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.

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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