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

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Introduction

In the past few years in the Pacific Northwest, there has been an increase in internal bulb decomposition of one or more scales. Unlike neck rot or plate rot, this internal decomposition is difficult to detect externally, resulting in bulb quality control issues in marketing. The internal decomposition is often associated with one or more scales that do not finish forming completely into the neck, resulting in small gaps close to the neck, and also associated with dry scales extending into the bulb from the neck. The last few years have been unusually warm, suggesting that excessive heat could be associated with the problems of incomplete scale, dry scale, and internal decomposition. This trial sought to determine whether excessive heat is a causative factor and whether or not treatments that increase or reduce the heat load in the soil and onion bulbs would increase or reduce the incidence of the problems.

Materials and Methods

Onions were grown in 2016 on an Owyhee silt loam previously planted to wheat. A soil analysis taken in the fall of 2015 showed that the top foot of soil had a pH of 7.5, 3.4% organic matter, 6 ppm nitrate, 1 ppm ammonium, 30 ppm phosphorus (P), 629 ppm potassium (K), 43 ppm sulfur (S), 4,808 ppm calcium (Ca), 822 ppm magnesium (Mg), 413 ppm sodium, 4.3 ppm zinc (Zn), 10 ppm manganese (Mn), 2.8 ppm copper (Cu), 51 ppm iron, and 0.6 ppm boron (B). In the fall of 2015, the wheat stubble was shredded and the field was irrigated. The field was then disked, moldboard plowed, and groundhogged. Based on a soil analysis, 66 lb P/acre, 400 lb S/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 March 23 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/1,000 ft of row (0.82 lb ai/acre) over the seed rows and the soil surface was rolled. Onion emergence started on April 7. On May 9, alleys 4 ft wide were cut between split plots, leaving split plots 23 ft long. On May 16-20, 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 with two varieties as split plots within each treatment plot. Each variety split plot was planted in plots 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 that attempted to reduce the heat load on the onions. The artificial heat was applied using heat cables (Self-regulating heat cable, maximum temperature 185°F) laid next to each of the middle 2 double rows in the center of each plot. The heat cables were turned on automatically each day from 12 p.m. to 4 p.m. starting on July 6 and ending August 26. 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 2, June 22, July 5, July 12, and July 25. The straw was applied between the onion double rows at 243 ft^3/acre (32 7.5-ft^3 bales/acre) on June 2.

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 on May 2: GoalTender® at 0.09 lb ai/acre (4 oz/acre), Buctril® at 12 oz/acre, Poast® at 0.25 lb ai/acre (16 oz/acre), and Prowl® H_2O at 0.83 lb ai/acre (2 pt/acre).

For thrips control, the following insecticides were applied: Movento® at 5 oz/acre and Aza-Direct® at 12 oz/acre on May 26 and June 2 by ground application; Agri-Mek® SC at 3.5 oz/acre on June 10 and 17 by ground application; Radiant® at 10 oz/acre on June 25 and July 2 and 23 by aerial application; Lannate® at 3 pt/acre on July 10, 17, and 30 by aerial application.

Urea ammonium nitrate solution (URAN) at 20 lb nitrogen (N)/acre was applied through the drip tape on May 27, June 10 and 24, totaling 60 lb N/acre. Starting on June 14, 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 60 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 80 lb K/acre was applied in 20-lb increments during the season based on the soil and tissue analyses.

Table 1. Onion root tissue nutrient content, Malheur Experiment Station, Oregon State University, Ontario, OR, 2016.

Nutrient	Sufficiency range	14-Jun	23-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug
NO_3-N (ppm)		8501	7667	6833	6000	5168	4338	3508	2678
NO_3-N (ppm)		3050	2521	3097	2575	2550	3172	3916	3137
P (%)	0.32 - 0.7	0.38	0.47	0.53	0.62	0.51	0.51	0.32	0.41
K (%)	2.7 - 6.0	3.33	4.42	2.24	1.92	2.28	2.50	3.20	2.30
S (%)	0.24 - 0.85	0.50	0.70	0.82	0.93	0.71	0.61	0.47	0.70
Ca (%)	0.4 - 1.2	0.30	0.45	0.46	0.47	0.63	0.90	0.66	0.57
Mg (%)	0.3 - 0.6	0.33	0.33	0.27	0.20	0.20	0.30	0.21	0.20
Zn (ppm)	25 - 50	46	53	65	55	38	52	29	30
Mn (ppm)	35 - 100	107	160	98	115	95	63	35	50
Cu (ppm)	6 - 20	9	11	12	18	10	13	18	10
B (ppm)	19 - 60	36	42	30	21	29	39	32	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. Numbers following each nutrient are the critical levels. Malheur Experiment Station, Oregon State University, Ontario, OR, 2016.

Nutrient	Critical level, lb or oz	14-Jun	23-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug
N	Critical level, lb	8.6	7.8	7	6.2	5.4	4.6	3.8	2.8
N		9.4	8.1	9.9	12.0	14.6	15.0	15.4	18.4
P	0.7 lb	1.0	0.9	1.2	1.0	1.2	1.5	1.3	1.8
K	5 lb	4.9	4.2	6.1	4.3	3.7	4.3	5.2	6.2
S	1 lb	4.2	4.5	6.5	7.1	7.6	9.5	9.9	8.6
Ca	3 lb	4.0	4.1	4.9	5.8	4.4	5.2	6.7	4.1
Mg	2 lb	5.1	5.5	7.9	9.0	6.2	8.6	9.5	5.3
Zn	1 oz	4.2	5.9	5.5	5.7	6.1	4.4	2.6	3.6
Mn	1 oz	0.9	0.7	0.4	0.3	0.2	0.3	0.4	0.5
Cu	0.4 oz	0.6	0.5	0.7	1.0	0.7	0.9	1.1	0.9

Table 3. Nutrients applied through the drip irrigation system, Malheur Experiment Station, Oregon State University, Ontario, OR, 2016.

Date	N	K
	----- lb/acre -----	
27-May	20	
10-Jun	20	
20-Jun		20
24-Jun	20	
8-Jul		20
15-Jul		20
22-Jul		20
Total	60	80

Table 4. Soil available N (NO_3 + NH_4) in the top foot of soil, Malheur Experiment Station, Oregon State University, Ontario, OR, 2016.

Date	Available soil N, lb/acre
14-Jun	66
23-Jun	57
29-Jun	69
6-Jul	84
13-Jul	102
20-Jul	105
27-Jul	108
3-Aug	129

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 (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 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 18 and irrigations ended September 2.

Onion bulb temperature and soil surface temperature were measured weekly in the mid-afternoon using an infrared thermometer starting on July 1 and ending August 12. The bulb temperature was measured approximately 0.5 inches from the soil surface and the soil surface temperature was measured approximately 0.5 inches from the bulb. Four temperature measurements for the bulbs and the soil were taken weekly in each plot.

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 12 to field cure. Onions from the middle two rows in each split plot were topped by hand and bagged on September 17. The bags were put in storage on September 30. 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 October 26.

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 from each plot were saved for evaluations of internal bulb quality. Twenty-five 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*. Incomplete or dry scales were defined as scales that had either more than 0.25 inch from the center of the neck missing or dry or any part missing or dry lower down on the 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.

Results and Discussion

The rate of accumulation and total number of growing degree-days (50-86°F) in 2016 were higher than average, but below the record year of 2015 (Fig. 1).

Bulb temperatures for the check treatment onions were 10 to 20°F higher than ambient air temperature (Table 5). The artificial heat treatment resulted in significantly higher soil and bulb temperatures on two of the six measurement dates that were subject to artificial heat (7 July through 12 August). Straw mulch resulted in significantly lower soil temperature than the check treatment on three of the seven measurement dates. Straw mulch resulted in significantly lower bulb temperature than the check treatment on five of the seven measurement dates. Kaolinite only significantly reduced soil temperature on two dates and significantly reduced bulb temperature on one date compared to the check. Averaged over the seven measurement dates, artificial heat resulted in higher soil and bulb temperatures than the check. Averaged over the seven measurement dates, both straw mulch and kaolinite resulted in lower soil and bulb temperatures than the check. On average, straw mulch resulted in a 12° reduction in soil temperature and in a 7° reduction in bulb temperature compared to the check treatment.

There was no statistically significant interaction between treatment and variety. There were statistically significant differences between treatments on the average over varieties. Averaged over the two varieties, straw mulch resulted in among the highest total and marketable onion yields; artificial heat and kaolinite resulted in among the lowest total and marketable onion yields (Table 6). Straw mulch resulted in the highest supercolossal and colossal bulb yields. Straw mulch resulted in among the lowest percentage of tops down and leaf dryness (Table 6). It is not clear whether the higher colossal and supercolossal bulb yields were a direct result of lower temperatures or a result of straw modification of the soil moisture, consistent with previous reports (Shock et al. 1999). Artificial heat resulted in among the highest percentage of tops down and leaf dryness. Averaged over treatments, Joaquin had higher yields than Granero.

The percentage of bulbs with incomplete and dry scales increased from the first measurement date (Oct. 31) to the third date (Feb. 20, Table 7). The percentage of bulbs with incomplete and dry scales without internal decay on December 15 was high, averaging 80%. By February 20, 2017, the percentage of bulbs with incomplete and dry scales without internal decay was lower (55.4%), similar to the percentage on October 15. However, the percentage of bulbs with internal decay with or without incomplete or dry scales did not change over time and was low, averaging 1.4% over the three dates.

Bulbs with perfect scale formation showed fewer signs of bacterial decay or *Fusarium proliferatum* than bulbs with incomplete scales, consistent with the pattern of disease incidence observed in the onion variety trials in both 2015 and 2016 (Shock et al. 2016, 2017).

There was no statistically significant effect of heat treatment on bulb internal defects or internal decay, except for dry scale. Averaged over the three dates for Joaquin, both kaolinite and straw mulch resulted in a slightly higher percentage of bulbs with dry scales than the check treatment or the heat treatment. This difference in dry scale was statistically significant, but the amounts were very low and did not detract from the value of the straw mulch in increasing yields. During this 2016 trial, neither soil nor bulb temperature appeared to be related to the occurrence of incomplete scales, dry scale, or internal decomposition.

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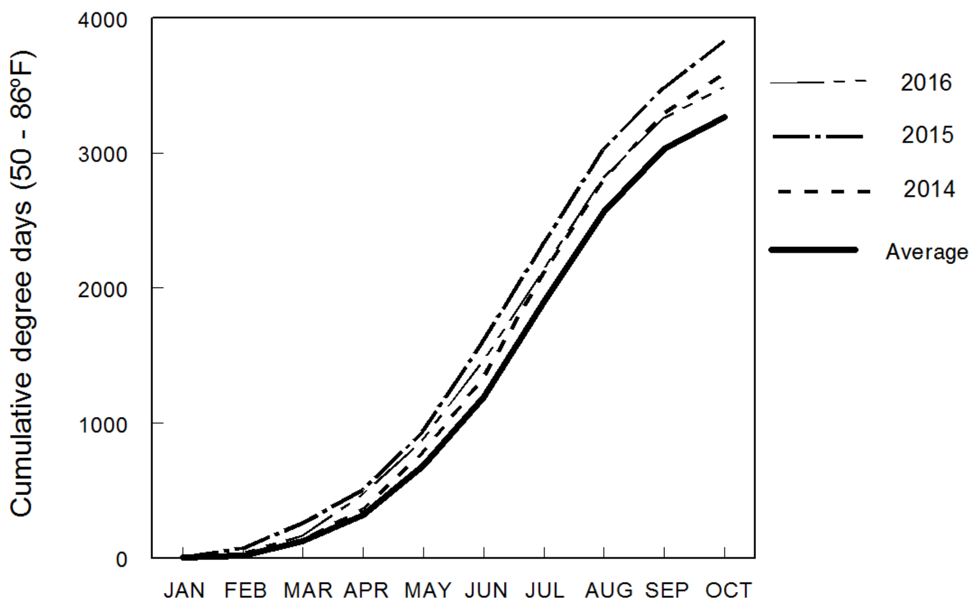

Figure 1. Growing degree-days (50-86°F) for 2014-2016 and 21-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2016.

Table 5. Soil and onion bulb temperature (°F) measurements for four treatments. Measurements were made between 12:30 and 3:30 p.m. Ambient air temperature was recorded at 2 p.m. Artificial heat treatment was started on July 6. Malheur Experiment Station, Oregon State University, Ontario, OR, 2016.

	Ambient air (°F)							
	1-Jul	7-Jul	14-Jul	18-Jul	27-Jul	5-Aug	12-Aug	Average
	95	86	87	87	93	86	87	88
	Soil							
	1-Jul	7-Jul	14-Jul	18-Jul	27-Jul	5-Aug	12-Aug	Average
Check	134.7	99.6	96.5	108.4	134.2	116.9	120.2	114.4
Heat	130.1	105.6	102.6	112.5	140.8	131.3	138.1	122.6
Kaolinite	120.9	95.0	95.3	109.7	116.8	108.2	115.0	107.8
Straw	108.8	97.5	95.1	94.4	112.5	99.9	109.6	102.2
LSD (0.05)	11.9	7.4	3.4	12.0	8.9	17.1	12.8	4.0
	Bulb							
	1-Jul	7-Jul	14-Jul	18-Jul	27-Jul	5-Aug	12-Aug	Average
Check	113.4	85.5	95.9	100.1	114.0	102.0	108.8	102.0
Heat	109.5	92.3	102.8	100.7	117.4	105.3	115.9	105.9
Kaolinite	105.8	85.8	93.7	98.7	108.8	96.6	103.1	98.4
Straw	101.2	86.0	94.5	91.5	103.6	92.1	101.6	95.3
LSD (0.05)	5.7	4.9	4.0	5.3	6.1	7.7	8.9	2.5

Table 6. Yield and grade of onions submitted to four temperature treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2016.

			Marketable yield by grade											Maturity Aug 8	
Variety	Treatment	Total yield	Total	>4¼ in	4-4¼ in	3-4 in	2¼-3 in	Small	No. 2s	Bulb counts >4¼ in	Total Rot	Neck rot	Plate rot	Tops down	Leaf dryness
		cwt/acre								#/50 lb	%				
Joaquin	Check	1175	1158	134.6	496.8	502.7	24.3	6.2	0.0	32.8	0.9	0.3	0.6	11.7	2.5
	Heat	1168	1149	137.5	458.2	532.1	21.0	7.3	0.0	31.4	0.9	0.2	0.7	12.5	4.2
	Kaolinite	1156	1132	131.2	466.0	511.4	23.3	9.9	3.1	32.2	0.9	0.2	0.7	11.7	4.2
	Straw	1213	1196	218.0	557.9	405.9	14.5	3.7	0.0	32.2	0.9	0.3	0.7	5.8	2.5
	average	1178	1159	155.3	494.7	488.0	20.8	6.8	0.8	32.2	0.9	0.3	0.7	10.4	3.3
Granero	Check	1060	1046	55.2	400.0	568.7	22.6	6.0	0.4	32.3	0.6	0.1	0.5	28.3	11.7
	Heat	1040	1015	56.6	337.9	588.2	32.1	5.1	0.0	32.6	1.9	0.2	1.7	30.0	12.5
	Kaolinite	1037	1010	42.8	378.7	565.7	23.3	7.5	0.8	31.6	1.6	0.1	1.5	20.0	10.0
	Straw	1105	1088	77.5	457.4	535.4	17.7	4.8	0.6	32.3	0.9	0.1	0.8	17.5	8.3
	average	1061	1040	58.0	393.5	564.5	23.9	5.8	0.5	32.2	1.2	0.1	1.1	24.0	10.6
Average	Check	1118	1102	94.9	448.4	535.7	23.5	6.1	0.2	32.6	0.8	0.2	0.6	20.0	7.1
	Heat	1104	1082	97.1	398.0	560.2	26.6	6.2	0.0	31.9	1.4	0.2	1.2	21.3	8.3
	Kaolinite	1096	1071	87.0	422.4	538.5	23.3	8.7	2.0	31.9	1.3	0.2	1.1	15.8	7.1
	Straw	1159	1142	147.7	507.6	470.7	16.1	4.2	0.3	32.3	0.9	0.2	0.7	11.7	5.4
	average	1119	1099	106.7	444.1	526.3	22.3	6.3	0.6	32.2	1.1	0.2	0.9	17.2	7.0
LSD (0.05)															
Treatment		51.4[a]	47	43.5	54.7	69.9[a]	NS[b]	2.9	NS	NS	NS	NS	NS	5.2	2.0
Variety		39	39	27.0	36.2	37.5	NS	NS	NS	NS	0.5	NS	0.36	3.1	1.4
Treatment X variety		NS	NS	NS	NS	NS	NS	NS	NS	NS	0.7[a]	NS	NS	NS	NS

[a]LSD (0.10).

[b]Not significant.

Table 7. Internal defects on three dates for onions submitted to four treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2016. Continued on next page.

			No disease				Bacterial rot				Fusarium proliferatum				Neck rot				Total	
Date	Variety	Treatment	No scale defect	Incompl. scale	Dry scale	Inc. + dry scale	No scale defect	Incompl. scale	Dry scale	Inc. + dry scale	No scale defect	Incompl. scale	Dry scale	Inc. + dry scale	No scale defect	Incompl. scale	Dry scale	Inc. + dry scale	Inc. + dry scale	Internal rot
			%																	
31 Oct	Joaquin	Check	43.3	39.3	0.7	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	54.7	0.0
		Heat	48.7	52.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.0	0.0
		Kaolinite	46.7	32.7	4.7	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	52.7	0.7
		Straw	49.3	39.3	4.7	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.7	0.0
		average	47.0	40.8	2.5	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	52.5	0.2
	Granero	Check	41.3	43.3	2.0	9.3	0.0	0.7	0.7	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	54.7	2.7
		Heat	49.3	40.7	2.7	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	50.0	0.7
		Kaolinite	50.0	40.7	0.0	8.7	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	49.3	0.7
		Straw	48.0	45.3	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	50.7	2.0
		average	47.2	42.5	1.8	6.8	0.0	0.2	0.2	0.0	0.0	0.2	0.7	0.3	0.0	0.0	0.0	0.0	51.2	1.5
	Average	Check	42.3	41.3	1.3	12.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.7	0.0	0.0	1.0	0.0	54.7	1.3
		Heat	49.0	46.3	1.3	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	51.0	0.3
		Kaolinite	48.3	36.7	2.3	12.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	51.0	0.7
		Straw	48.7	42.3	3.7	4.7	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	50.7	1.0
		average	47.1	41.7	2.2	8.0	0.0	0.1	0.1	0.0	0.0	0.1	0.3	0.3	0.0	0.0	0.3	0.0	51.8	0.8
15 Dec	Joaquin	Check	24.7	35.3	0.0	38.0	0.0	0.7	0.0	0.7	0.0	0.0	0.0	0.7	0.0	1.3	0.0	0.0	73.3	2.0
		Heat	16.0	43.3	0.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.7	83.3	0.7
		Kaolinite	15.3	42.7	0.0	39.3	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	82.0	1.3
		Straw	28.7	34.7	0.0	34.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.7	69.3	1.3
		average	21.2	39.0	0.0	38.0	0.0	0.2	0.0	0.5	0.0	0.0	0.0	0.7	0.0	0.8	0.0	0.3	77.0	1.3
	Granero	Check	17.3	38.7	0.0	42.7	0.0	0.0	0.0	1.3	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	81.3	2.0
		Heat	13.3	41.3	0.0	44.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	85.3	2.0
		Kaolinite	20.7	40.0	0.0	38.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	78.0	1.3
		Straw	11.3	52.0	0.0	34.7	0.0	1.3	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	86.7	3.3
		average	15.7	43.0	0.0	39.8	0.0	0.5	0.0	1.2	0.0	0.2	0.0	0.3	0.0	0.0	0.0	0.0	82.8	2.2
	Average	Check	21.0	37.0	0.0	40.3	0.0	0.3	0.0	1.0	0.0	0.3	0.0	0.3	0.0	0.7	0.0	0.0	77.3	2.0
		Heat	14.7	42.3	0.0	42.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.3	84.3	1.3
		Kaolinite	18.0	41.3	0.0	38.7	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	80.0	1.3
		Straw	20.0	43.3	0.0	34.7	0.0	0.7	0.0	1.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.3	78.0	2.3
		average	18.4	41.0	0.0	38.9	0.0	0.3	0.0	0.8	0.0	0.1	0.0	0.5	0.0	0.4	0.0	0.2	79.9	1.8

Table 7. (Continued) Internal defects averaged over three dates for onions submitted to four treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2016.

			No disease				Bacterial rot				Fusarium proliferatum				Neck rot				Total	
Date	Variety	Treatment	No scale defect	Incompl. scale	Dry scale	Inc. + dry scale	No scale defect	Incompl. scale	Dry scale	Inc. + dry scale	No scale defect	Incompl. scale	Dry scale	Inc. + dry scale	No scale defect	Incompl. scale	Dry scale	Inc. + dry scale	Inc. + dry scale	Internal rot
			%																	
20 Feb	Joaquin	Check	41.6	52.0	0.0	2.4	0.0	0.0	0.0	0.8	0.0	0.8	0.0	0.0	0.0	1.6	0.0	0.0	54.4	1.6
		Heat	46.7	48.7	0.0	1.3	0.0	1.3	0.0	0.0	0.0	0.7	0.0	0.0	0.0	1.3	0.0	0.0	50.0	2.0
		Kaolinite	42.7	49.3	0.0	3.3	0.0	0.7	0.0	0.0	0.0	2.0	0.0	0.0	0.0	2.0	0.0	0.0	52.7	2.7
		Straw	38.7	48.7	0.0	0.7	0.0	2.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	9.3	0.0	0.0	49.3	2.7
		average	42.4	49.6	0.0	1.9	0.0	1.0	0.0	0.2	0.0	1.0	0.0	0.0	0.0	3.7	0.0	0.0	51.5	2.3
	Granero	Check	38.7	56.7	0.0	0.7	0.0	0.7	0.0	0.0	0.0	0.7	0.0	0.0	0.0	2.7	0.0	0.0	57.3	1.3
		Heat	44.7	46.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.7	0.0	0.0	54.0	0.7
		Kaolinite	33.6	60.8	0.0	4.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.8	1.6
		Straw	36.7	60.7	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	62.0	0.0
		average	38.6	55.8	0.0	3.5	0.0	0.5	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.2	0.0	0.0	59.3	0.9
	Average	Check	40.0	54.5	0.0	1.5	0.0	0.4	0.0	0.4	0.0	0.7	0.0	0.0	0.0	2.2	0.0	0.0	56.0	1.5
		Heat	45.7	47.3	0.0	4.7	0.0	0.7	0.0	0.0	0.0	0.7	0.0	0.0	0.0	1.0	0.0	0.0	52.0	1.3
		Kaolinite	38.5	54.5	0.0	3.6	0.0	1.1	0.0	0.0	0.0	1.1	0.0	0.0	0.0	1.1	0.0	0.0	58.2	2.2
		Straw	37.7	54.7	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	5.3	0.0	0.0	55.7	1.3
		average	40.5	52.7	0.0	2.7	0.0	0.8	0.0	0.1	0.0	0.7	0.0	0.0	0.0	2.4	0.0	0.0	55.4	1.6
Average over dates	Joaquin	Check	36.2	41.6	0.2	19.3	0.0	0.2	0.0	0.5	0.0	0.2	0.0	0.2	0.0	0.9	0.7	0.0	61.2	1.2
		Heat	37.1	48.0	0.0	13.8	0.0	0.4	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.4	0.0	0.2	61.8	0.9
		Kaolinite	34.9	41.6	1.6	19.3	0.0	0.2	0.0	0.4	0.0	0.7	0.0	0.2	0.0	1.3	0.0	0.0	62.4	1.6
		Straw	38.9	40.9	1.6	14.0	0.0	0.7	0.0	0.0	0.0	0.2	0.0	0.4	0.0	3.1	0.0	0.2	56.4	1.3
		average	36.8	43.0	0.8	16.6	0.0	0.4	0.0	0.2	0.0	0.3	0.0	0.3	0.0	1.5	0.2	0.1	60.5	1.2
	Granero	Check	32.4	46.2	0.7	17.6	0.0	0.4	0.2	0.4	0.0	0.4	0.0	0.4	0.0	0.9	0.0	0.0	64.4	2.0
		Heat	35.8	42.7	0.9	19.6	0.0	0.2	0.0	0.0	0.0	0.2	0.2	0.4	0.0	0.2	0.0	0.0	63.1	1.1
		Kaolinite	34.8	46.4	0.0	17.6	0.0	0.5	0.0	0.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	64.0	1.2
		Straw	32.0	52.7	0.9	12.9	0.0	0.4	0.0	0.7	0.0	0.0	0.7	0.0	0.0	0.4	0.0	0.0	66.4	1.8
		average	33.7	47.0	0.6	16.9	0.0	0.4	0.1	0.4	0.0	0.2	0.2	0.2	0.0	0.4	0.0	0.0	64.5	1.5
	Average	Check	34.3	44.0	0.5	18.4	0.0	0.3	0.1	0.5	0.0	0.3	0.0	0.3	0.0	0.9	0.3	0.0	62.9	1.6
		Heat	36.4	45.3	0.4	16.7	0.0	0.3	0.0	0.0	0.0	0.2	0.1	0.3	0.0	0.3	0.0	0.1	62.4	1.0
		Kaolinite	34.9	43.9	0.8	18.5	0.0	0.3	0.0	0.5	0.0	0.5	0.0	0.1	0.0	0.7	0.0	0.0	63.2	1.4
		Straw	35.4	46.8	1.2	13.4	0.0	0.6	0.0	0.3	0.0	0.1	0.3	0.2	0.0	1.8	0.0	0.1	61.4	1.6
		average	35.3	45.0	0.7	16.7	0.0	0.4	0.0	0.3	0.0	0.3	0.1	0.3	0.0	0.9	0.1	0.1	62.5	1.4
LSD (0.05)	Treatment		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Variety		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.7	NS
	Date		7.3	6.3	0.9	3.8	NS	NS	NS	0.5	NS	0.5	NS	NS	NS	1.6	NS	NS	5.0	NS
	Treatment X variety		NS	NS	1.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Variety X date		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.6