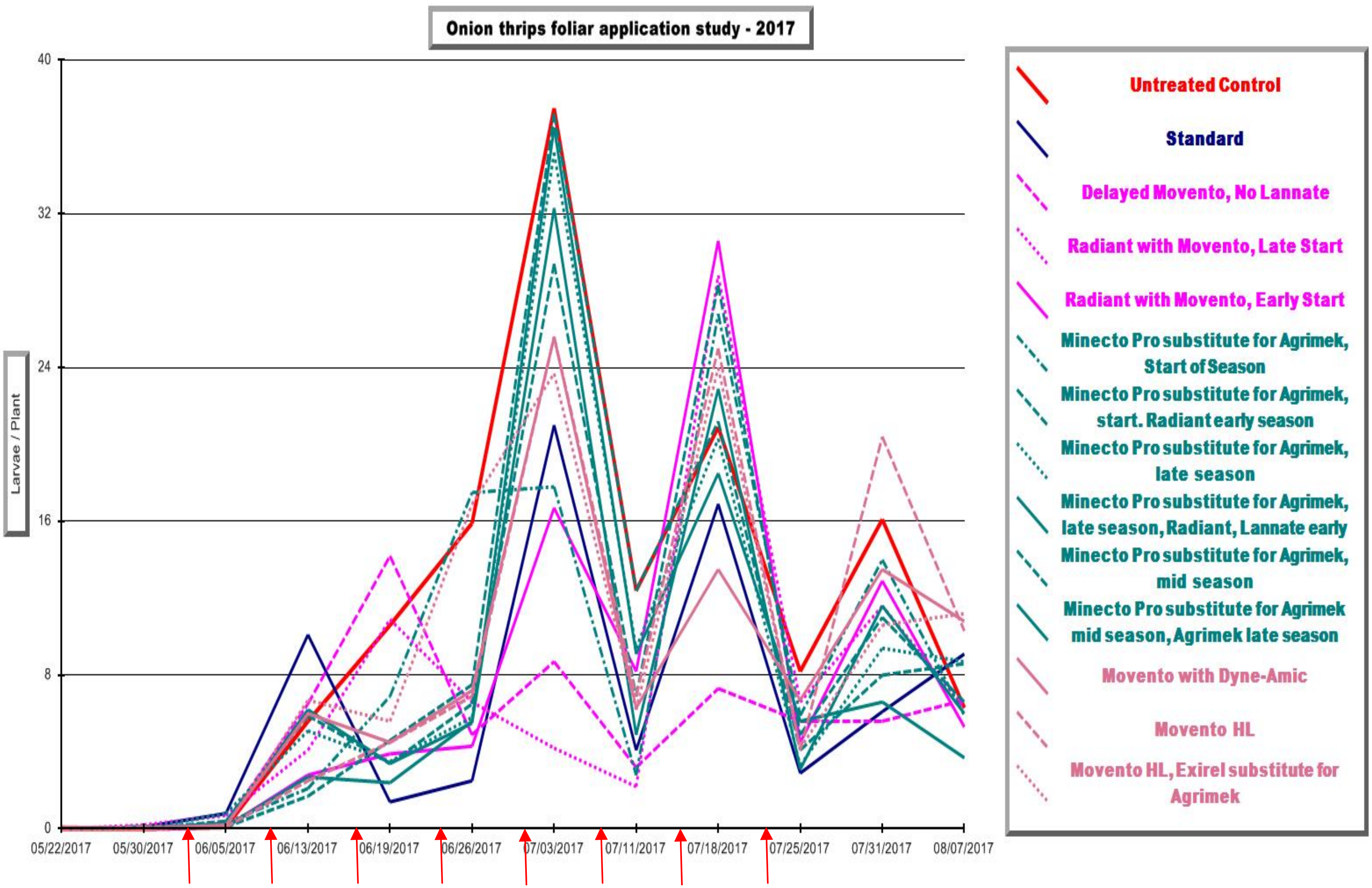

Figure 2. Average immature thrips per onion plant in the foliar thrips trial. Arrows on the date axis mark when applications were made. Malheur Experiment Station, Ontario, OR 97914.

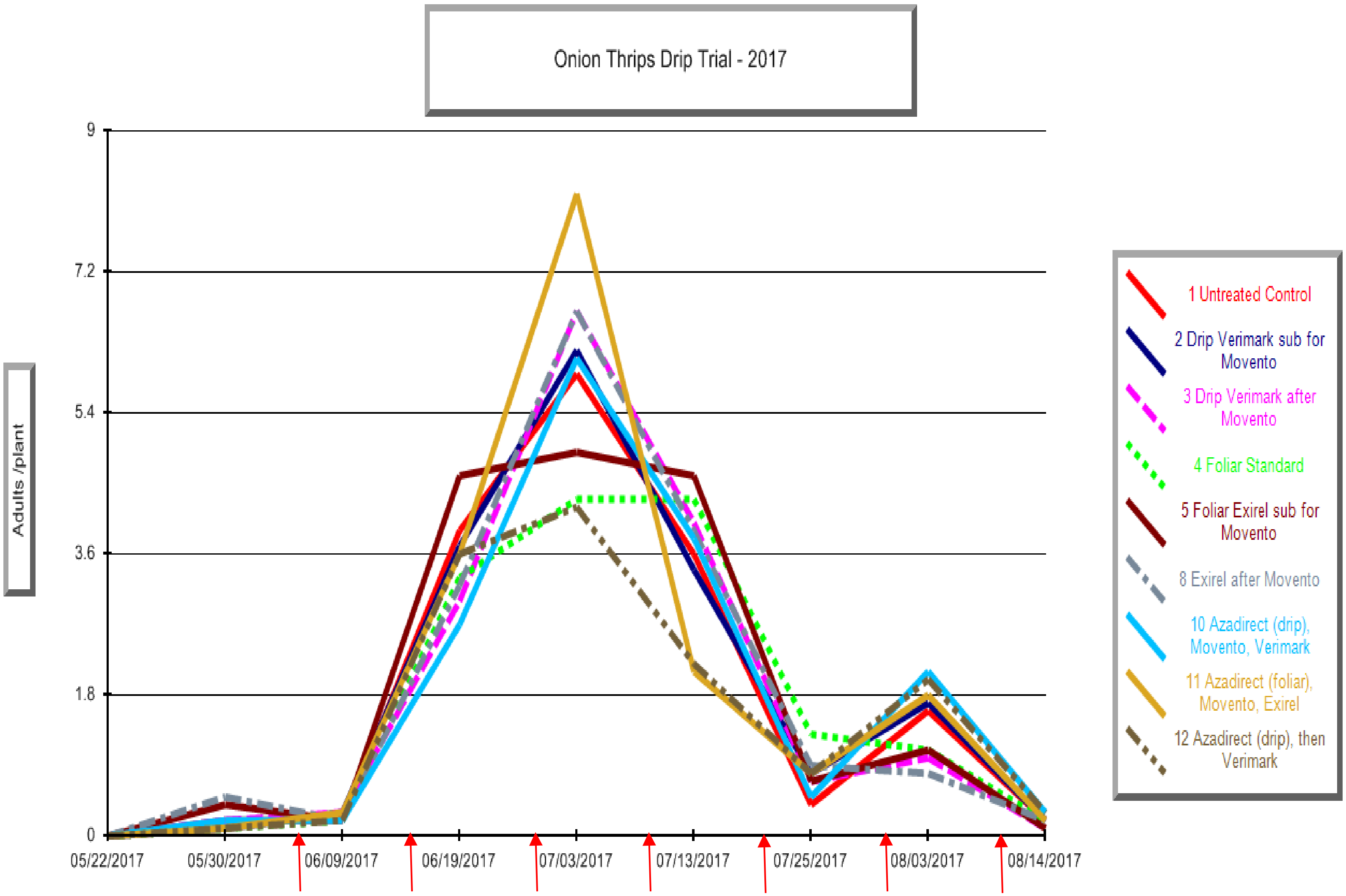

Figure 3. Average adult thrips per onion plant in the drip thrips trial. Malheur Experiment Station, Ontario, OR, 2017.

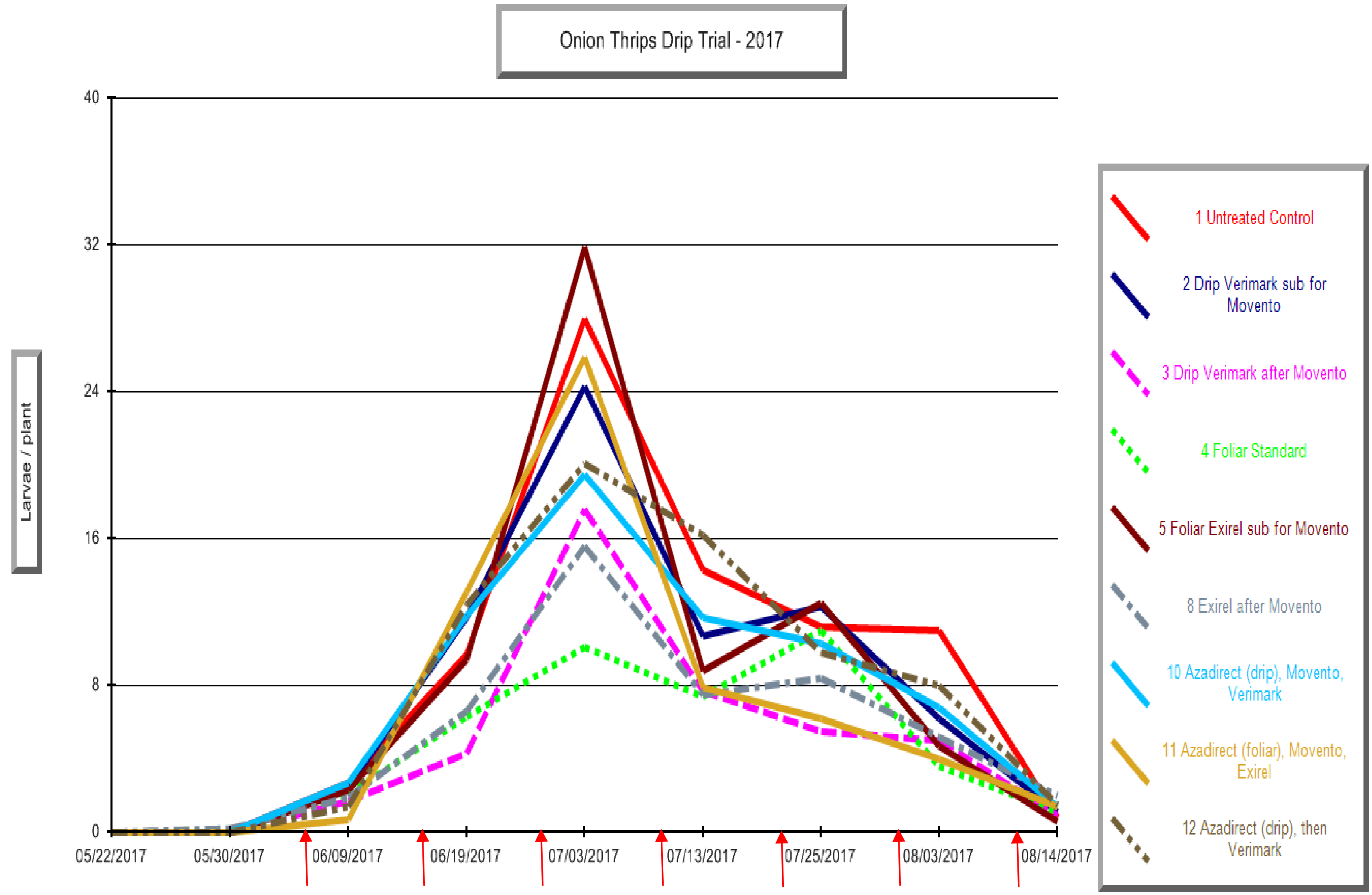

Figure 4. Average immature thrips per onion plant in the drip trial. Malheur Experiment Station, Ontario, OR, 2017.

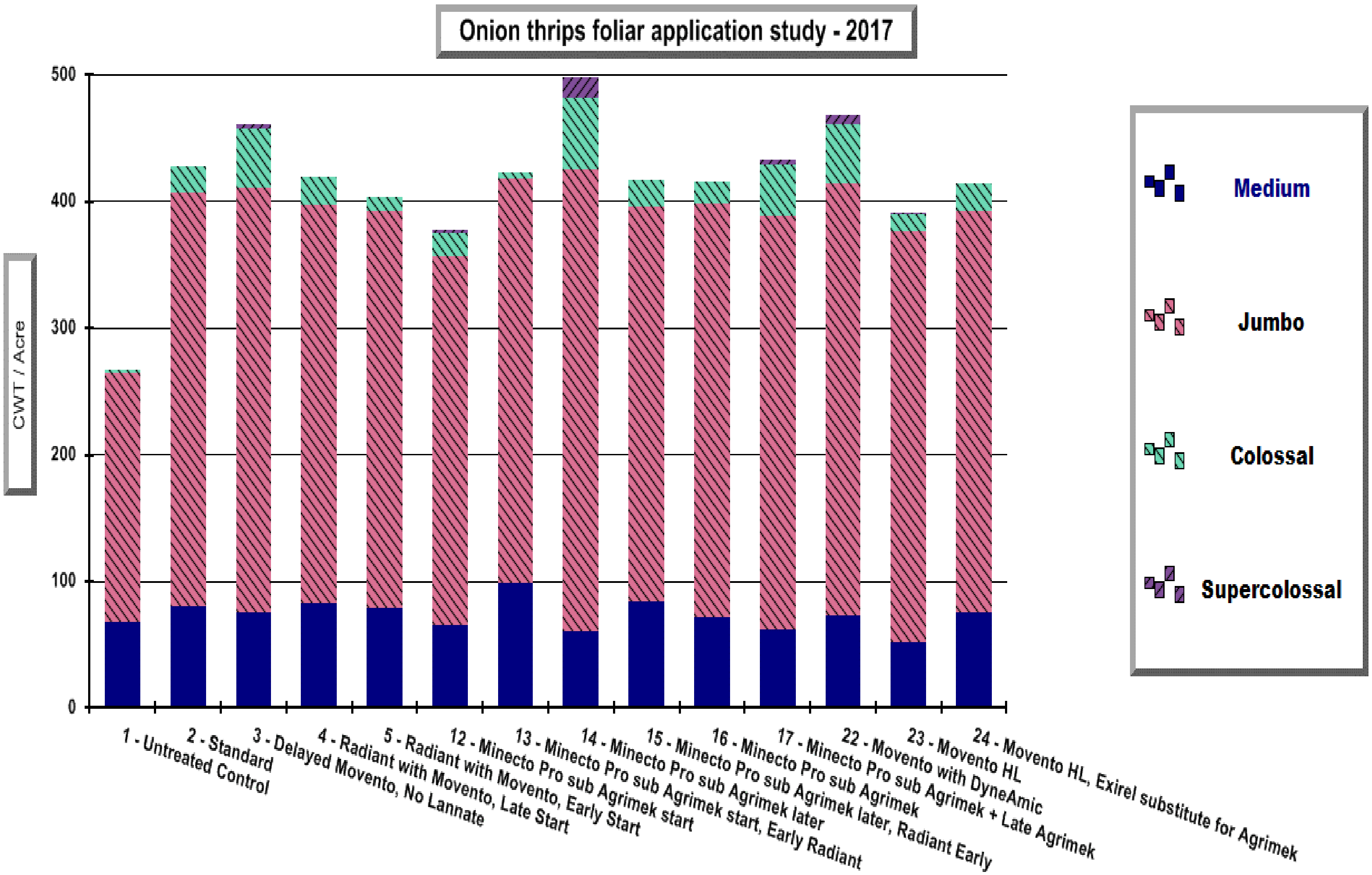

Figure 5. Onion yield by size class (cwt/acre) in the foliar trial. Malheur Experiment Station, Ontario, OR, 2017.

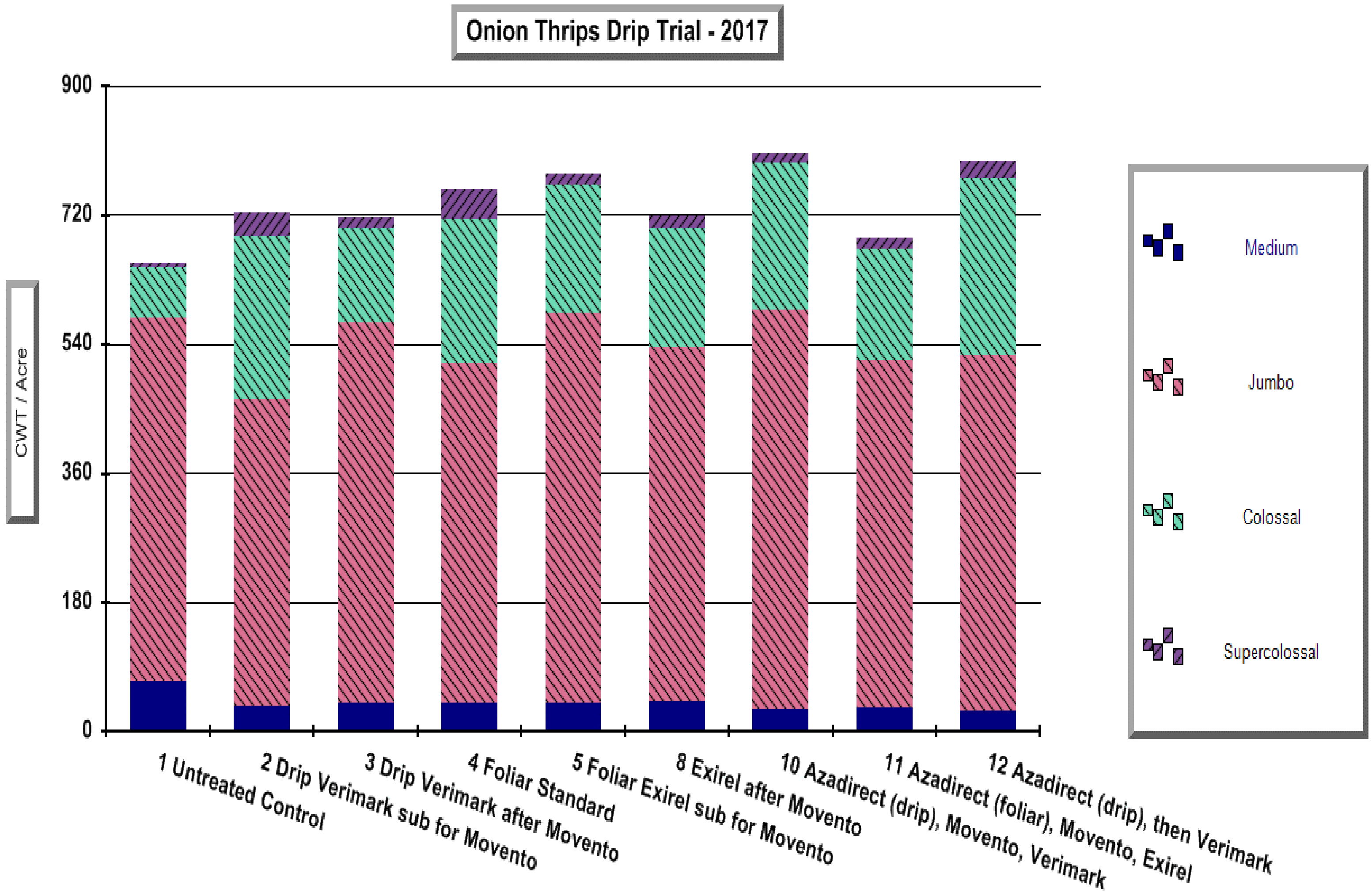

Figure 6. Onion yield by size class (cwt/acre) in the drip trial. Malheur Experiment Station, Ontario, OR, 2017.

MONITORING ONION PESTS ACROSS THE TREASURE VALLEY - 2017

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 those 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 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-six of the fields were yellow onions and six were red onions. The most common variety among these fields was ‘Joaquin’ (n = 12). There were no more than three fields of any other variety.

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

Results and Conclusions

Adult thrips were first detected in fields on May 19 in the Adrian area. Plants in the two fields with thrips were at the 2-leaf stage. Other fields in the monitoring network were in the 1- to 2-leaf state. By the following week, adult thrips had colonized at least some fields in all growing areas. Immature thrips were also found in fields in Adrian and Ontario. Thrips populations built up rapidly in early June. Plants with thrips went from 8% on May 26 to 82% on June 15.

Adult thrips numbers peaked around the first week of July in most areas. Immature thrips numbers peaked in the second half of July. Despite later plantings than normal in 2017 because of the weather, the timing of peak thrips abundance in mid- to late July was similar to other recent years.

Iris yellow spot virus emerged later and with a much lower incidence in 2017 than in recent years. The first plants infected with IYSV in commercial fields were found on June 15, 2 weeks later than in 2016. Ironically, these first infections were found in a field on the Oregon Slope, which usually has much lower incidence than other growing areas. The earliest increase in IYSV incidence occurred in Fruitland, reaching 5% on July 21, while all other areas remained at ≤1%. The incidence of IYSV began to increase substantially during the week of July 28 and continued to escalate over the last 2 weeks of monitoring. However, the final seasonal incidence remained relatively low (2% in Parma to 27% in Vale). In contrast, IYSV incidence in 2016 ranged from 12% on the Oregon Slope/Weiser to over 80% in Fruitland, Nyssa, and Ontario. Infections on individual plants in 2017 did not appear to be very severe or extensive. The low incidence and severity of IYSV in 2017 suggest that direct feeding damage would have been more important in determining yield losses from thrips than virus damage.

Thrips populations varied across the growing regions and fluctuated depending on insecticide applications (Fig. 1). Fields on the Oregon Slope tended to have the fewest thrips and lowest incidence of IYSV (Figs. 1 and 2). Fields in Nyssa, Ontario, and Fruitland/Parma had the highest incidence of IYSV, with the earliest outbreaks occurring in Fruitland/Parma.

Acknowledgments

I appreciate the assistance of the cooperating growers and crop advisors. This project was funded by the Idaho-Eastern Oregon Onion Committee, cooperating onion seed companies, Oregon State University, and the Malheur County Education Service District.

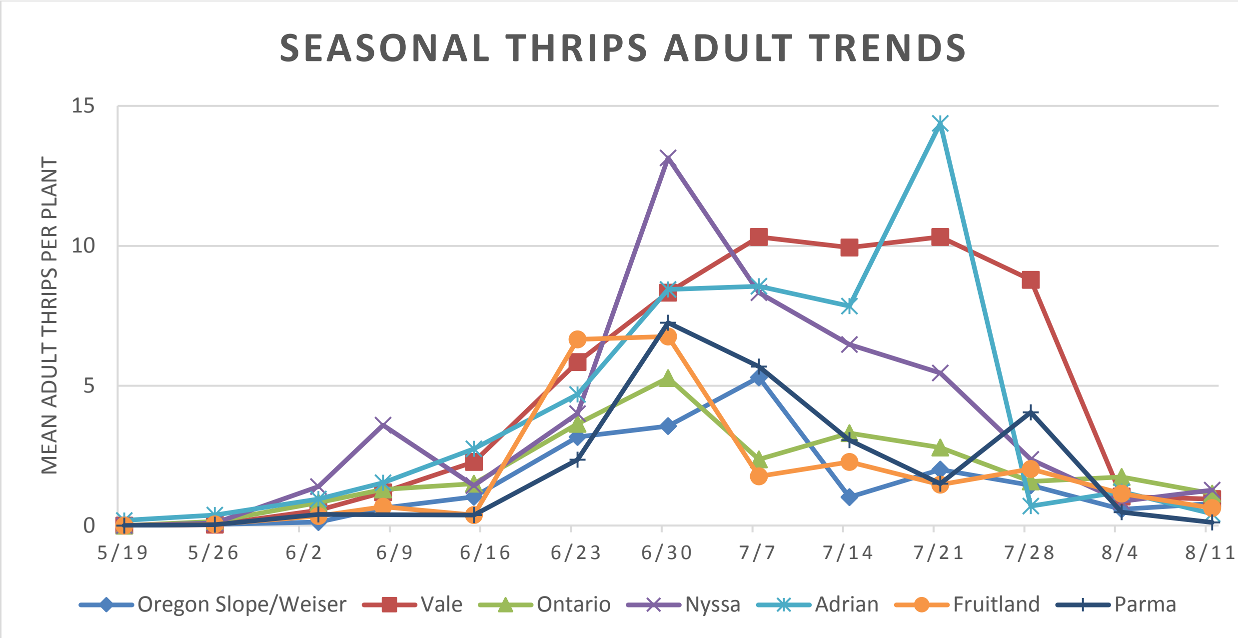

Figure 1. Seasonal trends of adult thrips in onion growing areas of the Treasure Valley during 2017.

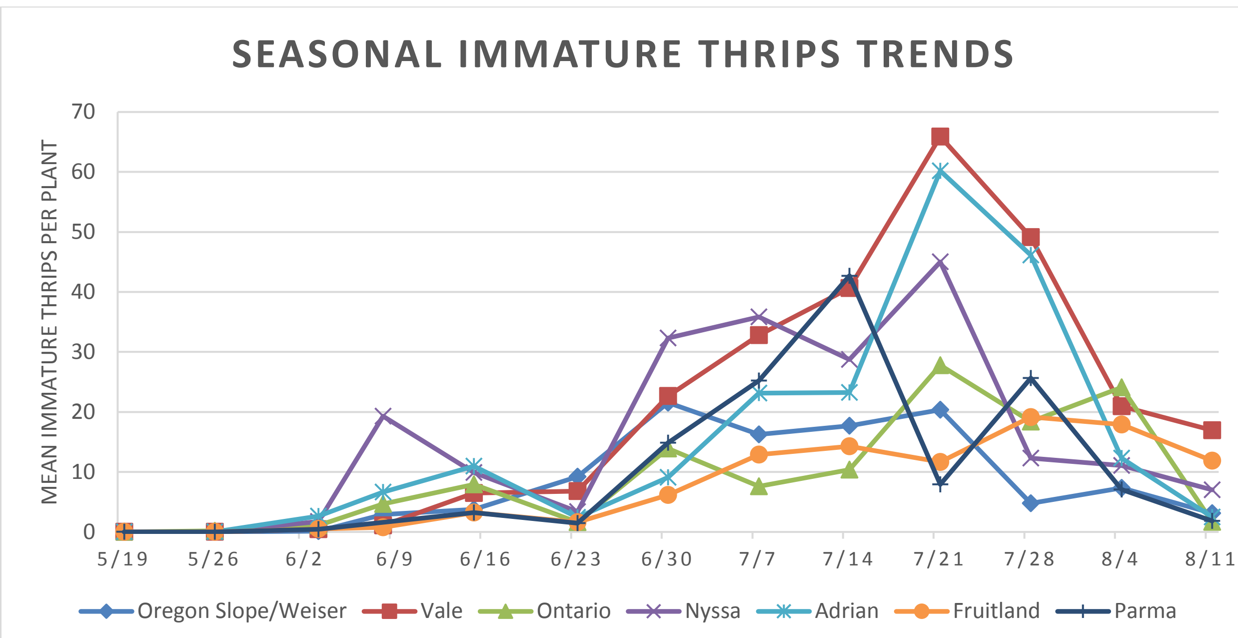

Figure 2. Seasonal trends of immature thrips in onion growing areas of the Treasure Valley during 2017.

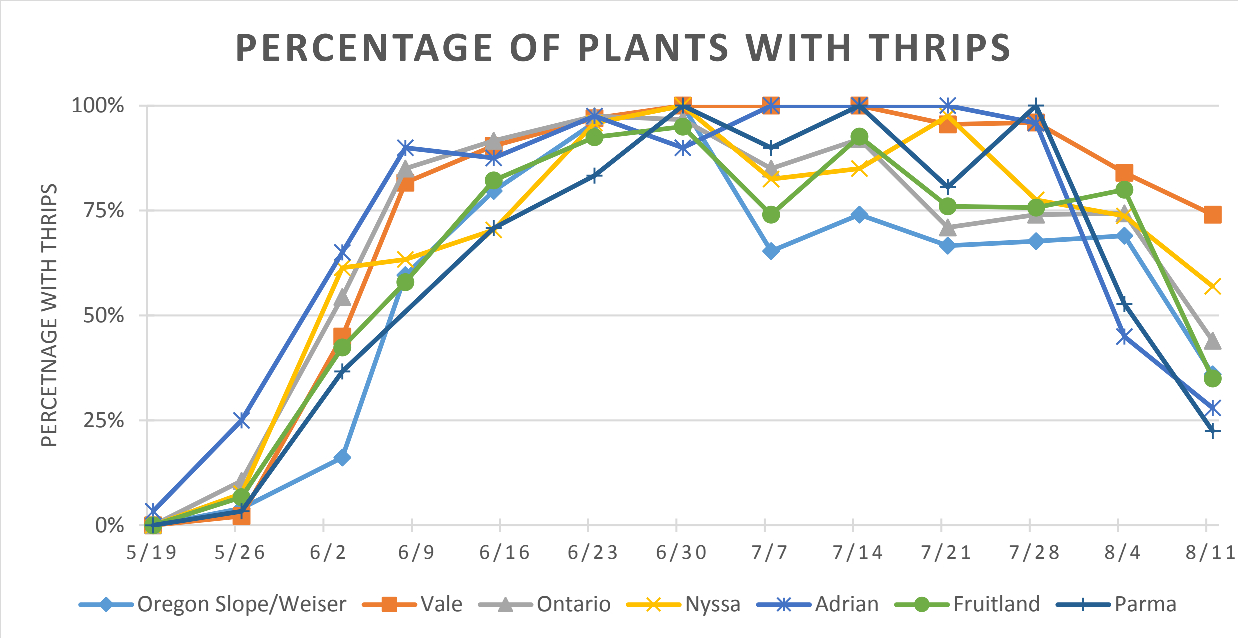

Figure 3. Average percentage of onion plants with thrips present during the 2017 season from different growing areas of the Treasure Valley.

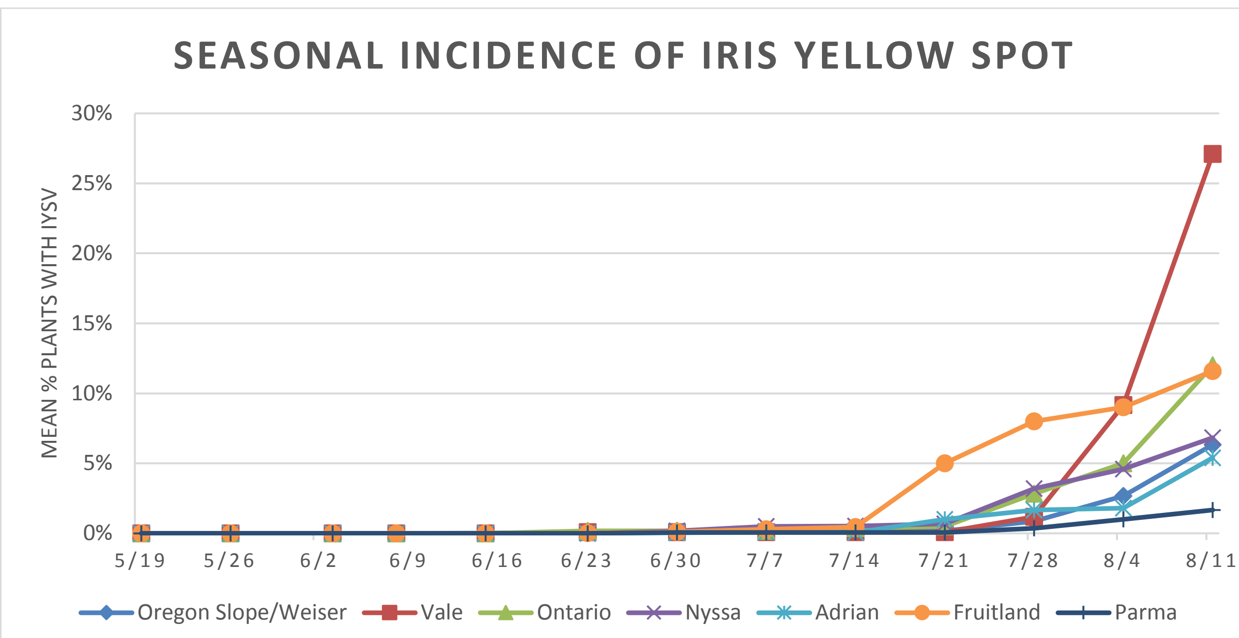

Figure 4. Seasonal incidence of Iris yellow spot virus in commercial onion fields from different growing areas of the Treasure Valley, 2017. Values are the mean percentage of infected plants per field for each area.

ONION CULTIVAR TRIAL: EVALUATION OF CULTIVAR RESISTANCE TO *FUSARIUM PROLIFERATUM* STORAGE ROT

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Introduction

In the United States, storage onions are produced on more than 110,000 acres annually. This high-value vegetable crop produces >$900 million in annual farm receipts (USDA-NASS 2004-2014). Storage onion acreage in the western United State comprises about 66% of national onion production, with 18% or more of the production occurring in Oregon and Idaho (USDA NASS 2014). Production costs can be significant ($4,000/acre), making stakeholder losses to onion bulb rots during storage costly (http://www.ipmcenters.org/CropProfiles/docs/WAonions.pdf). More than 20 different bacterial and fungal pathogens cause onion losses under field and storage conditions, resulting in up to 25-50% crop loss (Schwartz and Mohan 2008). In many cases, bulb infection is asymptomatic prior to harvest (Schwartz and Mohan 2008), and the infected bulbs go into storage undetected. These infections can develop into storage rot and when they do, an entire season of production and storage expenses has been incurred and can result in significant financial losses during storage. Accurate diagnosis and differentiation of the pathogens using traditional methods can take weeks to months to complete.

Recently, *Fusarium proliferatum* has emerged as a new pathogen causing bulb rot of onion and is responsible for causing significant losses in the Pacific Northwest. *F. proliferatum* is present in the Treasure Valley and onion growers have reported increased incidence of bulb rot associated with this pathogen during the past three seasons. Bulb rot appears at harvest with limited or no symptoms present in the field prior to harvest. Bulb decomposition may develop in storage. *Fusarium oxysporum* f. sp. *cepae,* a different species of *Fusarium*, is a well-known pathogen and causes rot at the base of the bulb during the growing season. Unfortunately, little is known about the biology of *F. proliferatum*, inoculum sources, vectors, relative resistance of onion varieties, or the impact of curing on disease development.

Growers and shippers requested information about the potential resistance that different onion cultivars may have to *F. proliferatum.* The Oregon State Onion Cultivar trial is an excellent resource providing critical information for onion stakeholders in the Treasure Valley of Idaho.

We sought to assess whether onion cultivars grown in the onion variety trial differ significantly in susceptibility to storage rot caused by *F. proliferatum.*

Materials and Methods

A total of 20 of the onion cultivars grown in the 2017-2018 Onion Variety Trial at the OSU Malheur Experiment Station (Shock et al. 2018) were inoculated with a spore suspension of *F. proliferatum*. The cultivars chosen were recommended by stakeholders because of their use in commercial production. Bulbs were harvested, cured, and stored, then inoculated on October 18, 2017.

A total of 20 bulbs per cultivar from each of 4 replicates were treated in one of three ways as follows:

a. Inoculation with 0.5 ml *Fusarium proliferatum* (1.0×10^6 spores/ml) in sterile water;
b. Inoculation with 0.5 ml of sterile water (negative check);
c. Non-inoculated check.

Spots to be inoculated were wiped with 70% ethanol, inoculated, and the inoculated spot was marked. Bulbs were stored under commercial conditions. Onion bulbs were evaluated on February 7, 2018 by Brenda Schroeder and scored for bulb rot.

The means and standard errors were calculated from 4 replications of 20 onion bulbs. LSD for disease is presented in Table 1. All analyses were performed using SAS (SAS Institute Inc., Cary, NC).

Results and Discussion

Bulbs not inoculated with *F. proliferatum* did not develop the disease. Results of this study indicate that onion bulb cultivars exhibit a range of resistance responses in response to *F. proliferatum* (Table 1). Onion cultivars 'Oloroso', 'Vaquero', 'Tucannon', 'Sedona', 'Pandero' and SV6646 were among those most susceptible to *F. proliferatum* in this assay. Onion cultivars 16000, 'Avalon', and 'Grand Perfection' were among the least susceptible to *F. proliferatum* evaluated in this study. A second year of testing will be needed to demonstrate the reliability of these cultivars to resist *F. proliferatum.*

Knowing how different onion cultivars respond to *F. proliferatum* could provide critical knowledge to stakeholders about cultivar choices. This knowledge could aid in the management of this storage rot problem and reduce onion bulb losses to *F. proliferatum*.

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United States Department of Agriculture-National Agriculture Statistics Service http://www.nass.usda.gov/QuickStats/PullData_US.jsp

Table 1. Percent bulb rot resulting from inoculation of onion bulbs by 5 x 10^5 spores of *Fusarium proliferatum* at harvest and stored for 4 months, Oregon State University, Malheur Experiment Station, Ontario, Oregon, 2017.

Cultivar	Percent disease*
Oloroso	23.8 A
Vaquero	22.4 AB
Tucannon	21.8 ABC
Sedona	21.1 ABC
Pandero	20.6 ABC
SV6646	20.4 ABCD
Joaquin	20.3 BCD
Hamilton	20.1 BCDE
Swale	20.1 BCDE
Granero	19.9 BCDEF
Montero	18.9 CDEFG
Morpheus	18.5 CDEFG
Arcero	17.2 EFDG
SV6672	16.8 EFGH
Annillo	16.5 FGH
Barbaro	16.4 GH
Scout	13.5 HI
16000	12.6 I
Avalon	12.6 I
Grand Perfection	7.59 J

*Treatments within each effect followed by different letters are significantly different at $P \leq 0.001$.

DIRECT SURFACE SEEDING SYSTEMS FOR THE ESTABLISHMENT OF NATIVE WILDFLOWERS IN 2016 AND 2017

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Introduction

Seed of native plants is needed to restore rangelands of the Intermountain West. Reliable commercial seed production is needed to make seed readily available. Direct seeding of native range plants in the Intermountain West is often problematic. Fall planting is helpful in establishing stands for many of these native species to overcome physiological dormancy through cold stratification. Fall planting alone may be insufficient for adequate stands for seed production, and it may be necessary to combine fall planting with other techniques.

Previous trials to address poor stand examined seed pelleting, planting depth, and soil anticrustant with four fall-planted species (Shock et al. 2010). Planting at depth with soil anticrustant improved emergence compared to surface planting whereas seed pelleting did not improve emergence. Planting at ⅛-inch depth resulted in higher emergence than either surface planting or planting at ¼-inch depth for three of the four species. Emergence for one species was too poor for any conclusions to be made. Despite these results, emergence was extremely poor for all species tested. Soil crusting, loss of soil moisture, and bird damage could have contributed to the poor emergence.

In established native perennial fields at the Malheur Experiment Station, Ontario, Oregon, and in rangelands, we observed prolific emergence from seed naturally falling on the soil surface and subsequently covered by thin layers of normally occurring organic debris. Building on this observation, we developed and tested planting systems, focusing on surface-planted seed (Table 1, Shock et al. 2012-2014). Treatments included row cover, sawdust, sand, and seed treatments. Row cover can act as a protective barrier against soil desiccation and bird damage. Sawdust was intended to mimic the protective effect of organic debris. Sand could help hold the seed in place. Seed treatment could protect the emerging seed from fungal pathogens that might cause seed decomposition or seedling damping off. Trials did not test all possible combinations of treatments, but focused on combinations likely to result in adequate stand establishment based on previous observations.

Materials and Methods

In 2016 and 2017, 14 species for which stand establishment has been problematic were included and an additional species (*Penstemon speciosus*) was chosen as a check, because it has reliably produced adequate stands at Ontario. Seed weights for all species were determined. In November each year, a portion of the seed was treated with a liquid mix of the fungicides Thiram and Captan (10 g Thiram, 10 g Captan in 0.5 L of water). Seed weights of the treated seeds were determined after treatment. The seed weights of untreated and treated seed were used to make seed packets containing approximately 300 seeds each. The seed packets were assigned to one of seven treatments (Table 1). The trials were planted manually on November 23, 2015 and on December 1, 2016. The experiments had randomized complete block designs with six replicates. Treatments were planted on beds 30 inches wide by 5 ft long. The seed was placed on the soil surface in two rows on each bed.

The four factors (row cover, sawdust, sand, and mulch) were applied in combined systems after planting. Sawdust was applied in a narrow band over the seeded row at 0.26 oz/ft of row (558 lb/acre). For the treatment systems receiving both sawdust and sand, sand was applied at 0.65 oz/ft of row (1404 lb/acre) as a narrow band over the sawdust. Following planting and sawdust and sand applications, some 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. Mouse bait packs were scattered under the row covers. For the hydroseeding mulch treatments, 10 lb of hydroseeding paper mulch (Premium Hydroseeding Mulch, Applegate Mulch, http://applegatemulch.com) was mixed in 50 gal of water in a jet agitated 50-gal hydroseeder (Turbo Turf Technologies, Beaver Falls, PA). The mulch was applied with the hydroseeder in a thin 3-cm band over the seed row. In early April each year, the row cover was removed and the trial was sprayed with Poast® at 24 oz/acre for control of grass weeds. The trial was hand weeded. Emergence counts were recorded in all plots on May 2, 2016 and May 4, 2017.

Tetrazolium tests were conducted to determine seed viability of each species (Table 2) and the seed viability results were used to correct the emergence data to emergence as a percentage of planted viable seed. Data were analyzed using analysis of variance (General Linear Models Procedure, NCSS, Kaysville, UT). Means separation was determined using a protected Fisher's least significant difference test at the 5% probability level, LSD (0.05).

Results and Discussion

2016 Results

The row cover with sawdust plus seed treatment resulted in higher stands than no row cover (bare ground) with sawdust and seed treatment for *Chaenactis douglasii, Machaeranthera canescens, Phacelia hastata, P. crenulata, Heliomeris multiflora, Penstemon speciosus*, and *Achillea millefolium* (Table 3). Sawdust added to the row cover plus seed treatment only improved stand of *Penstemon speciosus* and reduced stand of *Nicotiana attenuata* and *Achillea millefolium.*

Adding seed treatment to sawdust plus row cover did not improve stand of any species and reduced stands of *Phacelia crenulata, Heliomeris multiflora,* and *Ipomopsis aggregata*. Adding sand to sawdust, seed treatment, plus row cover combination improved stand for *Machaeranthera canescens* and *Cleome lutea* and reduced stand for *Achillea millefolium.* Hydroseed mulch with seed treatment resulted in lower stand than row cover with seed treatment for *Machaeranthera canescens, Phacelia hastata, P. crenulata, Heliomeris multiflora, Nicotiana* *attenuata, Thelypodium milleflorum, Penstemon speciosus,* and *Achillea millefolium.* For *Chaenactis douglasii, Phacelia linearis, Cleome lutea,* and *Ipomopsis aggregata,* there was no difference in stand between hydroseed mulch with seed treatment and row cover with seed treatment. However, for *Ipomopsis aggregata,* seed treatment was detrimental and all systems with seed treatment resulted in low stand, negating an evaluation of hydroseed mulch for this species.

2017 Results

The row cover with sawdust plus seed treatment resulted in higher stands than no row cover (bare ground) with sawdust and seed treatment only for *Machaeranthera canescens* (Table 4). Sawdust added to the row cover plus seed treatment did not improve stand of any species and reduced stand of *Nicotiana attenuata* and *Achillea millefolium.*

Adding seed treatment to sawdust plus row cover only improved stand of *Machaeranthera canescens* and *Chaenactis douglasii* and reduced stands of *Phacelia crenulata, Cleome serrulata,* and *Ipomopsis aggregata*. Adding sand to sawdust, seed treatment, plus row cover combination only improved stand of *Penstemon speciosus.* Hydroseed mulch with seed treatment resulted in lower stand than row cover with seed treatment for *Machaeranthera canescens, Nicotiana attenuata,* and *Achillea millefolium.* For the other species there was no difference in stand between hydroseed mulch with seed treatment and row cover with seed treatment. However, for *Ipomopsis aggregata,* seed treatment was detrimental and all systems with seed treatment resulted in low stand, negating an evaluation of hydroseed mulch for this species.

2-year Average Results

The row cover with sawdust plus seed treatment resulted in higher stands than no row cover (bare ground) with sawdust and seed treatment for *Machaeranthera canescens, Heliomeris multiflora, Penstemon speciosus,* and *Achillea millefolium* (Table 5). Sawdust added to the row cover plus seed treatment only improved stand of *Penstemon speciosus* and reduced stand of *Nicotiana attenuata* and *Achillea millefolium.*

Adding seed treatment to sawdust plus row cover only improved stand of *Machaeranthera canescens* and reduced stands of *Heliomeris multiflora, Ipomopsis aggregata, Phacelia crenulata,* and *Cleome serrulata*. Adding sand to sawdust, seed treatment, plus row cover combination improved stand of *Phacelia hastata* and *Cleome lutea* and reduced stand of *Achillea millefolium.* Hydroseed mulch with seed treatment resulted in lower stand than row cover with seed treatment for *Machaeranthera canescens, Phacelia hastata, Heliomeris multiflora, Nicotiana attenuata, Dalea ornata, Achillea millefolium,* and *Phacelia crenulata.* For the other species there was no difference in stand between hydroseed mulch with seed treatment and row cover with seed treatment. However, for *Ipomopsis aggregata*, seed treatment was detrimental and all systems with seed treatment resulted in low stand, negating an evaluation of hydroseed mulch for this species.

Averaged over species, the row cover with sawdust plus seed treatment resulted in higher stand than no row cover (bare ground) with sawdust and seed treatment in 2016, but not in 2017. Averaged over species, adding seed treatment to sawdust plus row cover reduced stands in 2016 and did not improve stands in 2017. Sawdust added to the row cover plus seed treatment did not improve stands in 2016 and reduced stands in 2017. Adding sand to sawdust, seed treatment, plus row cover combination improved stands in 2016, but not in 2017.

Discussion

Snow cover over the winter of 2016-2017 was deeper and longer lasting than in 2015-2016. In the winter of 2015-2016 the ground was covered by snow continuously from December 18 to January 22 (36 days) with an average snow depth of 2.3 inches. In the winter of 2016-2017 the ground was covered by snow continuously from December 9 to March 5 (87 days) with an average snow depth of 13 inches. The longer snow cover in 2017 probably was a factor in row cover with sawdust plus seed treatment resulting in higher stand than no row cover (bare ground) with sawdust and seed treatment in 2016, but not in 2017.

Seed treatment, sawdust, and sand were factors that had inconsistent results for most species over the 2 years. Some species showed consistent results over the 2 years for seed treatment and sawdust. Seed treatment resulted in lower stands for *Ipomopsis aggregata* and *Phacelia crenulata* both years. Sawdust reduced stands of *Nicotiana attenuata* and *Achillea millefolium* both years.

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Table 1. Planting systems evaluated for emergence of 15 native plant species. Malheur Experiment Station, Oregon State University, Ontario, OR, fall 2015 and 2016.

#	Row cover	Seed treatment[a]	Sawdust	Sand	Mulch
1	yes	yes	yes	no	no
2	yes	yes	no	no	no
3	yes	no	yes	no	no
4	yes	yes	yes	yes	no
5	no	yes	yes	no	no
6	no	yes	no	no	yes
7	no	no	no	no	no

[a]Mixture of Captan and Thiram fungicides for prevention of seed decomposition and seedling damping off.

Table 2. Seed weights and tetrazolium test (seed viability) results for seed used for the planting system treatments in the fall of 2015 and 2016, Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Common name	Preplant untreated seed weight	Tetrazolium test 2016	Tetrazolium test 2017
		seeds/g	%	
Chaenactis douglasii	Douglas' dustymaiden	682	72	29
Machaeranthera canescens	hoary tansyaster	1,590	70	83
Phacelia hastata	silverleaf phacelia	1,098	98	95
Phacelia crenulata	cleftleaf wildheliotrope	918	87	89
Phacelia linearis	threadleaf phacelia	4,091	98	98
Heliomeris multiflora	showy goldeneye	1,800	76	76
Nicotiana attenuata	coyote tobacco	8,333	90	93
Thelypodium milleflorum	manyflower thelypody	3,629	97	96
Ipomopsis aggregata	scarlet gilia	616	81	79
Penstemon speciosus	showy penstemon	662	85	86
Dalea ornata	Western prairie clover	341	84	83
Dalea searlsiae	Searls' prairie clover	274	81	51
Achillea millefolium	common yarrow	12,162	37	45
Cleome lutea	yellow beeplant	214	87	85
Cleome serrulata	Rocky Mountain beeplant	134	90	97

Table 3. Plant stands of 15 native plant species on May 2, 2016 in response to 7 planting systems used in November 2015. Stand for each species was corrected to the percent of viable seed based on the tetrazolium test. To evaluate systems, the following treatment comparisons were used: Row cover, treatments 1 and 5; Seed treatment, treatments 1 and 3; Sawdust, treatments 1 and 2; Sand, treatments 1 and 4. Oregon State University, Malheur Experiment Station, Ontario, OR.

Species	Row cover, seed treatment, sawdust	Row cover, seed treatment	Row cover, sawdust	Row cover, seed treatment, sawdust, sand	Seed treatment, sawdust	Mulch, seed treatment	Untreated check	Average
	------------------------------ % stand ------------------------------							
Chaenactis douglasii	22.3	16.3	24.2	23.2	10.7	14.2	5.3	16.6
Machaeranthera canescens	28.9	26.0	25.2	38.7	14.8	16.2	16.0	23.7
Phacelia hastata	23.2	28.3	21.8	31.7	11.1	3.6	8.5	18.3
Phacelia linearis	6.2	1.8	2.3	11.7	4.5	2.7	1.8	4.4
Heliomeris multiflora	33.1	31.0	44.9	41.2	6.7	1.2	2.3	22.9
Nicotiana attenuata	6.5	21.7	15.2	10.1	0.1	0.1	0.4	7.7
Thelypodium milleflorum	10.9	15.3	9.8	14.4	9.3	6.1	5.2	10.1
Ipomopsis aggregata	2.6	1.8	22.9	4.1	0.6	0.2	2.7	5.0
Penstemon speciosus	23.4	11.4	15.9	26.3	3.7	0.5	0.5	11.7
Dalea ornata	4.0	6.4	4.8	4.0	0.4	0.1	0.0	2.8
Dalea searlsiae	2.8	2.3	1.0	3.0	0.3	0.1	0.1	1.4
Achillea millefolium	27.9	51.1	25.7	18.2	10.5	8.0	9.3	21.5
Cleome lutea	19.0	14.4	18.2	28.9	11.9	6.3	6.1	15.0
Cleome serrulata	7.2	2.6	7.0	7.7	4.6	1.4	1.5	4.6
Phacelia crenulata	15.5	13.9	30.5	17.1	2.3	1.9	0.8	11.7
2016 Average	15.6	16.3	18.0	18.7	6.1	4.2	4.0	11.8

Table 4. Plant stands of 15 native plant species on May 4, 2017 in response to 7 planting systems used in November 2016. Stand for each species was corrected to the percent of viable seed based on the tetrazolium test. To evaluate systems, the following treatment comparisons were used: Row cover, treatments 1 and 5; Seed treatment, treatments 1 and 3; Sawdust, treatments 1 and 2; Sand, treatments 1 and 4. Oregon State University, Malheur Experiment Station, Ontario, OR.

Species	Row cover, seed treatment, sawdust	Row cover, seed treatment	Row cover, sawdust	Row cover, seed treatment, sawdust, sand	Seed treatment, sawdust	Mulch, seed treatment	Untreated check	Average
	% stand							
Chaenactis douglasii	26.2	21.5	13.5	25.3	26.2	24.4	12.9	21.4
Machaeranthera canescens	77.7	77.4	13.7	73.4	67.7	59.4	18.6	55.4
Phacelia hastata	9.5	13.7	12.3	15.2	11.8	11.8	12.7	12.4
Phacelia linearis	13.7	10.7	13.3	12.1	10.7	11.5	11.2	11.9
Heliomeris multiflora	7.7	8.7	16.2	10.2	8.2	11.3	12.4	10.7
Nicotiana attenuata	12.5	35.8	10.2	21.1	9.9	6.3	8.4	14.9
Thelypodium milleflorum	6.3	6.1	10.2	5.3	9.3	8.7	11.2	8.2
Ipomopsis aggregata	0.6	4.9	18.6	0.3	0.2	3.5	12.5	5.8
Penstemon speciosus	10.8	7.6	13.0	20.2	12.7	10.3	11.2	12.3
Dalea ornata	11.0	9.6	10.3	11.6	6.0	2.1	3.6	7.8
Dalea searlsiae	3.2	2.1	2.6	3.8	1.1	1.1	1.2	2.1
Achillea millefolium	30.6	49.0	36.4	27.4	31.1	38.6	46.0	37.0
Cleome lutea	18.1	19.0	26.1	24.6	22.5	21.2	32.5	23.4
Cleome serrulata	8.4	8.6	24.4	8.2	10.5	9.6	36.9	15.2
Phacelia crenulata	5.2	11.5	15.0	8.7	5.7	3.9	13.3	9.0
2017 Average	16.1	19.1	15.7	17.8	15.6	14.9	16.3	16.5

Table 5. Plant stands of 15 native plant species averaged over 2 years in response to 7 planting systems used in the previous fall. Stand for each species was corrected to the percent of viable seed based on the tetrazolium test. To evaluate systems, the following treatment comparisons were used: Row cover, treatments 1 and 5; Seed treatment, treatments 1 and 3; Sawdust, treatments 1 and 2; Sand, treatments 1 and 4. Oregon State University, Malheur Experiment Station, Ontario, OR, 2016-2017.

Species	Row cover, seed treatment, sawdust	Row cover, seed treatment	Row cover, sawdust	Row cover, seed treatment, sawdust, sand	Seed treatment, sawdust	Mulch, seed treatment	Untreated check	Average
	--- % stand ---							
Chaenactis douglasii	24.3	19.1	18.4	24.3	18.4	18.8	8.8	18.9
Machaeranthera canescens	53.3	51.7	19.4	56.1	41.2	37.8	17.3	39.6
Phacelia hastata	16.4	21.0	17.1	23.4	11.4	7.7	10.6	15.4
Phacelia linearis	9.9	6.2	7.8	11.9	7.6	7.1	6.5	8.2
Heliomeris multiflora	20.4	19.8	30.6	25.7	7.5	6.2	7.3	16.8
Nicotiana attenuata	9.5	28.7	12.7	15.6	5.0	3.2	4.4	11.3
Thelypodium milleflorum	8.6	10.7	10.0	9.8	9.3	7.4	8.2	9.2
Ipomopsis aggregata	1.6	3.4	20.8	2.2	0.4	1.9	7.6	5.4
Penstemon speciosus	17.1	9.5	14.5	23.2	8.2	5.4	5.9	12.0
Dalea ornata	7.5	8.0	7.5	7.8	3.2	1.1	1.8	5.3
Dalea searlsiae	3.0	2.2	1.8	3.4	0.7	0.6	0.6	1.8
Achillea millefolium	29.3	50.0	31.0	22.8	19.9	23.3	29.1	29.3
Cleome lutea	18.5	16.7	21.8	26.6	17.2	13.7	19.3	19.1
Cleome serrulata	7.8	5.6	15.7	8.0	7.6	5.5	19.2	9.9
Phacelia crenulata	10.3	12.7	22.8	12.9	4.0	2.9	7.0	10.4
2016-2017 Average	15.8	17.7	16.8	18.2	10.8	9.5	10.2	14.2
LSD (0.05)								
Treatment	1.4							
Species	2.4							
Year	0.9							
Species X year	3.5							
Treatment X species	6.4							
Treatment X year	2.4							
Treatment X species X year	9.2							

IRRIGATION REQUIREMENTS FOR SEED PRODUCTION OF VARIOUS NATIVE WILDFLOWER SPECIES

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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 in the fall of 2012 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/acre, 10 lb phosphorus/acre, and 0.3 lb iron/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.

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 nonirrigated 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) with the exception of *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 *Enceliopsis 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 and 2017, seed of *C. intermedia* was harvested by mowing and bagging just prior to the seed heads opening. A seed sample from each plot of *C. intermedia* in 2016 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). 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 (Table 3).

Achillea millefolium. Seed yields of *Achillea millefolium* showed a quadratic response to irrigation in 2017 with a maximum seed yield of 220 lb/acre at 6.2 inches of water applied (Tables 4 and 5).

Thelypodium milleflorum. Seed yield of *Thelypodium milleflorum* did not respond to irrigation in 2014 or 2016 (Tables 4 and 5). Highest seed yields averaged 225 lb/acre over the 2 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. Seed yields increased each year from 2015 to 2017 with highest seed yields of 349 lb/acre in 2017.

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, seed yields showed a quadratic response to irrigation with a maximum seed yield at 4.2 inches of water applied. In 2017, seed yields were highest with no irrigation. Highest seed yields averaged 1146 lb/acre over the 5 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. Highest seed yields averaged 149 lb/acre over the 5 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.

Chaenactis douglasii. Stands of *Chaenactis douglasii* were poor in 2013 and 2014, and did not permit evaluation of irrigation responses. After replanting in the fall of 2013 and 2014, an adequate stand of *C. douglasii* was established, allowing evaluations of irrigation responses in 2015, 2016, and 2017. *Chaenactis douglasii* seed yields did not respond to irrigation in 2015-2017. Highest seed yields averaged 288 lb/acre over the 3 years.

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. The replanting done in the fall of 2015 was successful, but stands continue to decline, especially in the irrigated plots. Highest seed yields averaged 25 lb/acre over the 4 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, and averaged over the 3 years, seed yields of *M. canescens* did not respond to irrigation. Highest seed yields averaged 240 lb/acre over the 3 years. Partial die-off of *Machaeranthera 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. Seed yields of *Nicotiana 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. In 2015 and 2017, stands of *Nicotiana attenuata* were uneven and did not permit evaluation of irrigation responses.

Phacelia hastata. Irrigation responses for *P. hastata* were evaluated for two sets of plots: the 3-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 5.4 and 7.5 inches of water applied in 2013 and 2014, 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. 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, seed yields of *P. hastata*, showed a quadratic response to irrigation with a maximum seed yield at 4 inches of water applied. In 2017, seed yields of *P. hastata* did not respond to irrigation. Averaged over the 3 years, seed yields of *P. hastata* showed a quadratic response to irrigation with a maximum seed yield of 163 lb/acre and 62 lb/acre at 6.6 and 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 and then a decline in the third year.

Phacelia linearis. Seed yields of *Phacelia 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. Stand of *P. linearis* was poor at the end of 2014 and the area was replanted in the fall. Stand of replanted *P. linearis* was very poor in 2015; it was replanted in the fall of 2016 in a different location in the field, but stand in the spring of 2016 was extremely poor.

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, 2013-2017. Continued on 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
***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, 6-8 to 7-15
2016	23-May		22-Jul	23-May	8-Jul	weekly, 6-17 to 7-7
2017	25-May	7-Jun	19-Jul	9-May	20-Jun	weekly, 6-16 to 7-6
***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			
***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

Table 2. (Continued) Native wildflower flowering, irrigation, and seed harvest dates by species. Malheur Experiment Station, Oregon State University, Ontario, OR, 2013-2017.

	Flowering dates			Irrigation dates		
Year	Start	Peak	End	Start	End	Harvest
***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	
***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
***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
***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
***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				
***Crepis intermedia,* limestone hawksbeard**						
2015	28-Apr	5-May	1-Jun	21-Apr	3-Jun	weekly, 6-1 to 7-2
2016	29-Apr		25-May	27-Apr	7-Jun	26-May
2017	15-May		7-Jun	9-May	20-Jun	8-Jun
***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, 2013-2017.

	Precipitation (inch)			Growing degree-days (50-86°F)
Year	Spring	Winter + spring	Fall + winter + spring	Jan–June
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
5-year average:	2.4	5.6	9.3	23-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, 2013-2017

Species	Year	Irrigation rate 0 inches	4 inches	8 inches	LSD (0.05)
		---------------- lb/acre --------------			
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
	Average	289.5	288.2	279.2	NS
Crepis intermedia	2015	75.5	75.8	153.7	58.1
	2016	91.9	113.1	85.6	NS
	2017	331.6	348.5	315.8	NS
	Average	166.3	179.1	192.0	NS
Cymopterus bipinnatus	2013	194.2	274.5	350.6	NS
	2014	1236.2	1934	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
	Average	732.1	1145.7	1035.3	195.6
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
	Average	27.0	27.6	22.1	NS
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
	Average	89.0	106.7	148.9	27.5
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
	Average	163.0	240.3	233.3	NS
Nicotiana attenuata	2016	49.4	151.0	95.8	81.4
Phacelia hastata (planted fall 2012)	2013	35.3	102.7	91.2	35.7
	2014	87.7	305.7	366.4	130.3
	2015	78.8	79.3	65.0	NS
	Average	67.3	162.6	174.2	34.5
Phacelia hastata (planted fall 2014)	2015	0.0	21.4	50.4	13.7
	2016	82.5	125.2	83.1	26.8
	2017	20.3	23.2	23.2	NS
	Average	34.3	61.7	52.2	20.7
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
	Average	171.7	224.6	152.6	NS
Achillea millefolium	2017	59.2	213.3	220.4	99.8

[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 $y = a + b \cdot x + c \cdot x^2$. 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, 2013-2017. Continued on next page.

Species	Year	intercept	linear	quadratic	R^2	P	Maximum seed yield	Water applied for maximum yield
							lb/acre	inches/season
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		
	Average	289.5	0.7	-0.2	0.01	NS		
Crepis intermedia	2015	58.6	12.7		0.32	0.10	160	8.0
	2016	91.9	11.4	-1.5	0.25	NS		
	2017	331.6	10.4	-1.5	0.03	NS		
	Average	166.3	3.2		0.05	NS		
Cymopterus bipinnatus	2013	194.9	19.6		0.07	NS		
	2014	1214.6	190.6		0.41	0.05	2739	8.0
	2015	312.3	210.5	-25.3	0.46	0.10	750	4.2
	2016	1501.4	272.4	-29.4	0.34	NS		
	2017	308.1	-24.4		0.38	0.10	308	0.0
	Average	732.1	168.9	-16.4	0.51	0.05	1168	5.2
Enceliopsis nudicaulis	2013	3.1	0.4		0.16	NS		
	2014	1.5	13.1	-1.2	0.6	0.05	37.1	5.4
	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
	Average	27.0	0.9	-0.2	0.04	NS		
Heliomeris multiflora	2013	27	8.5		0.38	0.05	95	8
	2014	150.5	14.6		0.27	0.10	267	8
	2015	75.2	13.3		0.48	0.05	182	8
	2016	90.7	0.7		0.01	NS		
	2017	83.5	0.3		0.01	NS		
	Average	84.9	7.5		0.49	0.05	145	8

[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, 2013-2017.

Species	Year	intercept	linear	quadratic	R^2	*P*	Maximum seed yield	Water applied for maximum yield
							lb/acre	inches/season
Ipomopsis aggregata	2014	48.5	2.1		0.23	NS[a]		
	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	224	2.4
	2014	946.1	122	-14	0.13	NS		
	2015	311.1	19.4		0.02	NS		
	Average	163.0	29.9	-2.6	0.03	NS		
Nicotiana attenuata	2016	49.4	45.0	-4.9	0.50	0.05	153	4.6
Phacelia hastata	2013	35.3	26.7	-2.5	0.66	0.01	107	5.3
(planted fall 2012)	2014	87.7	74.2	-4.9	0.76	0.01	369	7.6
	2015	78.8	2.0	-0.5	0.04	NS		
	Average	67.3	34.3	-2.6	0.9	0.001	180	6.6
Phacelia hastata	2015	-1.3	6.3		0.88	0.001	49	8
(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		
	Average	34.3	11.5	-1.2	0.56	0.05	62.8	5.0
Phacelia linearis	2013	121.4	68.3	-5.5	0.69	0.01	333	6.2
	2014	131.9	21.1	-2.7	0.11	NS		
	Average	126.7	44.7	-4.1	0.48	0.1	249	5.5
Thelypodium milleflorum	2014	200.5	22.2	-2.7	0.12	NS		
	2016	121.9	1.4	-1.1	0.35	NS		
	Average	171.7	28.8	-3.9	0.20	NS		
Achillea millefolium	2017	59.2	56.9	-4.6	0.75	0.01	235	6.2

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

NATIVE BEEPLANT SEED PRODUCTION IN RESPONSE TO IRRIGATION IN A SEMI-ARID ENVIRONMENT

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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 inches, 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. *Cleome lutea* seed yield was highest with no irrigation in 2016. *Cleome lutea* seed yield did not respond to irrigation in 2012, 2014, or 2015. *Cleome lutea* stands were lost to flea beetles in 2013 and to poor emergence in 2017. Flea beetle control is essential for seed production when flea beetles occur.

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 4 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, 2 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 each year in 30-inch rows using a custom-made small-plot grain drill with disc openers in mid-November. 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

Flea beetles were observed feeding on leaves of *Cleome serrulata* and *C. lutea* in April of 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.

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, *Cleome 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
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			

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 seed pods and might also 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 that had the highest seed yield also had the lowest June and July growing degree-days, suggesting the possibility of a negative effect of higher temperatures on sustained flowering and seed set.

Cleome lutea, yellow spiderflower or yellow beeplant

Seed yields did not respond to irrigation in 2012, 2014, or 2015 (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 *Cleome 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, 2011-2017.

	Precipitation (inch)			Growing degree-days (50-86°F)
Year	Spring	Winter +spring	Fall + winter + spring	June + July
2011	4.8	9.3	14.5	1099
2012	2.6	6.1	8.4	1235
2013	0.9	2.4	5.3	1294
2014	1.7	5.1	8.1	1323
2015	3.2	5.9	10.4	1390
2016	2.2	5.0	10.1	1256
2017	4.0	9.7	12.7	1300
12-year average:	2.9	6.3	9.8	23-year average: 1213

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, 2011-2017.

		Irrigation rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
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
	Average	114.5	120.0	136.4	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		
	Average	130.3	108.7	110.3	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 $y = a + b•x + c•x^2$. Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2017.

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		
Average	112.6	2.7		0.32	0.1	134.6	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
Average	126.5	-2.5		0.04	NS		

[a]Not significant.

IRRIGATION REQUIREMENTS FOR NATIVE BUCKWHEAT SEED PRODUCTION IN A SEMI-ARID ENVIRONMENT

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Summary

Native buckwheats (*Eriogonum* spp.) are important perennials 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 10 of the 11 years, with 5 to 11 inches of water applied plus spring precipitation maximizing yields, depending on year. Averaged over 11 years, seed yield of *E. umbellatum* showed a quadratic response to irrigation rate plus spring precipitation and was estimated to be maximized at 232 lb/acre/year by irrigation plus spring precipitation of 9.4 inches. Over six 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 6 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 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, 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 minisprinkler 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 minisprinkler 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 *Eriogonum 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 (*Eriogonum 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 *Eriogonum 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 *Eriogonum umbellatum*. On November 17, 2006, November 9, 2007, April 15, 2008, December 4, 2009, and November 17, 2010, all plots of *E. umbellatum* had Prowl® at 1 lb ai/acre broadcast on the soil surface for weed control. On March 18, 2009, Prowl at 1 lb ai/acre and Volunteer® at 8 oz/acre were broadcast on all *E. umbellatum* plots for weed control. On April 3, 2013, Select Max® at 32 oz/acre was broadcast for grass weed control on all plots of *E. umbellatum.* On November 9, 2011 and November 7, 2012, Prowl at 1 lb ai/acre was broadcast on all plots of both species. On February 26, 2014, Prowl at 1 lb ai/acre and Select Max at 32 oz/acre were broadcast on all plots of both species. On March 13, 2015, Prowl at 1 lb ai/acre was broadcast on all plots of both species. On November 11, 2015, Prowl at 1 lb ai/acre and Poast® at 30 oz/acre were broadcast on all plots of *E. umbellatum.* On October 27, 2016, Prowl at 1 lb ai/acre was broadcast on all plots of both species. On April 21, 2017, Prowl at 1 lb ai/acre and Poast® at 30 oz/acre were 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 $y = a + b \cdot x + c \cdot x^2$. 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 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, 2010, 2011, and 2017 was higher than the average and spring precipitation in 2007, 2008, 2013, and 2014 was lower than the average of 2.9 inches. The accumulated growing degree-days (50-86°F) from January through June in 2007, and 2013-2016 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-days (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 and 2012-2016, 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 12 years, seed yield showed a quadratic response to irrigation rate plus spring precipitation and was estimated to be maximized at 221 lb/acre/year by irrigation plus spring precipitation of 9.4 inches.

***Eriogonum heracleoides,* parsnipflower buckwheat**

For *E. heracleoides*, there was only one year where a yield response to irrigation existed, so yield responses only to water applied are reported.

In 2013, seed yields showed a quadratic response to irrigation with a maximum seed yield at 4.9 inches of water applied. Seed yields did not respond to irrigation in 2011, 2012, and 2014-2017 (Tables 3 and 4). Averaged over 7 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

The total irrigation requirements for these arid-land species were low and varied by species. *Eriogonum heracleoides* responded to irrigation only in 2013, a drier than average year. 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 10 of the 12 years, with irrigation plus spring precipitation of 9.4 inches maximizing yields. Buckwheat flowering and harvests have been earlier in 2013-2016 than in previous years, probably due to warmer weather.

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Table 1. *Eriogonum umbellatum* and *E. heracleoides* flowering, irrigation, and seed harvest dates by species in 2006-2017, 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
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

Table 2. Precipitation and growing degree-days at the Malheur Experiment Station, Ontario, OR, 2006-2017.

	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
12-year average:	2.9	6.3	9.8	23-year average: 1207

Table 3. *Eriogonum umbellatum* and *E. heracleoides* seed yield in response to irrigation rate (inches/season) in 2006 through 2017. 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
	Average	157.3	216.5	205.7	24.2
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
	Average	212.9	312.2	280.1	59.4

[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•x + c•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
Average	29.1	41.0	-2.2	0.73	0.01	220.7	9.4	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	40.7	-4.1	0.38	NS		
Average	212.9	41.2	-4.1	0.63	0.05	316.5	5.0

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

PRAIRIE CLOVER AND BASALT MILKVETCH SEED PRODUCTION IN RESPONSE 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 7-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. 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 4 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, 2 drip tapes 5 feet apart (T-Tape TSX 515-16-340) were buried at 12-inch depth to irrigate the 4 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 non-irrigated 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, Prowl® at 1 lb ai/acre was broadcast on all plots of all species 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 all 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 and 2017.

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 from January through June was close to average in 2012 and 2014-2016, higher than average in 2011 and 2017, and lower than average in 2013 (Table 3). The accumulation of growing degree-days (50-86°F) was increasingly higher than average from 2012 to 2016, 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 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 7 years, maximum seed yields were 227 lb/acre achieved with 16.1 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 with a maximum seed yield at 16.1, 13.3, 14.9, 14.9, and 14.6 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 seven years, maximum seed yields were 350 lb/acre achieved with 15.3 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 was among the irrigation rates resulting in 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, 2011-2017.

		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
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
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, 2006-2017.

	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
12-year average:	2.9	6.3	9.8	23-year average: 1207

Table 4. Native wildflower seed yield in response to irrigation rate (inches/season). Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2017.

		Irrigation rate			
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
	Average	157.9	218.0	221.2	13.4
Dalea ornata					
	2011	451.9	410.8	351.7	NS[a]
	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
	Average	219.6	339.9	323.1	49.9
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, 2011-2017.

Dalea searlsiae

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus precipitation for max. yield	Precipitation, fall, winter, spring
						(lb/acre)	(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
Average	-232.0	57.1	-1.8	0.60	0.05	226.8	16.1	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)	(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	9.4
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
Average	-659.0	131.5	-4.3	0.83	0.001	349.7	15.3	9.8

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

IRRIGATION REQUIREMENTS FOR *LOMATIUM* SEED PRODUCTION

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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 nine 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 11 seed production seasons, *L. triternatum* (nineleaf biscuitroot) seed yield was maximized by 12.4 inches of water applied plus spring precipitation. Over six seed production seasons, *L. nudicaule* (barestem biscuitroot) seed yield responded to irrigation only in 2017. In four 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 *Lomatium 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 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, 2005, seed of the three species (*Lomatium 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 minisprinkler 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 minisprinkler 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 *Lomatium 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 *Lomatium 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. 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.

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 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.

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.

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 in 2006

On October 27, 2006, 50 lb phosphorus (P)/acre and 2 lb zinc (Zn)/acre were injected through the drip tape to all plots. On November 11, 100 lb nitrogen (N)/acre as urea was broadcast to all plots. On November 17, all plots had Prowl® at 1 lb ai/acre broadcast on the soil surface. Irrigations for all species were initiated on May 19 and terminated on June 30.

Cultural practices in 2007

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

Cultural practices in 2008

On November 9, 2007 and on April 15, 2008, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2009

On March18, Prowl at 1 lb ai/acre and Volunteer® at 8 oz/acre were broadcast on all plots for weed control. On April 9, 50 lb N/acre and 10 lb P/acre were applied through the drip irrigation system to the three *Lomatium* spp.

On December 4, 2009, Prowl at 1 lb ai/acre was broadcast for weed control on all plots.

Cultural practices in 2010

On November 17, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2011

On May 3, 2011, 50 lb N/acre was applied to all *Lomatium* spp. plots as URAN (urea ammonium nitrate) injected through the drip tape. On November 9, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2012

Iron deficiency symptoms were prevalent in 2012. Liquid fertilizer was injected containing 50 lb N/acre, 10 lb P/acre, and 0.3 lb iron (Fe)/acre using a brief pulse of water through the drip irrigation system to all plots on April 13. On November 7, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2013

Liquid fertilizer was injected containing 20 lb N/acre, 25 lb P/acre, and 0.3 lb Fe/acre using a brief pulse of water through the drip irrigation system to all plots on March 29. On April 3, Select Max® at 32 oz/acre was broadcast for grass weed control on all plots.

Cultural practices in 2014

On February 26, Prowl at 1 lb ai/acre and Select Max at 32 oz/acre were broadcast on all plots for weed control. Liquid fertilizer was injected containing 20 lb N/acre, 25 lb P/acre, and 0.3 lb Fe/acre using a brief pulse of water through the drip irrigation system to all plots on April 2.

Cultural practices in 2015

On March 13, Prowl at 1 lb ai/acre was broadcast on all plots for weed control. Liquid fertilizer was injected containing 20 lb N/acre, 25 lb P/acre, and 0.3 lb Fe/acre using a brief pulse of water through the drip irrigation system to all plots on April 15. On November 6, Prowl at 1 lb ai/acre and Roundup® at 24 oz/acre were broadcast on all plots for weed control.

Cultural practices in 2016

Liquid fertilizer was injected containing 20 lb N/acre, 25 lb P/acre, and 0.3 lb Fe/acre using a brief pulse of water through the drip irrigation system to all plots on March 31. On October 27, Prowl H_2O at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2017

On March 28, Prowl H_2O at 1 lb ai/acre and Poast® at 0.75 lb ai/acre were broadcast on all plots for weed control. Liquid fertilizer was injected containing 0.3 lb Fe/acre using a brief pulse of water through the drip irrigation system to all plots on April 4.

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 2009-2011 and 2017 was higher, and spring precipitation in 2007, 2008, 2013, and 2014 was lower than average. The accumulated growing degree-days (50-86°F) from January through June in 2006, 2007, and 2013-2016 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, and 2017 (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 8 years, seed yield showed a quadratic response to irrigation rate plus spring precipitation and was estimated to be maximized at 999 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 and 2016 (Tables 5 and 7). Seed yields were estimated to be maximized by 6.5 inches of applied water plus spring precipitation in 2014. Seed was inadvertently not harvested in 2015. In 2016, seed yields were estimated to be maximized by 7.5 inches of applied water plus spring precipitation. In 2017, seed yields were estimated to be maximized by 8 inches of applied water plus spring precipitation. Over years, seed yields were estimated to be maximized by 9.3 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) and 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. Over years, seed yields were estimated to be maximized by 7.7 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 (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, probable due to heavy winter and spring precipitation. On average, seed yields of *L. triternatum* were maximized at 1,213 lb/acre by 12.4 inches of applied water plus spring precipitation.

***Lomatium nudicaule,* barestem biscuitroot**

Seed yields did not respond to irrigation from 2012 to 2016 (Tables 4 and 6). In 2017, seed yields showed a quadratic response to irrigation rate. Seed yields in 2017 were 212 lb/acre with 8 inches of applied water.

***Lomatium suksdorfii,* Suksdorf's desert parsley**

Lomatium suksdorfii started flowering in 2013, but only in small amounts. In the 4 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 its 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 2006-2017, 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
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
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

Table 2. Continued. *Lomatium* flowering, irrigation, and seed harvest dates by species in 2006-2017, 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
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

Table 3. Precipitation and growing degree-days at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2006-2017.

	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
12-year average:	2.9	6.3	9.8	23-year average: 1207

Table 4. Seed yield response to irrigation rate (inches/season) for four *Lomatium* species in 2006 through 2017. Malheur Experiment Station, Oregon State University, Ontario, OR.

		Irrigation rate						Irrigation rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)	Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
Lomatium dissectum		--------- lb/acre -----				*Lomatium grayi*		---------- lb/acre ----------			
	2006	---- no flowering ----					2006	---- no flowering ----			
	2007	---- no flowering ----					2007	36.1	88.3	131.9	77.7[b]
	2008	- very little flowering -					2008	393.3	1287.0	1444.9	141.0
	2009	50.6	320.5	327.8	196.4[b]		2009	359.9	579.8	686.5	208.4
	2010	265.8	543.8	499.6	199.6		2010	1035.7	1143.5	704.8	NS
	2011	567.5	1342.8	1113.8	180.9		2011	570.3	572.7	347.6	NS
	2012	388.1	460.3	444.4	NS		2012	231.9	404.4	377.3	107.4
	2013	527.8	959.8	1166.7	282.4		2013	596.7	933.4	1036.3	NS
	2014	353.4	978.9	1368.3	353.9		2014	533.1	1418.1	1241.3	672.0
	2015	591.2	1094.7	1376.0	348.7		2015	186.4	576.7	297.6	213.9
	2016	1039.4	1612.7	1745.4	564.2		2016	483.7	644.2	322.9	218.7
	2017	488.2	713.1	674.4	220.5[b]		2017	333.5	259.5	246.3	NS
9-year average		474.7	923.3	968.5	137.1	11-year average		438.4	718.9	621.6	210.5

		Irrigation rate						Irrigation rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)	Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
Lomatium nudicaule		---------- lb/acre ----------				*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	---- no flowering ----					2010	1637.2	2829.6	3194.6	309.4
	2011	---- no flowering ----					2011	1982.9	2624.5	2028.1	502.3[b]
	2012	53.8	123.8	61.1	NS		2012	238.7	603.0	733.2	323.9
	2013	357.6	499.1	544.0	NS		2013	153.7	734.4	1050.9	425.0
	2014	701.3	655.6	590.9	NS		2014	240.6	897.1	1496.7	157.0
	2015	430.6	406.1	309.3	NS		2015	403.2	440.8	954.9	446.6
	2016	363.0	403.7	332.5	NS		2016	395.0	475.7	638.4	175.7
	2017	53.7	159.7	212.0	49.7		2017	932.8	948.9	1266.2	216.8
6-year average		326.7	374.7	341.6	NS	11-year average		578.5	1037.5	1211.2	128.2

[a]LSD (0.10)

Table 5. Seed yield response to irrigation rate (inches/season) for two *Lomatium* species in 2014-2017. Malheur Experiment Station, Oregon State University, Ontario, OR.

		Irrigation rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
		---------- lb/acre ----------			
Lomatium dissectum 'Riggins'	2014	276.8	497.7	398.4	163
	2016	299.1	679.5	592.4	247.4
	2017	315.1	405.1	440.0	87.4
3-year average		297.0	527.4	476.9	141.8
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
4-year average		508.4	596.7	523.7	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
4-year average		206.9	371.2	309.2	124.8
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
4-year average		1025.7	979.8	1025.7	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 2006-2017, and 9- to 11-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.

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
Average	-146.8	240.2	-12.6	0.91	0.001	999	9.5	2.9

Lomatium grayi Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus fall, winter, and spring 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
Average	-159.2	221.2	-8.9	0.81	0.001	1213	12.4	2.9

Table 7. Regression analysis for seed yield response to irrigation rate (inches/season) in 2012-2017 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 Experiment Station, Oregon State University, 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
Average	399.2	-1.2		0.01	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		
Average	608.9	133.4	-10.2	0.28	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
Average	-209.5	162.4	-8.8	0.65	0.01	542	9.3	2.8

***Lomatium dissectum* '38'**

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2014	281.9	44.1	-6.4	0.11	NS			1.7
2015	865.4	-11.3		0.01	NS			3.2
2016	474.8	61.7	-5.4	0.32	NS			2.2
2017	398.8	68.8	-6.2	0.38	NS			4.0
Average	508.4	42.2	-5.0	0.1	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
Average	-41.3	108.7	-7.1	0.49	0.05	377	7.7	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	9+
Lomatium grayi	14.3	fall, winter, and spring	2	9+
Lomatium nudicaule	no response in 5 out of 6 years, 8 inches in 2017		3	4+
Lomatium triternatum	12.4	spring	2	9+
Lomatium suksdorfii	no response in 2014, 2016, and 2017, 8 inches irrigation in 2015	undetermined	5	5+

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

IRRIGATION REQUIREMENTS FOR SEED PRODUCTION OF FIVE NATIVE *PENSTEMON* SPECIES

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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 7 years of testing, *P. cyaneus* (blue penstemon) responded to irrigation only in 2013, a dry year with 4 inches of water applied maximizing yields. In 7 years of testing, *P. pachyphyllus* (thickleaf beardtongue) seed yields responded to irrigation only in 2013 with 8 inches of water applied maximizing yields. In 7 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 2017, *P. speciosus* showed a quadratic response to irrigation in 7 out of the 11 years. *Penstemon speciosus* showed either no response or a negative response to irrigation in 3 years with higher than average spring 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

Plant establishment: *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 *Penstemon deustus*. On November 11, 2006, the *P. deustus* plots were replanted again at 30 seeds/ft of row.

Cultural practices in 2006

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 November 17, all plots had Prowl® at 1 lb ai/acre broadcast on the soil surface for weed control. Irrigations for all species were initiated on May 19 and terminated on June 30.

Cultural practices in 2007

Penstemon acuminatus and *P. speciosus* were sprayed with Aza-Direct® at 0.0062 lb ai/acre on May 14 and 29 for lygus bug control. Irrigations for each species were initiated and terminated on different dates (Table 2).

Cultural practices in 2008

On November 9, 2007 and on April 15, 2008, Prowl at 1 lb ai/acre was broadcast on all plots for weed control. Capture® 2EC at 0.1 lb ai/acre was sprayed on all plots of *Penstemon acuminatus* and *P. speciosus* on May 20 for lygus bug control. Irrigations for each species were initiated and terminated on different dates (Table 2). Due to substantial stand loss, all plots of *P. deustus* were disked out.

Cultural practices in 2009

On March 18, Prowl at 1 lb ai/acre and Volunteer® at 8 oz/acre were broadcast on all plots for weed control. On December 4, 2009, Prowl at 1 lb ai/acre was broadcast for weed control on all plots.

Cultural practices in 2010

On November 17, Prowl at 1 lb ai/acre was broadcast on all plots for weed control. Due to substantial stand loss, all plots of *P. acuminatus* were disked out.

Cultural practices in 2011

On November 9, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2013

On April 3, Select Max® at 32 oz/acre was broadcast for grass weed control on all plots of *Penstemon speciosus.*

Cultural practices in 2014

On April 18, Orthene® at 8 oz/acre was broadcast on all plots of *Penstemon speciosus* for lygus bug control. On April 29, 5 lb iron (Fe)/acre was applied through the drip tape to all plots of *P. speciosus*.

Cultural practices in 2015

On April 20, Orthene at 8 oz/acre was broadcast on all plots of *Penstemon speciosus* for lygus bug control.

Stand of *P. speciosus* was poor in 2015 due to die-off, especially in the plots with the highest irrigation rate. On November 2, seed of *P. speciosus* was planted on the soil surface at 30 seeds/ft of row. Following planting, 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.

Weeds were controlled in the first year after fall planting by hand-weeding. In subsequent years, weeds were controlled by yearly applications of Prowl (soil active herbicide) and hand-weeding. Stands of *P. speciosus* have regenerated by natural reseeding, but replanting was required in 2015. Prowl was not applied after 2011 to encourage natural reseeding.

Cultural practices in 2016

On March 2, Poast® at 30 oz/acre was broadcast on all plots for grass control. On October 27, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

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.

Plant establishment: *Penstemon cyaneus, P. deustus,* and *P. pachyphyllus*

On November 25, 2009 seed of *Penstemon 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.

Cultural practices in 2010

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

Gaps in the rows were replanted by hand on November 5. 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.

Cultural practices in 2011

Seed from the middle 2 rows in each plot of *Penstemon deustus* was harvested with a small plot combine. Seed from the middle 2 rows in each plot of the other species was harvested manually.

Cultural practices in 2012

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, 0.3 lb Fe/acre was applied to all plots as liquid fertilizer injected through the drip tape.

A substantial amount of plant death occurred in the *Penstemon deustus* plots during the winter and spring of 2011-2012. For *P. deustus*, only the undamaged parts in each plot were harvested. Seed of all species was harvested and cleaned manually. On October 26, 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.

Cultural practices in 2013

Seed of *Penstemon cyaneus* and *P. pachyphyllus* was harvested manually. The replanted *P. deustus* did not flower in 2013.

Weeds were controlled by hand weeding as necessary.

Cultural practices in 2014

On April 29, 0.3 lb Fe/acre was applied through the drip tape to all plots.

Seed of *Penstemon deustus* was harvested with a small plot combine. Seed of the other species was harvested manually.

Cultural practices in 2015

Seed of *Penstemon deustus* was harvested with a small plot combine. Seed of the other species was harvested manually.

Stands of *P. deustus* and *P. speciosus* were poor at the end of 2015 due to die-off. On November 5, 2015, seed of *P. deustus* and *P. speciosus* was planted on the soil surface at 30 seeds/ft of row. Following planting, 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.

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.

Cultural practices in 2016

On October 27, 2016, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Irrigation for seed production

In April, 2006 each planted strip of *Penstemon 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). The plant stand for the first planting of *P. deustus* was too poor to result in reliable seed yield estimates. Replanting of *P. deustus* in the fall of 2006 did not result in adequate plant stand in the spring of 2007.

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 $y = a + b\bullet x + c\bullet x^2$. 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 *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 12 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, and 2015, 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, and 8.2 inches of water applied plus spring precipitation in 2006, 2007, 2008, 2009, 2012, 2014, and 2015, 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 2017, seed yields were responsive to irrigation only in 2013 (Tables 4 and 5). In 2013, seed yields showed a quadratic response to irrigation with a maximum seed yield at 4 inches of water applied.

***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 2017, seed yields only responded to irrigation in 2013 (Tables 4 and 5). In 2013, seed yields increased with increasing irrigation up to the greatest level of 8 inches.

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, *Penstemon 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, *Penstemon cyaneus* and *P. pachyphyllus* responded to irrigation only in 2013, which had the lowest spring precipitation of the 7 years. From 2006 to 2017, *P. speciosus* showed a quadratic response to irrigation in 7 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 2006-2017, 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
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
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
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					
	2017	8-May	15-May	7-Jun	2-May	20-Jun	17-Jul

Table 3. Early season precipitation and growing degree-days at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2006-2017.

	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
				23-year average:
12-year average:	2.9	6.3	9.8	1207

Table 4. Native wildflower seed yield in response to irrigation rate (inches/season) in 2006 through 2017. Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Year	Irrigation rate 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
	Average	276.9	326.5	343.5	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
	Average	314.5	323.0	305.6	NS

Species	Year	Irrigation rate 0 inches	4 inches	8 inches	LSD (0.05)
		--------------- lb/acre --------------			
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
	Average	235.0	193.7	232.8	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
	Average	106.4	174.8	147.1	33.9

[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 $y = a + b \cdot x + c \cdot x^2$ in 2006-2017, and 4- to 11-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
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	19.5	-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		
Average	282.3	8.3		0.36	0.05	348.9	8

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		
Average	314.5	5.4	-0.8	0.03	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 2006-2017, and 4- to 11-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		
Average	221.6	-0.3		0.0004	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
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 7 years	2	3
P. cyaneus	no response in 6 out of 7 years, 4 inches in 2013 (drier year)	1	3
P. pachyphyllus	no response in 6 out of 7 years, 8 inches in 2013 (drier year)	1-2	3
P. speciosus	0 in cool, wet years, 4-8 in warm, dry years	1-2	3

2017 POTATO VARIETY TRIALS

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Introduction

New potato varieties were evaluated in 2017 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 2017 included the Tristate Russet Trial with 14 entries, the Oregon Statewide Russet Trial with 12 entries, the Preliminary Yield Russet Trial with 73 entries, the Oregon Statewide Specialty Trial of 5 colored skin and/or flesh potato varieties, the Western Region Specialty Trial of 11 colored skin and/or flesh potato varieties, the Preliminary Yield Specialty Trial of 7 colored skin and/or flesh potato varieties, the Oregon Statewide Chip Trial with 7 entries, and the Preliminary Yield Chip Trial with 18 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 2017 on Greenleaf silt loam, following winter wheat using sprinkler irrigation. Based on a soil test, 166 lb potassium/acre, 175 lb sulfur/acre, 9 lb manganese/acre, 3 lb copper/acre, and 4 lb boron/acre were broadcast in the fall of 2016, prior to planting of the wheat. The field was fumigated with 20 gal/acre of Telone® II and bedded on 36-inch row spacing in the fall of 2016. On April 11, 2017, 100 lb nitrogen/acre and 20 oz/acre of Admire® (imidacloprid) were shanked in the bed center.

Seed of all varieties was cut by hand into 2-oz seed pieces, treated with Maxim MZ dust, and stored briefly to suberize. Potato seed pieces were planted in single-row plots 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 Oregon Statewide Chip Trial, State Russet Trial, and the TriState Russet Early Trial were planted on April 13. The Regional Specialty Trial, Chip Preliminary Yield Trial, and the Russet Preliminary Yield Trial were planted on April 17. The State Specialty Trial and the Specialty Preliminary Yield Trial were planted on April 18.

All trials, except the preliminary yield trials, 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).

After planting, hills were re-formed over the rows with a Lilliston rolling cultivator. The herbicides Prowl® H_2O at 0.95 lb ai/acre, Dual Magnum® at 1.27 lb ai/acre, and Roundup® at 2 pt/acre were applied as a tank mix for weed control on April 25. The herbicides were incorporated by sprinkler irrigation with approximately 0.5 inch of water. Roundup at 2 pt/acre was applied again on May 8. Matrix® at 0.25 oz ai/acre was applied on June 9 through the sprinkler system. On June 17 and August 6, Bravo® at 1 pt/acre (0.75 lb ai/acre) was broadcast aerially.

Emergence started on May 20. 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 6 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 six sensors. The last irrigation was on September 5.

Fertilization during plant growth was based on petiole and soil solution tests taken on July 4, 11, 17, and 31. Based on the tissue and soil tests, a total of 60 lb nitrogen/acre and 53 lb potassium/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 16 and on August 23 the potatoes were harvested. For the other trials, the vines were flailed on September 19. The harvest dates for the other trials were September 25 for the Oregon Statewide Specialty and Preliminary Yield Specialty, September 27 for the Oregon Statewide Russet and Oregon Statewide Chip, and September 28 for the Preliminary Yield Russet Trial and the Preliminary Yield 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

Due to excessive precipitation in the winter of 2016-2017, the potatoes were planted 1 week to 10 days later than the ideal planting date of April 7. Excessive heat in July was detrimental to the crop, with daily maximum and minimum air temperatures higher than average.

Tristate Russet Trial

The clones Russet Burbank, AO7098-4, AO7088-6, AOR07821-1, AO7705-4, and AO8422-2Vrsto were among those with the highest total yields (Table 1). The clones AO7088-6, AO8422-4Vrsto, AO7098-4’, AO8422-2Vrsto, and AOR07821-1 were among the clones with the highest U.S. No. 1 yields.

A07088-6 and AO71012-4BF were among the clones with the highest specific gravity (measure of tuber solids) in this trial (Table 1). The tuber internal defects encountered were hollow heart and black spot bruise (Table 2). Observations on visual appearance at harvest can be found in Table 3.

Oregon Statewide Russet Trial

The clones OR12133-10, AOR10633-1, and AOR10140-1 were among those with the highest total yields (Table 4). AOR10633-1, OR12133-10, and AOR10140-1 were among the clones with the highest U.S. No. 1 yields.

AOR11018-2, AOR11217-3, and AOR10633-1 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 70 clones tested, 13 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.

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 2017: Oregon Statewide Specialty, Preliminary Yield Specialty, and Western Region Specialty.

Oregon Statewide Specialty Trial

The clones 'Red LaSoda' and POR14PG14-5 were among those with the highest total yield (Table 10). Red LaSoda had the highest yield of tubers over 14 oz, an undesirable trait. POR14PG22-3KK had the highest yield of tubers under 4 oz, followed by POR14PG14-5. POR14PG14-1 had the highest yield of cull tubers, due to sprouting. The three experimental clones had substantial sprouting at harvest (Table 12).

Clones POR14PG14-1 and POR14PG14-5 were among those with the highest tuber specific gravity. Tuber internal defects for the clones are listed in Table 11.

Preliminary Yield Specialty Trial

The variety Red LaSoda was among those with the highest total yield and yield of tubers over 14 oz (Table 13). Clones POR15PG036-3, POR15PG015-3, and POR15PG009-1 had high yields of cull tubers due to sprouting at harvest (Table 15). Clones POR15PG036-3, POR15PG034-1, and POR15NCKY021-2 had high yields of tubers under 4 oz. 'Yukon Gold' and two of the clones had internal brown spot (Table 14). Exterior appearance observations can be found in Table 15.

Western Region Specialty Trial

The clones Red LaSoda, 'Chieftain', AC03534-2R/Y, and CO05035-1PW/Y were among those with the highest total yield (Table 16). Red LaSoda had the highest yield of tubers over 14 oz, an undesirable trait. Clone AC03534-2R/Y had the highest yield of tubers under 4 oz.

All varieties and clones had the internal defect internal brown spot, except COA07365-4RY (Table 17). Exterior appearance observations can be found in Table 18.

Oregon Statewide Chip Trial

Clone AOR11470-1 had the highest total yield (Table 19). Clone AOR11470-1 also had the highest yield of tubers over 10 oz, an undesirable trait. Clone AOR11470-1 also had the highest specific gravity. Tuber internal defects for the clones are listed in Table 20. Clones AOR11470-1 and AOR12197-2 had substantial sprouting at harvest (Table 21).

Preliminary Yield Chip Trial

Clones AOR13136-4, NYOR14Q9-5, and ‘Snowden’ were among those with the highest total yield (Table 22). Snowden and NYOR14Q9-5 were among those with the highest yield of tubers more than 10 oz. Snowden, ‘Atlantic’, and AOR13125-9 were among the clones with the highest specific gravity. Tuber internal defects for the clones are listed in Table 23. Exterior appearance observations can be found in Table 24.

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Table 1. Tristate Russet Trial potato yield, grade, and processing quality, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety	Percent No. 1	Total yield	U.S. No. 1 Total	U.S. No. 1 >20 oz	U.S. No. 1 10 to 20 oz	U.S. No. 1 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	64.2	417.0	270.9	2.0	69.5	152.6	46.7	106.2	377.1	34.9	5.0	5.9	5.9	2.0	1.093	45.9	0.0
Russet Burbank	44.7	503.0	226.9	5.5	29.4	104.6	87.3	187.0	413.9	76.6	12.6	5.1	8.1	2.1	1.077	37.4	2.5
Russet Norkotah	76.0	393.3	300.3	2.3	76.7	144.4	76.9	26.6	326.9	63.1	3.4	5.3	6.1	1.9	1.075	37.7	2.5
A07088-6	83.7	478.2	400.3	0.0	77.7	225.6	97.1	25.0	425.2	50.0	2.9	5.8	6.8	1.6	1.097	50.6	0.0
A07098-4	73.4	492.3	357.8	0.0	46.7	189.8	121.4	56.0	413.8	67.4	11.2	5.4	7.6	1.9	1.080	41.4	0.0
A071012-4BF	74.1	412.7	309.1	0.0	60.8	159.2	89.1	23.8	332.9	61.8	18.1	5.4	6.3	1.6	1.102	43.9	0.0
A07705-4	57.0	447.9	257.5	0.0	2.2	88.0	167.3	12.0	269.5	167.1	11.4	3.4	11.0	1.6	1.081	40.0	0.0
A07769-4	78.2	393.2	308.7	0.0	47.2	154.4	107.0	18.9	327.6	63.4	2.2	5.3	6.1	1.6	1.090	41.2	0.0
A08422-2Vrsto	78.1	438.3	342.2	0.0	35.0	199.4	107.8	15.7	357.9	75.1	5.3	4.9	7.4	1.6	1.087	44.2	0.0
A08422-4Vrsto	90.4	410.6	371.8	0.0	119.2	182.1	70.6	7.3	379.1	29.1	2.4	6.4	5.3	1.6	1.090	49.4	0.0
A08510-1LB	54.0	261.2	142.3	0.0	2.6	48.2	91.5	10.6	153.0	100.8	7.5	3.3	6.6	1.5	1.095	48.9	0.0
A10021-5TE	72.1	409.5	296.0	7.2	103.6	130.9	54.3	51.7	347.6	50.5	11.3	6.0	5.6	2.0	1.090	50.5	0.0
AOR06576-1	71.0	409.5	291.1	0.0	15.1	146.5	129.4	28.6	319.7	84.2	5.7	4.1	8.3	1.8	1.086	46.3	0.0
AOR07821-1	74.3	448.0	332.6	2.1	60.1	156.7	113.9	28.3	360.9	86.2	1.0	4.5	8.4	1.7	1.094	43.8	0.0
Mean	70.8	422.5	300.5	1.4	53.3	148.7	97.2	42.7	343.2	72.2	7.1	5.1	7.1	1.7	1.0884	44.4	0.4
LSD (0.05)	9.2	77.9	75.1	NS	36.3	44.5	36.8	35.1	74.5	28.0	NS	0.7	1.5	0.1	0.0050	1.6	NS

Table 2. Tristate Russet Trial tuber internal defects, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

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	0.0	0.0
Russet Norkotah	0.0	0.0	0.0	0.0
A07088-6	0.0	0.0	0.0	0.0
A07098-4	0.0	0.0	0.0	0.0
A071012-4BF	0.0	0.0	0.0	0.0
A07705-4	0.0	0.0	0.0	0.0
A07769-4	0.0	0.0	0.0	0.0
A08422-2Vrsto	0.0	0.0	0.0	0.0
A08422-4Vrsto	0.0	2.5	0.0	0.0
A08510-1LB	0.0	0.0	0.0	5.0
A10021-5TE	0.0	0.0	0.0	0.0
AOR06576-1	0.0	0.0	0.0	0.0
AOR07821-1	0.0	0.0	0.0	0.0
Average	0.0	0.2	0.0	0.4
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, 2017. 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	K or D	Description
Ranger Russet	3D, 1d	3 curved, 1 Curved, 2 Irregular, 2 irreg., 1 Pointed, 3 bottleneck, 1 Bottleneck, 2 dumbbell, 1 growth cracks, 1 sprouts, 1 jelly end rot
Russet Burbank	4 D	3 Pointed, 1 pointed, 1 sprouts, 1 heart, 3 growth cracks, 1 knobs, 4 Irregular, 3 Dumbbell, 1 dumbbell, 1 Bottleneck, 1 bottleneck
Russet Norkotah	2k, 2K	3 irregular, 1 pointed
A07088-6	4K	2 folded bud end, 2 irregular, 2 growth cracks
A07098-4	3k, 1K	3 heart, 1 growth cracks, 3 irregular, 1 swollen lenticels, 1 bottleneck, 1 sprouts
A071012-4BF	3k, 1K	1 knobs, 2 irregular, 1 Pointed, 1 heart
A07705-4	3D, 1?	2 sprouts, 2 small, 2 pointed
A07769-4	2K, 2k	1 small, 1 pointed, 1 growth cracks
A08422-2Vrsto	1d, 2K,1k	2 heart, 1 irregular, 2 wedge shape, 1 pointed
A08422-4Vrsto	2k, 2K	1 heart, 2 growth cracks, 3 pointed, 1 wedge shape, 1 folded bud end
A08510-1LB	2d, 1D, 1?	4 small
A10021-5TE	2k, 2d	1 irregular, 2 alligator hide, 2 rough skin, 1 growth cracks, 2 folded bud end, 1 heart, 1 sprouts, 1 curved
AOR06576-1	3k, 1?	1 irregular, 2 pointed, 1 small
AOR07821-1	2k, 1D, 1d	3 pointed, 1 Pointed, 1 small, 1 irregular, 2 heart, 1 alligator hide

Table 4. Oregon Statewide Russet Trial potato yield, grade, and processing quality, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety	Percent No. 1	Total yield	U.S. No. 1 Total	U.S. No. 1 >20 oz	U.S. No. 1 10 to 20 oz	U.S. No. 1 6 to 10 oz	U.S. No. 1 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	71.6	507.4	361.7	15.8	113.1	156.7	76.2	105.1	466.8	40.5	0.0	7.4	5.7	1.8	1.0894	43.9	0.0
Russet Burbank	65.1	494.8	322.8	0.0	39.2	141.5	142.1	84.8	407.6	86.9	0.3	5.0	8.2	2.0	1.0803	36.9	12.5
Russet Norkotah	73.8	321.4	237.1	0.0	42.8	125.7	68.6	18.4	255.5	65.9	0.0	5.1	5.3	1.8	1.0853	39.4	0.0
AOR08540-1	73.3	508.7	374.6	0.0	64.1	184.7	125.7	37.3	411.9	94.3	2.5	5.0	8.4	1.8	1.0880	39.9	5.0
AOR11018-2	68.0	472.1	321.6	4.5	112.4	128.9	75.8	75.5	397.1	71.8	3.2	5.6	7.0	1.9	1.0873	48.5	0.0
AOR11141-2	72.3	438.8	317.2	0.0	46.5	134.9	135.7	18.8	335.9	94.8	8.1	4.4	8.2	1.5	1.0767	41.9	5.0
AOR10140-1	85.5	526.6	449.8	4.4	168.9	189.9	86.6	24.0	473.8	52.8	0.0	6.9	6.3	1.7	1.0800	42.3	0.0
AOR10204-3	64.2	449.0	292.3	2.1	59.4	134.9	95.9	97.2	389.5	59.5	0.0	5.7	6.5	1.8	1.0867	46.2	0.0
AOR11217-3	77.1	439.8	338.6	0.0	48.3	165.2	125.1	14.6	353.1	86.7	0.0	5.4	6.8	1.8	1.0810	48.1	0.0
OR12133-10	81.6	595.5	485.1	2.0	90.3	244.3	148.5	31.2	516.3	79.2	0.0	6.0	8.2	1.7	1.0814	41.3	0.0
AOR12144-1	45.7	294.8	134.0	0.0	0.0	34.1	100.0	5.5	139.5	154.9	0.3	3.1	7.8	1.7	1.0883	38.5	0.0
AOR10633-1	90.6	541.1	491.2	9.6	224.4	182.3	74.9	18.6	509.9	31.2	0.0	7.7	5.8	1.8	1.0850	46.9	2.5
Mean	72.4	465.8	343.8	3.2	84.1	151.9	104.6	44.2	388.1	76.5	1.2	5.6	7.0	1.8	1.0841	42.8	2.1
LSD (0.05)	7.9	81.1	73.1	NS	45.7	41.7	30.4	37.0	74.8	18.3	4.3	0.9	1.0	0.2	NS	2.5	NS

Table 5. Oregon Statewide Russet Trial tuber internal defects, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

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
AOR08540-1	0.0	0.0	0.0	0.0	0.0
AOR11018-2	0.0	0.0	0.0	0.0	0.0
AOR11141-2	0.0	0.0	0.0	0.0	0.0
AOR10140-1	0.0	0.0	0.0	0.0	0.0
AOR10204-3	0.0	0.0	0.0	0.0	0.0
AOR11217-3	0.0	0.0	0.0	0.0	0.0
OR12133-10	0.0	0.0	0.0	0.0	0.0
AOR12144-1	0.0	0.0	0.0	0.0	0.0
AOR10633-1	0.0	0.0	0.0	10.0	5.0
Mean	0.0	0.0	0.0	0.8	0.4
LSD (0.05)	NS	NS	NS	NS	NS

Table 6. Oregon Statewide Russet Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. 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	K or D	Description
Ranger Russet	3d, 1D	2 knobs, 4 curved, 4 growth cracks, 2 heart shape, 1 bottleneck
Russet Burbank	4D	4 curved, 4 irregular shape, 4 knobs, 4 pointed, 4 growth cracks
Russet Norkotah	3k, 1d	low yield, irregular shape, knobs, heart shape
AOR08540-1	3k, 1?	bottleneck, pointed, knobs, 2 curved, 2 growth cracks, chain
AOR11018-2	3d, 1k	3 bottleneck, 1 heart shape, 3 irregular shape, 1 growth cracks, 2 knobs, 1 Knobs
AOR11141-2	3D, 1d	4 sprouts, 4 chain, 1 knobs
AOR10140-1	2k, 1K, 1d	sprouts , irregular shape
AOR10204-3	2k, 2d	pointed, heart shape, 2 bottleneck, 2 Bottleneck
AOR11217-3	3k, 1K	small, bottleneck, growth cracks
OR12133-10	2K, 1d, 1k?	2 curved, 2 irregular shape, heart
AOR12144-1	4d	4 small
AOR10633-1	1k, 2K, 1d	4 growth cracks, 1 curved, 1 bottleneck

Table 7. Preliminary Yield Russet Trial yield, grade, and processing quality for selected varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety	Percent No. 1	Total yield	U.S. No. 1 Total	U.S. No. 1 >20 oz	U.S. No. 1 10 to 20 oz	U.S. No. 1 6 to 10 oz	U.S. No. 1 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	80.0	500.9	401.0	46.5	149.8	162.0	42.7	72.7	473.7	27.2	0.0	8.6	4.8	1.80	1.0886	45.4	0.0
Russet Burbank	69.2	450.9	311.9	0.0	51.9	131.8	128.2	45.0	356.9	94.0	0.0	18.4	7.9	1.96	1.0785	37.9	0.0
Russet Norkotah	81.0	360.6	292.1	0.0	84.8	110.9	96.4	15.9	308.0	52.7	0.0	19.4	5.2	1.75	1.0714	42.0	0.0
AOR12145-3	84.2	435.0	366.0	0.0	88.7	202.3	75.1	21.6	387.7	41.5	5.8	20.2	6.2	1.79	1.1047	46.6	0.0
AOR12149-1	86.2	453.7	391.0	0.0	166.9	155.1	68.9	18.0	408.9	44.8	0.0	21.0	5.6	1.83	1.0855	48.8	0.0
AOR12342-2	91.2	498.3	454.4	0.0	204.4	186.9	63.0	16.0	470.4	27.9	0.0	22.3	5.4	1.72	1.0970	49.9	0.0
AOR12344-21	84.3	556.6	469.4	0.0	109.4	203.2	156.7	19.5	488.8	67.7	0.0	19.6	7.7	1.64	1.0909	48.7	0.0
AOR12350-5	88.4	411.4	363.6	6.7	111.7	172.3	72.9	5.8	369.3	42.0	0.0	20.8	5.1	1.76	1.0819	51.3	0.0
AOR13011-1	91.9	593.3	545.3	6.6	199.7	262.0	77.0	14.8	560.1	33.2	0.0	22.0	6.6	1.65	1.0846	47.5	0.0
AOR13011-2	91.2	583.7	532.4	13.6	254.0	194.1	70.8	3.2	535.6	48.0	0.0	21.8	6.6	1.62	1.0827	45.0	0.0
AOR13018-5	95.3	462.5	440.9	0.0	166.0	204.9	70.1	2.9	443.8	18.7	0.0	22.0	5.2	1.58	1.0769	49.4	0.0
AOR13038-1	86.3	477.5	412.0	0.0	132.4	188.0	91.7	32.1	444.2	33.3	0.0	21.1	5.7	2.14	1.0928	53.3	0.0
AOR13082-6	86.0	593.1	509.9	0.0	142.2	237.5	130.2	10.1	520.0	73.1	0.0	20.1	7.9	1.88	1.0806	54.9	0.0
AOR13343-16	78.5	599.7	470.6	0.0	70.9	246.8	152.9	17.9	488.6	111.1	0.0	5.4	6.9	1.60	1.0977	47.5	0.0
OR14SP016-3	87.4	589.3	515.2	0.0	141.3	253.7	120.2	6.7	521.9	63.2	4.3	6.3	5.8	1.92	1.0799	44.7	0.0
AOR13064-2	75.2	562.3	422.8	0.0	59.6	179.5	183.7	6.5	429.3	133.0	0.0	4.9	7.1	1.75	1.0942	49.9	0.0
Average	84.8	508.0	431.2	4.6	133.4	193.2	100.0	19.3	450.4	57.0	0.6	17.1	6.2	1.77	1.0868	47.7	0.0

Table 8. Preliminary Yield Russet Trial tuber visual observations at harvest for selected varieties, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. 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	
Ranger Russet	d	growth cracks, Curved, heart shape
Russet Burbank	D	bottleneck, Curved, knobs, dumbbell
Russet Norkotah	k	heart shape
AOR12145-3	k	growth cracks
AOR12149-1	k	irregular shape
AOR12342-2	k	curved, irregular shaped
AOR12344-21	k	growth cracks, bottleneck
AOR12350-5	k	irregular shape
AOR13011-1	k	heart shape
AOR13011-2	K	heart shape
AOR13018-5	k	irregular shape, heart shape
AOR13038-1	k	heart shape, curved
AOR13082-6	K	small, pointed
AOR13343-16	k	small, irregular shape
OR14SP016-3	K	
AOR13064-2	k	pointed, irregular shape, bottleneck

Table 9. Preliminary Yield Russet Trial tuber internal defects, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

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	10.0	0.0	0.0	0.0	0.0
AOR12145-3	0.0	0.0	10.0	0.0	10.0
AOR12149-1	0.0	0.0	0.0	0.0	0.0
AOR12342-2	0.0	0.0	10.0	0.0	0.0
AOR12344-21	0.0	0.0	0.0	0.0	0.0
AOR12350-5	0.0	0.0	0.0	0.0	0.0
AOR13011-1	0.0	0.0	0.0	0.0	0.0
AOR13011-2	0.0	0.0	0.0	0.0	0.0
AOR13018-5	0.0	0.0	0.0	0.0	0.0
AOR13038-1	0.0	0.0	30.0	0.0	0.0
AOR13082-6	0.0	0.0	40.0	0.0	0.0
AOR13343-16	0.0	0.0	0.0	0.0	0.0
OR14SP016-3	0.0	0.0	0.0	0.0	0.0
AOR13064-2	0.0	0.0	0.0	0.0	0.0
Average	0.6	0.0	5.6	0.0	0.6

Table 10. Oregon Statewide Specialty Trial yield and grade of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Clone/Variety	Total yield	<1¾ inch	U.S. No. 1 <4 oz	U.S. No. 1 4 to 6 oz	U.S. No. 1 6 to 10 oz	U.S. No. 1 10 to 14 oz	U.S. No. 1 >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	369.6	1.0	60.3	78.5	116.8	69.8	29.8	13.9	0.4	14.3	5.4	5.6	1.1	1.0822
Red LaSoda	561.0	2.6	60.0	83.4	194.4	139.3	62.4	17.4	4.0	21.4	6.3	7.3	1.3	1.0759
POR14PG14-1	344.1	3.6	72.8	14.5	8.8	0.0	0.0	6.2	241.7	248.0	2.3	12.2	1.2	1.0879
POR14PG14-5	444.1	4.7	164.5	97.2	70.3	21.1	2.2	51.1	37.6	88.8	4.3	9.6	1.4	1.0912
POR14PG22-3KK	400.1	12.6	285.2	56.6	19.6	1.1	0.0	16.6	21.1	37.7	2.0	16.5	1.0	1.0817
Mean	423.8	4.9	128.6	66.1	82.0	46.3	18.9	21.0	61.0	82.0	4.1	10.3	1.2	1.0838
LSD (0.05)	131.9	5.8	47.8	28.3	54.3	46.5	29.6	20.6	40.2	31.6	1.6	2.9	0.2	0.0044

Table 11. Oregon Statewide Specialty Trial tuber internal defects of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Clone/Variety	Vascular discoloration	Hollow heart	Internal brown spot	Brown center	Black spot bruise
	--	-- %	--	--	--
Yukon Gold	0.0	0.0	7.5	0.0	0.0
Red LaSoda	2.5	0.0	7.5	0.0	0.0
POR14PG14-1	0.0	0.0	0.0	0.0	2.5
POR14PG14-5	0.0	0.0	0.0	0.0	0.0
POR14PG22-3KK	0.0	0.0	7.5	0.0	0.0
Mean	0.5	0.0	4.5	0.0	0.5
LSD (0.05)	NS	NS	NS	NS	NS

Table 12. Oregon Statewide Specialty Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. 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	K or D	Description
Yukon Gold	3K, 1d	1 scab, 1 greening
Red LaSoda	4d	growth cracks
POR14PG14-1	2d, 2D	3 sprouts, 1 Sprouts, mixed variety
POR14PG14-5	D	1 Sprouts, 1 sprouts, irregular shape, 2 rough skin, nice yellow flesh
POR14PG22-3KK	4D	2 Sprouts, 2 sprouts, 1 nice

Table 13. Preliminary Yield Specialty Trial yield and grade of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety/Clone	Total yield	U.S. No. 1 <1.75	<4 oz	4 to 6 oz	6-10 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	331.0	1.6	67.0	86.2	107.0	58.1	11.8	0.9	0.0	0.9	5.4	5.1	1.10	1.0840
Red LaSoda	627.9	2.8	104.0	107.4	214.2	124.2	67.3	10.8	0.0	10.8	6.7	7.7	1.24	1.0805
POR15NCKY021-2	385.6	5.4	251.6	55.5	1.9	0.0	0.0	5.4	71.2	76.6	2.1	14.9	1.35	1.0890
POR15PG034-1	299.1	10.4	253.9	19.8	4.1	0.0	0.0	14.1	7.3	21.3	1.8	13.7	1.04	1.0840
POR15PG036-3	403.8	13.2	249.6	5.8	0.0	0.0	0.0	61.3	87.1	148.4	1.4	23.9	1.82	1.0667
POR15PG015-3	431.4	9.0	133.1	22.6	3.8	0.0	0.0	24.9	247.0	271.9	2.2	16.3	1.04	1.0725
POR15PG009-1	396.0	10.4	67.2	1.7	0.0	0.0	0.0	7.6	319.4	327.0	1.7	18.8	1.10	1.0955
Mean	410.7	7.5	160.9	42.7	47.3	26.0	11.3	17.8	104.6	122.4	3.1	14.3	1.24	1.0817

Table 14. Preliminary Yield Specialty Trial tuber internal defects of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

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
Red LaSoda	0.0	0.0	0.0	0.0	0.0
POR15NCKY021-2	0.0	0.0	30.0	0.0	0.0
POR15PG034-1	10.0	0.0	0.0	0.0	0.0
POR15PG036-3	0.0	0.0	0.0	0.0	0.0
POR15PG015-3	0.0	0.0	50.0	0.0	0.0
POR15PG009-1	0.0	0.0	0.0	0.0	0.0
Mean	1.4	0.0	15.7	0.0	0.0

Table 15. Preliminary Yield Specialty Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. 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	
Red LaSoda	d	deep eyes, irregular shape
POR15NCKY021-2	D	sprouts
POR15PG034-1	k	mixed variety, white variety mixed in
POR15PG036-3	D	sprouts
POR15PG015-3	D	sprouts
POR15PG009-1	D	sprouts

Table 16. Western Region Specialty Trial yield and grade of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

			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	Twos + culls	Average tuber weight	No. of tubers /plant	Length/ width	Specific gravity
	----------	----------	----------	----------	cwt/acre	----------	----------	----------	----------	----------	oz		ratio	g cm^{-3}
Chieftain	517.1	1.3	60.2	141.1	234.7	71.3	4.8	17.7	1.3	19.0	5.8	7.4	1.20	1.0775
Red LaSoda	569.5	2.3	58.6	92.2	205.4	142.4	55.6	35.1	0.0	35.1	6.4	7.4	1.24	1.0781
COTX00104-6R	314.0	1.4	31.8	55.6	108.3	94.8	18.2	13.1	0.0	13.1	6.6	3.9	1.22	1.0761
PORTX03PG25-2R/R	281.0	4.8	225.3	49.9	5.2	0.0	0.0	22.5	0.6	23.1	1.9	12.1	2.11	1.0733
AC03534-2R/Y	513.5	11.3	313.7	161.2	38.0	0.0	0.0	67.9	0.6	68.5	2.5	16.8	1.08	1.0721
CO05035-1PW/Y	506.7	3.3	128.1	132.8	165.6	38.4	17.9	20.9	20.9	41.8	4.2	10.0	1.32	1.0809
COA07365-4RY	327.8	5.7	196.1	96.9	33.1	1.1	0.0	32.9	0.2	33.1	2.7	10.2	1.21	1.0775
NDTX059759-3RY/Y Pinto	361.3	1.6	144.1	114.3	82.4	17.8	2.6	2.4	0.0	2.4	3.7	8.2	1.23	1.0843
Yukon Gold	378.0	1.9	69.0	89.8	139.3	65.9	6.9	25.3	0.0	25.3	5.2	6.0	1.15	1.0849
A06336-2Y	435.8	4.0	167.5	174.0	88.7	4.8	0.0	37.6	0.0	37.6	3.3	10.8	1.47	1.0647
A06336-5Y	416.9	9.8	269.1	104.0	20.5	1.2	0.0	22.0	22.0	44.1	2.3	14.9	1.09	1.0778
Mean	420.1	4.3	151.2	110.2	101.9	39.8	9.6	27.0	4.2	31.2	4.1	9.8	1.3	1.0770
LSD (0.05)	79.6	3.2	32.6	37.3	36.6	25.2	18.1	25.7	10.7	30.2	0.5	2.0	0.12	NS

Table 17. Western Region Specialty Trial tuber internal defects of colored flesh clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Clone/Variety	Vascular discoloration	Hollow heart	Internal brown spot	Brown center	Black spot bruise
	%				
Chieftain	0.0	0.0	15.0	0.0	0.0
Red LaSoda	0.0	0.0	12.5	0.0	0.0
COTX00104-6R	0.0	0.0	5.0	0.0	0.0
PORTX03PG25-2R/R	0.0	0.0	2.5	0.0	5.0
AC03534-2R/Y	0.0	0.0	7.5	0.0	0.0
CO05035-1PW/Y	0.0	0.0	5.0	0.0	0.0
COA07365-4RY	0.0	0.0	0.0	0.0	5.0
NDTX059759-3RY/Y Pinto	0.0	0.0	10.0	0.0	0.0
Yukon Gold	0.0	0.0	16.7	0.0	0.0
A06336-2Y	0.0	0.0	3.3	0.0	0.0
A06336-5Y	0.0	0.0	5.0	0.0	0.0
Mean	0.0	0.0	7.5	0.0	0.9
LSD (0.05)	NS	NS	NS	NS	NS

Table 18. Western Region Specialty Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. 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	4 k	3 dull skin, growth cracks, irregular shape
Red LaSoda	3 D, 1 d	4 Irregular shape, 3 deep eyes, 2 folded bud end, growth crack
COTX00104-6R	4 d	2 oversize, 3 dull skin
PORTX03PG25-2R/R	3 K, 1 k	
AC03534-2R/Y	4 k	knobs, dull skin, 2 sprouts, chain tubers
CO05035-1PW/Y	2 D, 2 d	4 sprouts, 2 oversize, 2 scab, 2 greening, knobs
COA07365-4RY	3 k, 1 K	3 knobs, chain tubers
NDTX059759-3RY/Y Pinto	4 k	
Yukon Gold	2 k, 1 d	oversize, folded bud end, knobs, heart shape, growth cracks
A06336-2Y	2 d, 1 D	3 sprouts, greening, 2 chain tubers, irregular, folded, heart shape
A06336-5Y	4 D	4 Sprouts, chain tubers

Table 19. Oregon Statewide Chip Trial yield and grade, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety	Total yield	>10 oz	6 to 10 oz	4 to 6 oz	<4 oz	>4 inch	Two's	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	430.2	44.0	70.1	166.0	139.8	42.1	7.3	2.9	6.4	5.5	1.04	1.0958	33.3	7.5
Snowden	551.4	83.7	161.9	223.8	65.1	16.7	14.2	2.6	5.3	8.6	1.04	1.0899	33.2	12.5
AOR11484-2	455.1	39.1	105.3	221.2	84.7	18.2	4.7	0.0	6.1	6.2	1.04	1.0846	32.1	5.0
AOR11488-1	477.2	157.0	155.5	137.7	3.5	0.0	12.2	11.1	3.8	10.3	1.06	1.0899	30.8	15.0
AOR11470-1	643.6	233.7	187.2	96.8	2.6	0.0	104.4	18.8	3.3	16.1	1.06	1.1113	35.2	0.0
AOR12197-2	466.4	142.2	108.1	72.7	3.7	0.0	76.6	63.2	3.5	11.0	1.08	1.0887	33.8	5.0
AOR12197-4	455.7	120.8	155.6	161.0	14.4	0.0	1.5	2.4	4.0	9.4	1.05	1.0848	34.5	7.5
Mean	497.1	117.2	134.8	154.2	44.9	11.0	31.6	14.4	4.6	9.6	1.05	1.0921	33.3	7.5
LSD (0.05)	69.5	23.0	36.2	58.4	39.8	20.0	35.3	33.0	0.6	1.2	NS	0.0034	NS	NS

Table 20. Oregon Statewide Chip Trial tuber internal defects for selected clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety	Vascular discoloration	Hollow heart	Internal brown spot	Brown center	Black spot bruise
	%				
Atlantic	0.0	0.0	2.5	0.0	0.0
Snowden	0.0	0.0	0.0	0.0	0.0
AOR11484-2	0.0	0.0	0.0	0.0	0.0
AOR11488-1	0.0	0.0	5.0	0.0	0.0
AOR11470-1	0.0	0.0	0.0	0.0	0.0
AOR12197-2	0.0	0.0	0.0	0.0	0.0
AOR12197-4	0.0	0.0	0.0	0.0	0.0
Mean	0.0	0.0	1.1	0.0	0.0
LSD (0.05)	NS	NS	NS	NS	NS

Table 21. Oregon Statewide Chip Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. 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
Atlantic	2d, 2k	3 oversized, greening, folded, scab
Snowden	2k, 2K	1 oversized
AOR11484-2	2K, 2k	1 died early
AOR11488-1	1d, 2k, 1K	3 small, 1 few sprouts
AOR11470-1	4D	4 chain, 2 Sprouts, 2 sprouts
AOR12197-2	3k, 1D	3 sprouts, 2 knobs
AOR12197-4	4K	scab

Table 22. Preliminary Yield Chip Trial yield and grade, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety	Total yield	>10 oz	6 to 10 oz	4 to 6 oz	<4 oz	>4 inch	Two	Culls	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	545.8	246.3	190.5	56.4	44.8	105.1	0.0	7.8	7.7	5.9	1.03	1.0979	43.2	0.0
Snowden	606.2	172.9	237.0	125.3	71.0	65.7	0.0	0.0	6.5	7.7	1.03	1.0922	45.9	0.0
AOR13125-2	389.5	76.0	175.6	81.5	51.2	15.4	0.0	5.2	5.9	5.5	1.00	1.0852	45.1	0.0
AOR13125-9	483.1	62.0	163.9	138.6	118.6	0.0	0.0	0.0	4.7	8.5	0.97	1.1045	35.5	10.0
AOR13136-2	389.4	34.5	95.5	124.8	130.5	5.3	2.8	1.3	4.2	7.8	1.07	1.0756	34.5	10.0
AOR13136-4	614.8	136.0	201.9	143.2	112.1	73.7	14.4	7.2	5.2	9.8	1.21	1.0841	35.8	0.0
NYOR14Q9-5	602.0	263.6	197.7	78.3	52.0	73.4	3.2	7.1	7.3	6.9	1.03	1.0854	43.5	0.0
NYOR14Q9-9	575.6	88.7	216.4	182.0	88.5	18.9	0.0	0.0	5.2	9.1	1.07	1.0907	40.6	0.0
NYOR14Q12-1	505.1	49.7	167.9	127.2	140.7	5.7	19.5	0.0	4.3	9.7	1.03	1.0903	44.4	0.0
Mean	523.5	125.5	182.9	117.5	89.9	40.3	4.4		5.7	7.9	1.05	1.0895	40.9	2.2

Table 23. Preliminary Yield Chip Trial tuber internal defects for selected clones, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017.

Variety	Vascular discoloration	Hollow heart	Internal brown spot	Brown center	Black spot bruise
	--- % ---				
Atlantic	0	0	0	0	0
Snowden	0	0	0	0	0
AOR13125-2	0	0	0	0	0
AOR13125-9	0	0	0	0	0
AOR13136-2	0	0	0	0	0
AOR13136-4	0	0	0	0	20
NYOR14Q9-5	0	0	0	0	0
NYOR14Q9-9	0	0	0	0	0
NYOR14Q12-1	0	0	0	0	0
Mean	0.0	0.0	0.0	0.0	2.2

Table 24. Preliminary Yield Chip Trial tuber visual observations at harvest, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017. 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	
Atlantic	k	oversize
Snowden	k	
AOR13125-2	k	greening
AOR13125-9	k	greening
AOR13136-2	k	
AOR13136-4	k	
NYOR14Q9-5	K	
NYOR14Q9-9	k	
NYOR14Q12-1	k	

EVALUATION OF POTATO PEST MANAGEMENT PROGRAMS

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Introduction

A number of insect pests reduce yield and quality of potatoes throughout the Pacific Northwest (PNW), although their distribution and intensity of infestations vary by location and year. Unfortunately, the number of insect pests has been increasing in recent years. In the early 1990s, the major insect pests of potatoes in the PNW were limited to wireworms, Colorado potato beetles, aphids, and two-spotted spider mites. Other species that have emerged as pests more recently (since the mid-1990s) include thrips, cutworms, loopers and armyworms, potato tuberworm (2004), beet leafhopper (2005), potato psyllid (2011), and stink bug (2013), and potentially *Lygus* bug. This increase in pest species coupled with rapid changes in registered insecticides have severely complicated management of potato insects in the PNW.

Most importantly, the potato psyllid has emerged as a serious threat to PNW potato production because of its ability to be a vector of the bacterium that causes zebra chip disease. The pest and disease have fundamentally changed insect management strategies and have effectively ended traditional integrated pest management programs. Although the urgency regarding potato psyllid and zebra chip have receded slightly, they remain the cornerstone for pest management in potatoes because processors have virtually zero tolerance for zebra chip defects. Detection of potato psyllids at any level can trigger a season-long insecticide treatment program, especially for long-season potato cultivars. Consequently, many growers at risk of potato psyllid are designing their insect management programs around this one pest and fitting management of other insect pests around psyllid management strategies.

Given this situation, there is a critical need to develop and refine psyllid management within the context of overall insect pest management programs to ensure that potato production in the PNW remains viable and economically sustainable. Most insecticides with psyllid efficacy also have activity, and are currently used, against other pests, including aphids, thrips, and Colorado potato beetles. Therefore, it is critical to determine what insecticides would be most suitable for psyllid management and which would be suitable for other pests. This information will enable growers to make better informed choices regarding their insecticide selections and will help develop appropriate insecticide resistance management programs for potatoes in the PNW.

Our regional research team conducted a series of experiments to evaluate insecticides for psyllid management and their effect on other pest and beneficial insects and to assess different plot designs and sampling strategies to help improve the efficiency of psyllid research trials.

Open field insecticide trials with small versus large plots and different sampling schemes were conducted at Eltopia and Pasco, Washington and Ontario, Oregon. Sleeve cage trials to evaluate insecticides were conducted in Kimberly, Idaho and Hermiston, Oregon. Results of the Ontario trial are reported below.

Materials and Methods

A trial for determining the efficacy of the insecticides Agri-Mek® (abamectin), Brigade® (bifenthrin), Exirel® (cyazapyr), and Movento® (spirotetramat) was conducted at the OSU Malheur Experiment Station. The trial was arranged on a randomized complete block design with four replications of each treatment and plot size. Small plots were 4 rows or 12 ft by 25 ft. Large plots were 8 rows or 24 ft by 25 ft. 'Ranger Russet' potatoes were planted on April 24, 2017. Treatments were made on a 14-day interval: August 4, and 18, and September 1, 2017. Treatments were applied with a CO_2 powered backpack sprayer applying insecticides at 20 gal water/acre and 30 psi.

Table 1. Insecticides used in potato field trial at the Oregon State University, Malheur Experiment Station, Ontario, OR, 2017.

Treatment products	Active ingredient	Rate (fl oz/acre)	Timing
Check	-	-	-
Movento	Spirotetramat	5	ABC
Agri-Mek SC	Abamectin	3.5	ABC
Brigade	Bifenthrin	4	ABC
Exirel	Cyazypyr	13.5	ABC

Evaluations were made using two different sampling methods, as follows:

- Leaf samples were randomly selected from the middle canopy of plants in the interior rows of each plot, and placed in a 1-gal Ziploc bag. Samples were brought back to the lab for evaluation under magnification. Intense samples consisted of 20 leaves per plot and standard samples consisted of 10 leaves per plot.
- An inverted leaf blower with an organza fabric bag was used on the outside rows, and the contents of each sample were place into 1-gal Ziploc bags, and evaluated with the use of dissecting microscopes. Intense samples were collected over a 3-min interval and standard samples were collected over a 90-sec interval.

Sample collection began 3 days after the first insecticide application and every 7 days thereafter.

Results

Overall insect populations were relatively low. Few potato psyllids were detected in this trial. Results were comparable between small and large plot samples (see figures below). The more intensive sampling regimens detected more insects and mites and tended to have less variation than the standard sampling regimens.

There were no significant differences in numbers of adult potato psyllids among the treatments (Fig. 1). However, there were significant differences in potato psyllid eggs among treatments (Fig. 2). Agri-Mek did not have an effect on potato psyllid eggs as there was no difference between the Agri-Mek treatment and the untreated check. Egg numbers were significantly lower in the Brigade, Exirel and Movento treatments compared with the untreated check. The same pattern was observed with the potato psyllid nymphs (Fig. 3).

In large-plot samples, two-spotted spider mite populations were significantly lower in the Agri-Mek, Brigade, and Movento treatments than in either the Exirel treatment or the untreated check. In the small plots, Agri-Mek and Movento performed the best. Exirel and Brigade had significantly lower populations than the untreated check, but higher than either Agri-Mek or Movento.

Thrips populations also differed among treatments. In both the small and large plots, there were significantly more thrips in the Brigade treatment than in any of the other treatments, including the untreated check. Agri-Mek, Exirel, and Movento performed equally well; all treatments had significantly fewer thrips than the untreated check.

Although we observed some statistical differences among treatments for psyllid eggs and psyllid nymphs, their biological importance is uncertain. The differences were consistent between the large and small plots but the averages ranged from only 0 to 2.3 per sample. Many leaves had no psyllid eggs or nymphs. The trial results support other trial results showing that pyrethroids (e.g., Brigade) flare thrips populations.

Conclusions

Psyllid pressure was again surprisingly low in 2017. In open field trials, we observed minor, but statistically different treatment effects on psyllid eggs and nymphs, with Brigade, Exirel, and Movento tending to have lower numbers than the untreated check. However, Brigade, a synthetic pyrethroid, led to significantly higher numbers of thrips.

Brigade also significantly reduced populations of beneficial insects.

Sleeve cage trials conducted at other locations with *Liberibacter*-infected psyllids did not demonstrate that insecticides significantly reduced the transmission of *Liberibacter*. However, there was a trend for lower levels of zebra chip disease symptoms with Agri-Mek and Brigade. Additional replication of these tests would be needed to confirm these results.

Acknowledgments

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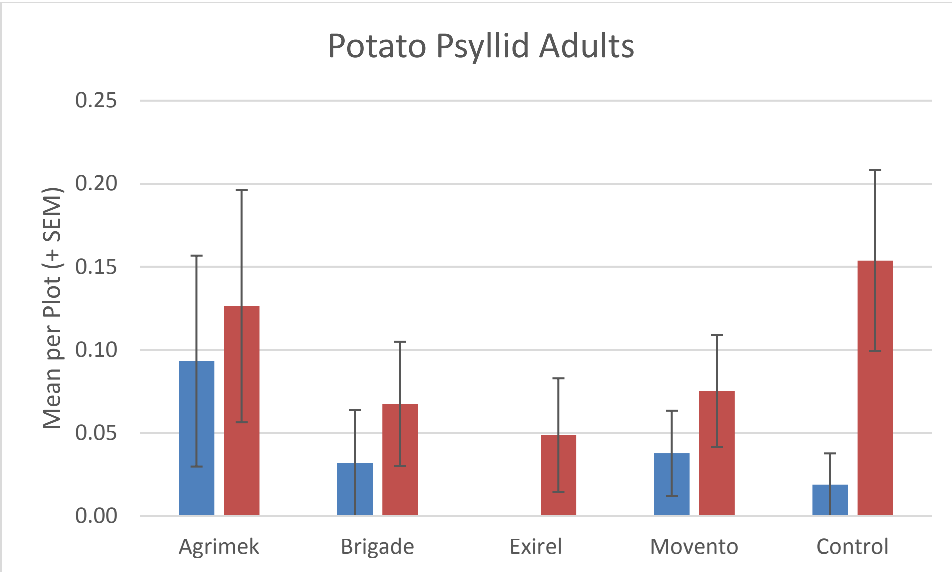

Figure 1. Mean number of adult potato psyllids by insecticide treatment in small plots (left) and large plots (right) in an efficacy trial at Ontario, OR, 2017. There were no statistical differences among the treatments.

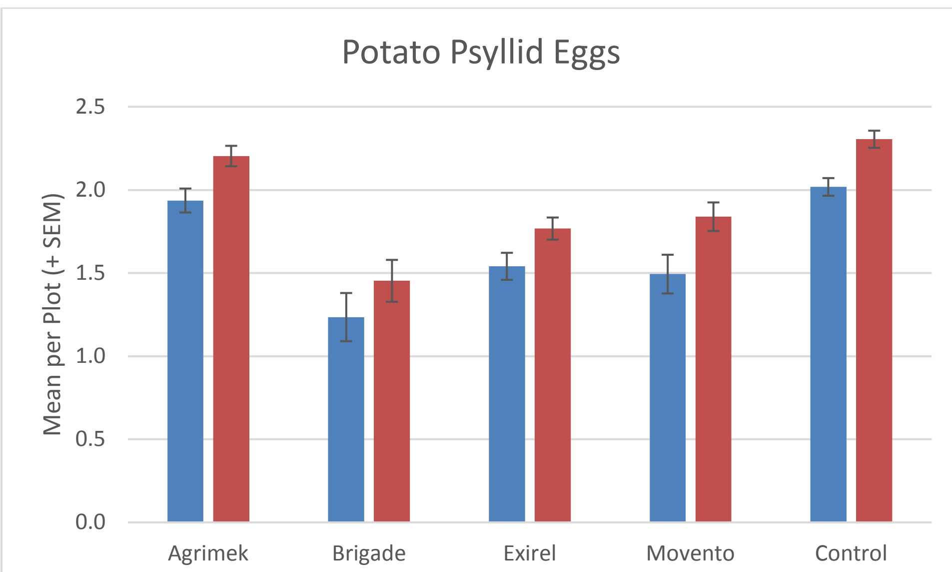

Figure 2. Mean number of potato psyllid eggs by insecticide treatment in small plots (left) and large plots (right) in an efficacy trial at Ontario, OR, 2017, Brigade, Exirel, and Movento had significantly fewer eggs than the untreated check or the Agri-Mek treatment.

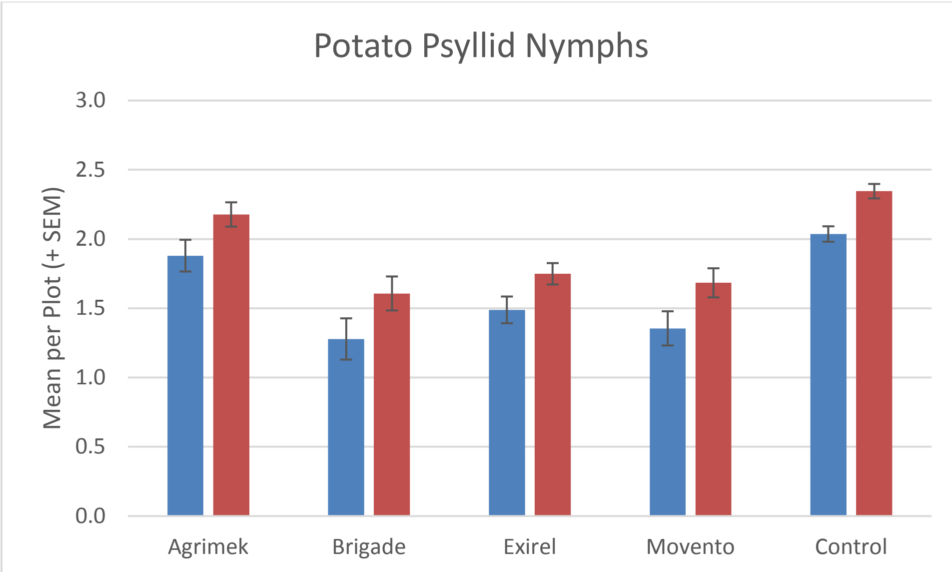

Figure 3. Mean number of potato psyllid nymphs by insecticide treatment in small plots (left) and large plots (right) in an efficacy trial at Ontario, OR, 2017. Brigade, Exirel, and Movento had significantly fewer nymphs than the untreated check or the Agri-Mek treatment.

EVALUATING POTENTIAL HORMETIC EFFECTS OF FOUR HERBICIDES ON SUGAR BEET

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Introduction

Hormesis is a term used by toxicologists to refer to a response of a subject to a sublethal dose of some kind of introduced agent that results in a positive reaction. It is a phenomenon that has been observed in humans, other animals, and plants. With plants, hormesis is the response to an environmental agent characterized by a low dose stimulation or beneficial effect and a high dose inhibitory or toxic effect. The use of this phenomenon might be beneficial to sugar beet production if the hormetic effect boosts sugar beet yield or better yet, boosts sucrose content without increasing sugar beet root biomass yield. Several herbicides and other chemicals have been found to cause hormesis in other crops.

Glyphosate at a nonlethal dose is actually registered for use on sugarcane to increase sugar content of plants prior to harvest. Another herbicide, sulfometuron (Oust®), which is a Group 2 herbicide, has been shown to increase sugar content in sugarcane when applied at rates ranging from 0.14 to 0.28 oz ai/acre. Because sugar beet is known to be extremely sensitive to sulfometuron, some other Group 2 herbicide could be explored with sugar beet. Several Group 4 growth regulator herbicides including 2,4-D, MCPA, and 2,4-DP have been used for growth stimulation of various crops, and have even improved the color of certain red potato varieties. There are many Group 2 and Group 4 herbicides that are commonly used for weed control in crops grown in Idaho and Oregon. The potential to increase sucrose content without increasing sugar beet root biomass could be of great benefit to the sugar beet industry.

The objective of this study was to evaluate multiple herbicides applied at sublethal rates towards the end of the growing season to determine if any of these products possess the potential for hormesis effects on sugar beet. The hormetic response will be determined by measuring sugar beet yield, sucrose content, and quality in response to the herbicides applied at various rates.

Materials and Methods

Sugar beet field studies were initiated during summer 2017 at the Malheur Experiment Station, Ontario, Oregon and the University of Idaho, Kimberly Research and Extension Center, Kimberly, Idaho, in fields previously planted to wheat. Production practices typical for each area were followed as closely as possible. The primary difference between growing practices at Malheur and Kimberly was surface furrow irrigation at Malheur and sprinkler irrigation at Kimberly.

Hybrid 27RR20 sugar beet seed was planted on April 21 at Malheur, while Holly hybrid SX1534RR sugar beet seed was planted on April 17 at Kimberly. The trials had factorial designs (4 herbicides at 4 rates each) arranged in randomized complete blocks with 6 replications. An untreated check was included. Weeds were controlled by applying glyphosate at 1.13 lb ae/acre plus ammonium sulfate at 2.5% v/v at the 2-leaf stage (May 3 at Malheur and May 16 at Kimberly) and at the 6-leaf stage (May 19 at Malheur and May 27 at Kimberly). The application at the 6-leaf stage included Outlook at 0.98 lb ai/acre. All other production practices including fertilization, irrigation, and preventative sprays for insects and diseases followed standard local practices.

Herbicide treatments to induce hormetic effects were applied on August 29 at Malheur and August 20 at Kimberly using a CO_2-pressurized backpack sprayer (Tables 1 and 2). Roots were harvested on September 19 at Malheur and October 9 at Kimberly. Percent sugar content and other sugar yield variables were determined at the Amalgamated Sugar Factory in Paul, Idaho. Data were subjected to analysis of variance using SAS and means compared using protected LSD at P = 0.05% level of confidence.

Results and Discussion

At the Malheur Experiment Station visible plant injury ranging from 5 to 20% was observed at 7 days after herbicide application on plants treated with Starane® Ultra at 0.8 fl oz/acre. Visual injury also was observed at the Kimberly site ranging from 10 to 27% at 7 days after treatment. Starane Ultra (fluroxypyr) and Defendor® (florasulam) applied at 0.8 and 0.4 fl oz/acre (10% of the 1X rate) had the most injury at Kimberly.

Sugar beet yield (52.2 to 58.1 ton/acre) and root conductivity (0.79 to 0.89 mmhos) were similar across treatments at Malheur (Table 1). Nitrate content and the estimated recoverable sugar varied widely across treatments. Application of Matrix® (rimsulfuron) at 0.001 to 0.01 oz/acre increased sucrose content by about 5% at Malheur, whereas MCPA at 0.00114, or Starane Ultra at 0.0008 to 0.008 fl oz/acre increased sucrose content by about 2% compared to the untreated check (Table 1).

No statistically significant differences were observed for any of the variables at Kimberly (Table 2). At Kimberly, application of Matrix at 0.001 oz/acre (0.1% of 1X) and MCPA at 0.114 fl oz/acre (1% of 1X) had improved sucrose content, though not statistically different from the check (Table 2).

The differences in results at the two sites may be related to the time lag between application and root harvest. Sugar beet was harvested 21 days after herbicide application at Malheur compared to 50 days at Kimberly. Studies in other crops have shown a decline in hormesis effects after 30 days of treatment. Follow-up studies in 2018 will be harvested not later than 30 days after treatment.

Disclaimer: products used in this study are for experimental purpose only and NOT registered for use in sugar beet production.

Table 1. Sugar beet yield, quality, and recoverable sucrose in response to various herbicides tested for possible hormesis effects at the Malheur Experiment Station, Ontario, OR, 2017.

Treatment[z]			Conductivity	Nitrate		Sucrose		Clean root yield	ERS [x]	
Rate			mmhos	ppm		%		t/acre	lb/acre	
Check	--		0.82	371	a-d[y]	14.3	bcd	53.4	12,476	abc[w]
Rimsulfuron	0.1	oz/acre	0.79	323	b-f	14.3	bcd	56.5	13,568	a
Rimsulfuron	0.01	oz/acre	0.84	281	ef	14.7	ab	53.9	13,208	a
Rimsulfuron	0.001	oz/acre	0.87	299	def	15.0	a	54.5	13,524	a
Rimsulfuron	0.0001	oz/acre	0.87	395	abc	13.8	cd	56.2	12,853	ab
Florasulam	0.4	fl oz/acre	0.88	249	f	13.0	e	53.3	11,375	c
Florasulam	0.04	fl oz/acre	0.85	298	def	13.7	d	56.1	12,679	ab
Florasulam	0.004	fl oz/acre	0.95	411	ab	14.2	bcd	57.2	13,232	a
Florasulam	0.0004	fl oz/acre	0.81	310	c-f	14.4	abc	52.8	12,746	ab
MCPA	1.14	fl oz/acre	0.78	337	b-e	14.1	bcd	54.0	12,794	ab
MCPA	0.114	fl oz/acre	0.83	344	b-e	14.3	bcd	54.6	13,013	ab
MCPA	0.0114	fl oz/acre	0.83	341	b-e	14.1	bcd	54.9	12,945	ab
MCPA	0.00114	fl oz/acre	0.82	290	def	14.6	ab	55.3	13,566	a
Fluroxypyr	0.8	fl oz/acre	0.93	459	a	12.6	e	58.1	11,921	bc
Fluroxypyr	0.08	fl oz/acre	0.89	305	def	14.3	bcd	53.7	12,642	ab
Fluroxypyr	0.008	fl oz/acre	0.87	350	b-e	14.4	abc	56.2	13,348	a
Fluroxypyr	0.0008	fl oz/acre	0.79	355	b-e	14.6	ab	52.2	12,775	ab
LSD (0.05)	Herbicide		NS	NS		0.3		NS	791	
	Dose		NS	NS		0.3		NS	791	
	Herbicide x dose		NS	98.5		0.7		NS	NS	

[z] Rimsulfuron = Matrix SG; florasulam = Defendor; MCPA = Sword; fluroxypyr = Starane Ultra.
[y] Treatment means followed by the same letter within the column are not significantly different according to Fisher's protected least significant difference (LSD) $P \leq 0.05$.
[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) $P \leq 0.05$.

Table 2. Sugar beet yield, quality, and recoverable sucrose in response to various herbicides tested for possible hormesis effects at the Kimberly Research and Extension Center, Kimberly, ID, 2017.

Treatment[z]			Conductivity	Nitrate	Sucrose	Clean root yield	ERS [x]
Rate			mmhos	ppm	%	t/acre	lb/acre
Check	--		0.69	233	14.10	47.9	12,248
Rimsulfuron	0.1	oz/acre	0.62	174	14.00	50.5	12,806
Rimsulfuron	0.01	oz/acre	0.72	251	14.12	54.2	13,985
Rimsulfuron	0.001	oz/acre	0.68	267	14.64	48.4	12,689
Rimsulfuron	0.0001	oz/acre	0.66	279	13.56	51.2	12,508
Florasulam	0.4	fl oz/acre	0.74	229	13.09	43.7	10,087
Florasulam	0.04	fl oz/acre	0.67	286	13.42	54.1	13,047
Florasulam	0.004	fl oz/acre	0.67	254	13.88	49.7	12,405
Florasulam	0.0004	fl oz/acre	0.72	189	12.91	47.8	10,770
MCPA	1.14	fl oz/acre	0.66	262	13.49	51.8	12,588
MCPA	0.114	fl oz/acre	0.71	227	14.43	51.0	13,092
MCPA	0.0114	fl oz/acre	0.66	268	13.61	52.7	13,188
MCPA	0.00114	fl oz/acre	0.65	278	13.31	48.2	11,632
Fluroxypyr	0.8	fl oz/acre	0.78	256	12.53	46.7	10,249
Fluroxypyr	0.08	fl oz/acre	0.69	254	13.73	51.4	12,582
Fluroxypyr	0.008	fl oz/acre	0.67	226	14.15	48.9	12,430
Fluroxypyr	0.0008	fl oz/acre	0.66	192	14.19	49.3	13,053
LSD (0.05)	Herbicide		NS	NS	NS	NS	NS
	Dose		NS	NS	NS	NS	NS
	Herbicide x dose		NS	NS	NS	NS	NS

[z] Rimsulfuron = Matrix SG; florasulam = Defendor; MCPA = Sword; fluroxypyr = Starane Ultra.
[x] ERS = Estimated recoverable sucrose.

SUGAR BEET RESPONSE TO DUAL MAGNUM® APPLICATION TIMING FOR YELLOW NUTSEDGE CONTROL

Joel Felix and Joey Ishida, Malheur Experiment Station, Oregon State University, Ontario, OR, 2017

Introduction

Irrigation and prevailing warm growing conditions provide ideal conditions for yellow nutsedge and other weeds to flourish in the Treasure Valley of eastern Oregon and southwestern Idaho. Weed control is an essential component of sugar beet production. Yellow nutsedge continues to be one of the most problematic weeds in some Treasure Valley fields; it presents a crop production challenge if not effectively managed in all crops grown in a rotation.

Yellow nutsedge populations can expand and contract in individual fields based on a variety of environmental and management factors. Given its perennial nature, yellow nutsedge remains a problem once it produces mature tubers in a field. Production of tubers makes control of yellow nutsedge difficult because tubers can persist in the soil for 3-5 years. Therefore, timely application of effective herbicides for each successive crop in a rotation is critical in the management of yellow nutsedge.

Because of early crop sensitivity, the current Dual Magnum® label only allows for its postemergence application after the sugar beet plants are at the first true leaf stage. At this stage, yellow nutsedge may have already emerged, and Dual Magnum does not control weeds already emerged, including yellow nutsedge. Therefore, the use of Dual Magnum and Outlook® as postemergence herbicides tank-mixed with glyphosate has largely failed to reduce yellow nutsedge in sugar beet fields.

Onion growers secured an indemnified label for Dual Magnum application to control yellow nutsedge the summer-fall preceding onion. The objective of this study was to evaluate a similar approach in which Dual Magnum would be applied and incorporated in the soil during mid-August to early September of the year preceding sugar beet.

Materials and Methods

A field study was initiated during fall 2016 in a growers' 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. The wheat stubble was flailed and the field was irrigated, disked, ripped, and rototilled in August 2016. 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 1, 2016 and the field was immediately moldboard plowed and disked to incorporate the herbicides in the soil. Post-plowing treatments were applied on September 14 and immediately disked into the soil. Fall fertilizer was broadcast on September 12, 2016 based on soil analysis. On October 18, 2016, the field was fumigated with Telone®C-17 at 18 gal/acre (1,3 dichloropropene 81.2% plus chloropicrin 16.5%) and simultaneously bedded on a 22-inch bed centers.

Seed of sugar beet hybrid 27RR20 was planted on April 21, 2017. The insecticide terbufos was applied on April 25 at 1.11 lb ai/acre (Counter® 15G at 7.4 lb/acre). Dual Magnum at the pre-emergence timing was applied on April 28. All plots (except the untreated check) were sprayed with glyphosate at 32 fl oz/acre plus Outlook at 21 fl oz/acre on May 19, 2017. Fertilizer was applied according the soil test results. Preventative sprays for diseases and insects were applied aerially by a commercial contractor. Otherwise all production practices including irrigation followed local production practices. Weed control and sugar beet injury were evaluated subjectively on May 4 based on 0 to 100% scale; where 0% = no weed control or crop injury and 100% = complete weed control or complete crop kill.

Plant tops were flailed and sugar beets were hand-harvested on September 20, 2017 from the two center rows of each plot. Sugar beet root weight from each plot was corrected for tare to estimate yield. Analysis for percent sucrose content and other sugar beet quality variables were conducted on September 25 at the Amalgamated Sugar Factory in Paul, Idaho. Data were subjected to analysis of variance using SAS and means compared using protected LSD at $P = 0.05\%$ level of confidence.

Results and Discussion

Sugar beet emergence was observed on May 2, 2017. Evaluation on May 4 indicated yellow nutsedge control ranging from 13 to 97% (Table 1). Plots treated with Dual Magnum at 1 or 1.33 pt/acre followed by moldboard plowing and disking had the lowest control. Application of Dual Magnum at 0.5 or 1 pt/acre after moldboard plowing and disking provided the best yellow nutsedge control at 95 and 97%, respectively. Evaluation during mid-season following glyphosate application when sugar beet plants were at the 2-leaf stage indicated 50 to 90% yellow nutsedge control across herbicide treatments (data not shown).

Dual Magnum treatments did not cause visible sugar beet foliar injury and did not reduce root yield or harvested root yield (Table 1). Similarly, there were no effects on percent sucrose content, nitrate (ppm), root conductivity, or the estimated recoverable sugar (ERS). Sucrose content ranged from 13.7 to 14.7% across treatments. Root conductivity ranged from 0.83 to 1 mmhos across treatments while nitrate content was 383 to 539%. Root yield ranged from 53.5 to 58.2 tons/acre across treatments. The estimated recoverable sugar ranged from 12,299 to 14,160 lb/acre.

It is not clear if the lack of sugar beet injury was influenced by the uncharacteristically high snow during winter 2016 and early spring precipitation. The increased moisture may have helped to move the herbicides below the top soil layer and mitigated the injury to emerging sugar beet seedlings. A follow-up study to confirm these results will be conducted in 2018 following the same procedures. If these results are confirmed, the data will be used to petition the EPA for a Dual Magnum label for application the fall preceding sugar beet.

Disclaimer: products used in this study are for experimental purpose only and NOT labeled for application the fall preceding sugar beet production.

Table 1. Yellow nutsedge control and sugar beet yield in response to Dual Magnum applied at different timeings at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2016-2017.

Treatment [z]	Rate/acre	Timing [y]	Y. nutsedge control	Sucrose	Clean root yield [x]		ERS [w]	
			%	(%)	(ton/acre) [v]		(lb/acre) [v]	
Fumigation			2.5 e	14.53	26.8	b	6539	b
Dual Magnum	1 pt	Fall/plow	12.5 de	14.44	57.5	a	13805	a
Dual Magnum	1.33 pt	Fall/plow	30.0 b	14.34	59.2	a	14160	a
Dual Magnum + EPTAM	1 pt 7 pt	Fall/plow	27.5 bc	14.72	55.5	a	13507	a
Dual Magnum + EPTAM	1.33 pt 7 pt	Fall/plow	21.3 bcd	14.20	56.6	a	13269	a
Dual Magnum + EPTAM fb Dual Magnum	0.5 pt +7 pt 0.5 pt	Fall/surface POST	94.5 a	14.46	55.6	a	13097	a
Dual Magnum + EPTAM	1 pt 7 pt	Fall/surface	97.3 a	14.64	58.2	a	13930	a
Dual Magnum fb Dual Magnum	0.5 pt 0.5 pt	Fall/plow POST	21.3 b	13.65	57.5	a	12955	a
Dual Magnum	0.75 pt	PRE	31.3 b	14.27	53.5	a	12299	a
Roundup + Outlook	22 fl oz 21 fl oz	POST	15.0 cde	14.35	56.4	a	13276	a
LSD (0.05)			14.1	NS	11.2		3021	
***P* > F**			0.0001	0.6743	0.0001		0.0013	

[z] fb = followed by

[y] Fall/plow = Treatments applied fall of 2016 preceding sugar beet; Fall/surface = treatments applied after soil tillage and disked in the soil twice during fall of 2016; PRE = herbicide applied immediately after sugar beet planting. POST = herbicide applied in season to sugar beet at the 2-leaf stage.

[x] Root yield was tared.

[w] ERS = Estimated recoverable sucrose.

[v] Means within a column followed by the same letter are not significantly different according to Fisher's protected least significant difference (LSD) $P \leq 0.05$.

SOYBEAN PERFORMANCE IN ONTARIO IN 2017

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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 for animal nutrition, 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-improving qualities 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 2017 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 2017 trial was conducted on Owyhee silt loam soil previously planted to wheat. In the fall of 2016, the field was disked twice, moldboard plowed, groundhogged twice, and bedded to 30-inch rows. On May 18, 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 19 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. The field was furrow irrigated once per week.

Plant height in each plot was measured on July 25. Each plot was evaluated for lodging and seed shatter on October 4. 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 from October 11-12 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

Yields in 2017 averaged 61 bu/acre and ranged from 44 bu/acre for selection number 128 to 70 bu/acre for selection number 103 (Table 1). None of the 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.

Summary

High 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

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Table 1. Performance of soybean cultivars in 2017. Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on the next page.

No.	Cross	Interm. sel.	Selection	Yield	Height	Lodging	Seed weight
				bu/acre	cm	0-10	seeds/lb
103	M92-220	311	35-6-10	69.6	104.1	2.8	2,875
40	M92-330	M16	19-6-10	67.1	104.8	5.8	2,312
41	M92-330	M16	19-7-10	66.9	108.0	4.3	2,461
95	M92-220	305	31-8-10	66.1	102.2	3.0	2,712
42	M92-330	M16	19-8-10	65.8	104.8	6.3	2,317
122	M92-314	608	41-3-10	65.6	108.6	5.8	2,329
43	M92-330	M16	19-9-10	65.1	105.4	6.8	2,624
117	M92-314	601	40-3-10	65.0	108.6	5.3	2,460
18	M92-330	M1	11-3-10	64.8	104.8	6.3	2,398
29	M92-330	M9	15-3-10	64.6	104.8	6.3	2,389
23	M92-330	M4	14-3-10	64.5	99.7	4.3	2,343
69	M92-085	107	24-1-09	63.8	102.9	2.5	2,896
30	M92-330	M12	16-8-10	63.4	108.0	6.8	2,378
32	M92-330	M13	17-4-10	63.3	106.7	5.0	2,436
58	M92-085	101	20-7-10	63.2	100.3	4.3	2,334
25	M92-330	M4	14-5-10	63.1	99.1	5.3	2,326
26	M92-330	M4	14-8-10	63.0	105.4	5.3	2,401
86	M92-220	303	30-1-10	62.9	106.0	5.3	2,880
66	M92-085	106	23-6-10	62.6	106.7	5.0	2,428
109	M92-220	312	36-7-10	62.6	104.8	2.3	2,826
96	M92-220	307	32-3-10	62.5	106.0	2.5	2,744
39	M92-330	M15	18-8-10	61.9	106.7	4.5	2,340
44	M92-330	M16	19-10-10	61.9	107.3	3.3	2,412
94	M92-220	305	31-5-10	61.8	101.0	3.3	2,892
56	M92-085	101	20-4-10	61.7	107.3	3.8	2,392
36	M92-330	M15	18-2-10	61.6	101.6	5.3	2,462
111	M92-220	312	36-10-10	61.6	107.3	4.3	2,356

Table 1. Continued from previous page. Performance of soybean cultivars in 2017. Malheur Experiment Station, Oregon State University, Ontario, OR.

No.	Cross	Interm. sel.	Selection	Yield	Height	Lodging	Seed weight
				bu/acre	cm	0-10	seeds/lb
89	M92-220	303	30-5-10	61.3	104.8	3.5	2,717
113	M92-220	313	37-9-10	61.3	109.2	4.5	2,528
16	M92-330	M1	11-21-09	61.2	104.8	4.0	2,815
35	M92-330	M13	17-10-10	61.1	106.7	3.8	2,377
33	M92-330	M13	17-5-10	61.0	107.3	3.8	2,451
24	M92-330	M4	14-4-10	60.8	104.1	4.5	2,389
77	M92-085	107	24-3-10	60.3	106.0	5.0	2,291
51	M92-085	101	20-11-09	60.0	102.2	3.8	2,809
31	M92-330	M12	16-10-10	59.8	106.7	6.0	2,430
108	M92-220	312	36-6-10	59.4	106.7	4.3	2,911
21	M92-330	M2	12-7-10	59.2	108.0	4.5	2,429
53	M92-085	101	20-11-09	59.1	99.1	3.3	2,901
88	M92-220	303	30-3-10	59.1	106.0	3.5	2,727
93	M92-220	305	31-3-10	59.1	102.9	3.5	2,773
50	M92-085	101	20-7-09	58.8	106.0	5.0	2,876
19	M92-330	M2	12-1-10	58.7	101.0	6.8	2,452
72	M92-085	107	24-2-09	58.7	99.7	3.5	2,943
55	M92-085	101	20-1-10	58.6	106.0	4.8	2,307
63	M92-085	103	21-12-10	58.5	102.9	6.0	2,528
91	M92-220	305	31-1-10	58.5	104.1	6.0	2,775
6	Korada		8-2-10	57.1	104.8	7.0	2,630
101	M92-220	309	34-1-10	57.0	102.9	2.5	2,766
38	M92-330	M15	18-7-10	56.5	102.9	6.0	2,403
71	M92-085	107	24-2-09	55.6	108.0	5.3	2,923
57	M92-085	101	20-6-10	54.2	103.5	4.8	2,462
102	M92-220	309	34-11-10	53.0	106.0	4.8	2,838
125	OR-6	905	42-8-10	48.2	97.2	9.0	2,783
128	OR-6	909	43-10-10	43.9	98.4	9.8	2,885
Average				60.8	104.6	4.8	2579
LSD				8.4	NS	2.2	169.2

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.
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
Fierce	flumioxazin + pyroxasulfone	Valent Corporation
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
Sencor	metribuzin	Bayer CropScience
Sequence	glyphosate + s-metolachlor	Syngenta
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
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
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	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	DuPont
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
M-Pede	potassium salts of fatty acids	Gowen 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
Propulse	flupyram + prothioconazole	Bayer CropScience

APPENDIX B. INSECTICIDES, FUNGICIDES, AND NEMATICIDES (continued)

Trade name	Common or code name	Manufacturer
Quadris Opti	azoxystrobin	Syngenta
Radiant	spinetoram	Dow AgriSciences
Requiem	*Chenopodium ambrosioides*	Bayer CropScience
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
Venom	dinotefuran	Valent
Verimark	cyantraniliprole	DuPont
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, 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, 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*