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

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

Introduction

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

Materials and Methods

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

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

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

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

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

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

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

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

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

first two single rows in each plot had the number of leaves counted and the diameter measured. After harvest, the onions from each plot were evaluated out of storage monthly starting in mid-November.

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

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

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

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

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

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

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

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

Results and Discussion

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

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

Both dry scales and incomplete scales were detected starting in early August (Table 5). The percentage of bulbs with incomplete scales with or without dry scales increased over time through the November evaluation for both varieties. Incomplete and dry scales became prominent by 21 September in 2018 (Table 5). The percentage of bulbs with internal decomposition in 2018 was very low (Table 6). For Joaquin, bulbs with bacterial decomposition

were found only on November 20 at 1% and bulbs with *Fusarium proliferatum* were found only on September 21 at 0.5%. For Granero, bulbs with bacterial decomposition were found only on July 12 at 1%. No other type of internal decomposition was found.

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

Acknowledgements

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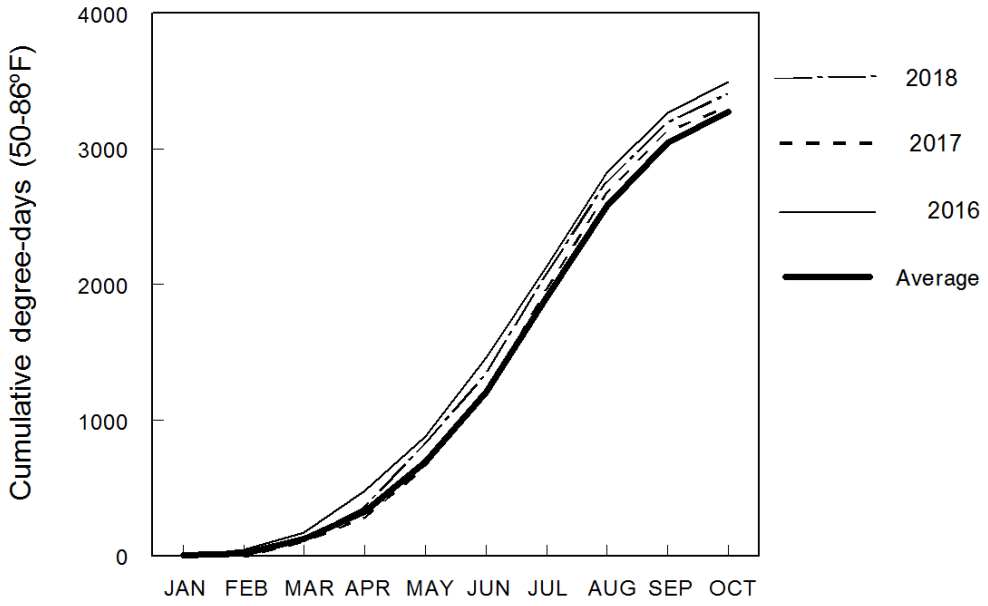

Figure 1. Cumulative growing degree-days (50-86°F) for 2016-2018 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

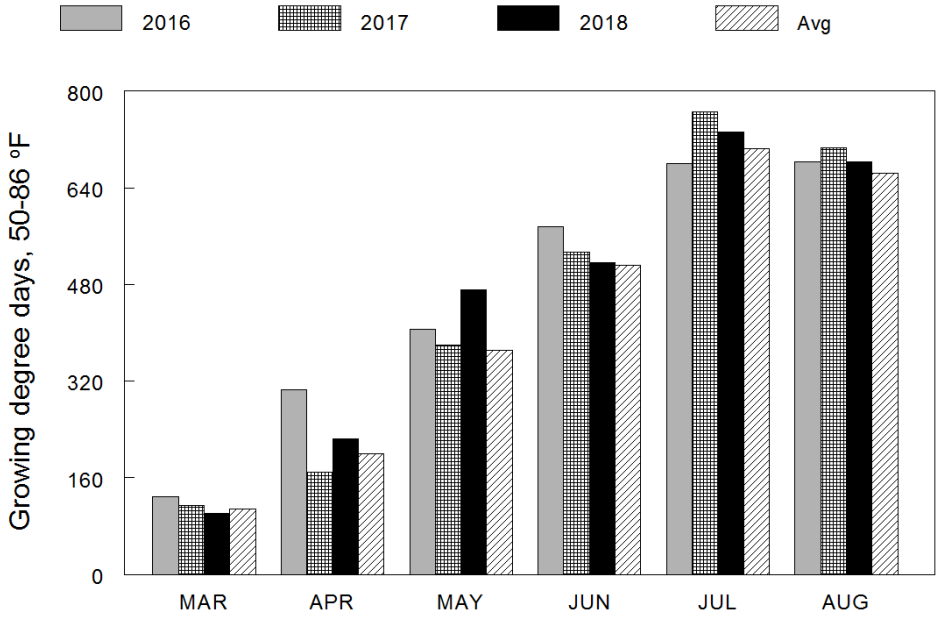

Figure 2. Monthly growing degree-days (50-86°F) for 2016-2018 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

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

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

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

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

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

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

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

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