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

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Introduction

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

Materials and Methods

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Results and Discussion

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

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

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

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

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

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

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

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

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

Acknowledgements

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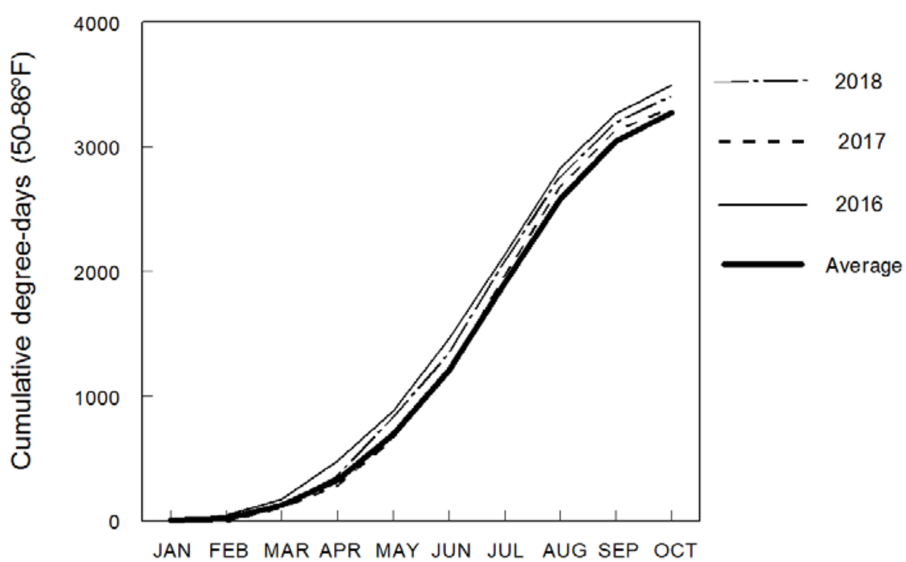

Figure 1. Cumulative growing degree-days (50-86°F) for 2016, 2017, 2018 and 24-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

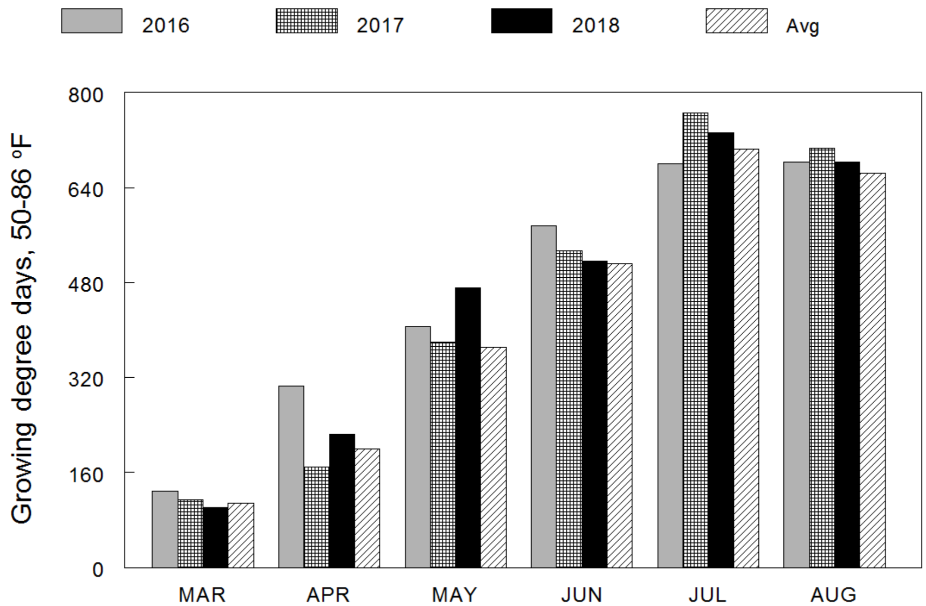

Figure 2. Monthly growing degree-days (50-86°F) for 2016-2018 and 25-year average, Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

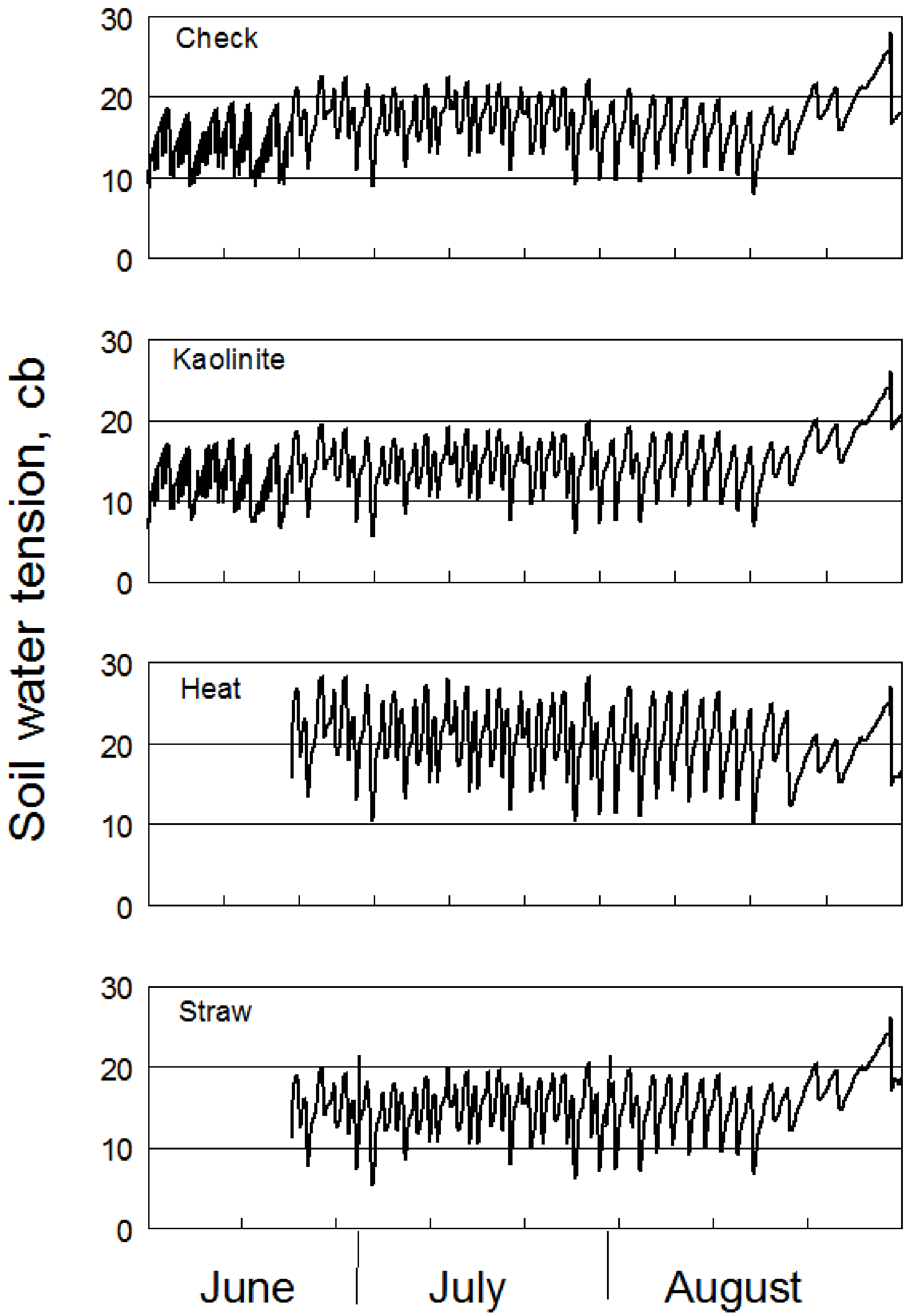

Figure 3. Soil water tension over time for four treatments of two onion varieties. Malheur Experiment Station, Oregon State University, Ontario, OR, 2018.

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

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

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

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

[a]Not significant.

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

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

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

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

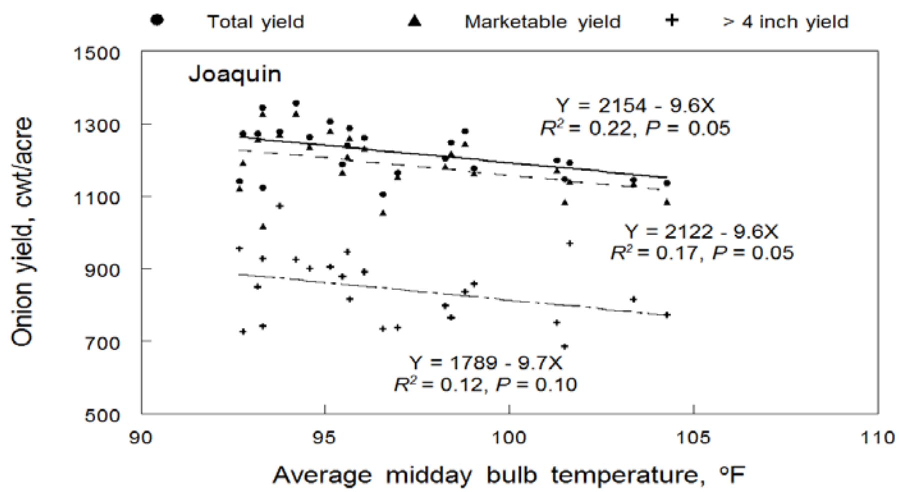

Figure 4. Onion yield response to average midday bulb temperature for 'Joaquin', Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. The bulb temperatures were measured on the south side of the bulbs farthest from the drip tape and approximately 0.5 inch above the soil surface.

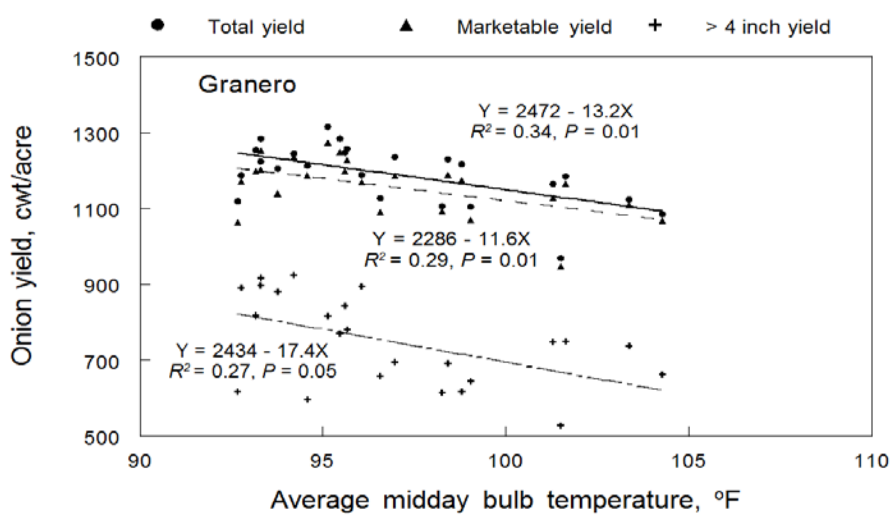

Figure 5. Onion yield response to average midday bulb temperature for 'Granero', Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. The bulb temperatures were measured on the south side of the bulbs farthest from the drip tape and approximately 0.5 inch above the soil surface.

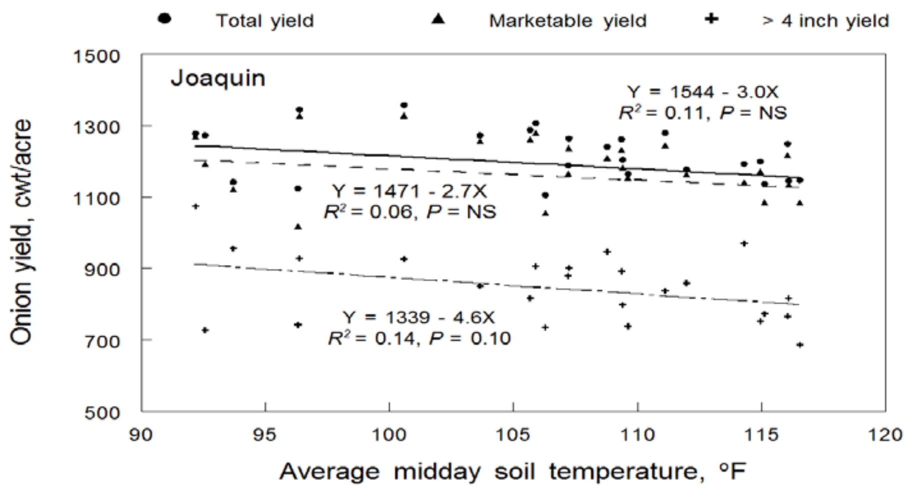

Figure 6. Onion yield response to average midday soil surface temperature for 'Joaquin', Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. The soil surface temperature was measured approximately 0.5 inch to the south from the bulbs farthest from the drip tape.

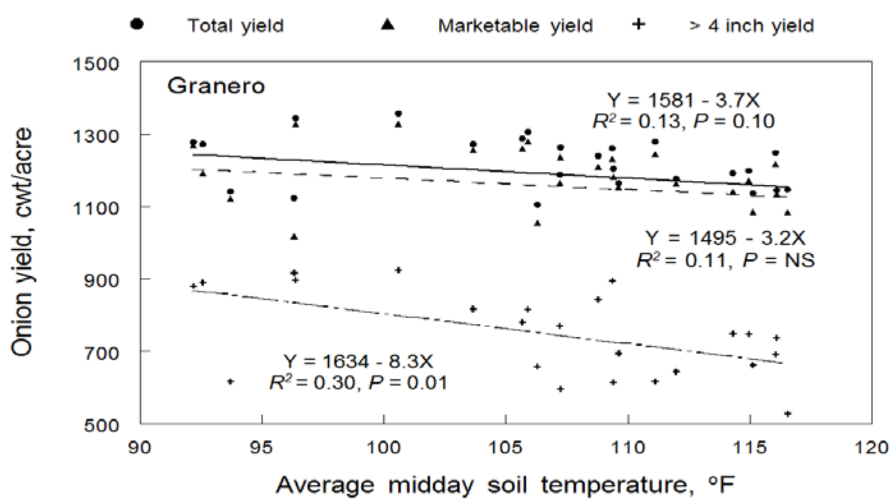

Figure 7. Onion yield response to average midday soil surface temperature for 'Granero', Malheur Experiment Station, Oregon State University, Ontario, OR, 2018. The soil surface temperature was measured approximately 0.5 inch to the south from the bulbs farthest from the drip tape.