

Onion (*Allium cepa* ‘Calibra’, ‘Highlander’)
Slippery skin; *Burkholderia gladioli* pv. *allicola*
Center rot; *Pantoea agglomerans*

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Effects of nitrogen management on onion bacterial bulb rot in the Columbia Basin of Washington State, 2023-24.

The effect of nitrogen management on onion bacterial bulb rot was evaluated in two trials, each planted with a different onion cultivar (Calibra and Highlander), in Othello, WA, on a silt loam soil under sprinkler irrigation. Separate trials were conducted with each cultivar due to differences in days to maturation and, thus, the different duration of irrigation required. Each trial was designed as a 5-by-2 factorial, strip plot, randomized complete block design with five replicates. Five nitrogen fertilizer application rates were applied as the main plot treatment, and strip plots were inoculated or not inoculated with plant pathogenic bacteria to create high and low (natural infection) disease pressure (two inoculation treatments). Onion plants were sown in 7.6-m-long and 1.7-m-wide raised beds. Nitrogen fertilizer was not applied prior to planting, but UAN-32 (urea ammonium nitrate with 32% N) was applied in-season at 0, 69, 159, 249, or 338 kg N ha⁻¹, each split into four applications that started when plants had three or four true leaves and ended at bulb initiation. There was 65 kg N ha⁻¹ of residual soil inorganic nitrogen at planting, so total soil available nitrogen rates, including residual nitrogen and fertilizer nitrogen, were 65, 134, 224, 314, and 403 kg N ha⁻¹. Inoculation was performed at the first sign of tops down and again two weeks later with a mix of *B. gladioli* pv. *allicola* and *P. agglomerans* at 10⁸ cfu/ml using a CO₂-pressurized backpack sprayer. The main plots were divided into two 3-m-long strip plots with a 1.6-m-long buffer between them. Inoculum was applied in strips; therefore, no buffer was needed between adjacent beds to avoid inoculum drift (strip plots were randomized once within each replicate rather than within each main plot). The field was irrigated briefly before every inoculation, and inoculum was applied in the evening to facilitate infection. Irrigation was stopped at the end of the season at 50% tops down. The roots of onion plants were undercut on 30 Aug 23 (‘Highlander’) and 5 Sep 23 (‘Calibra’), and bulbs were left in the field to cure for at least 12 days prior to harvest. Onions were planted in four double rows per bed, from which the bulbs in a 1.5-m section of half of each bed (2 rows) were harvested. Bulbs with no visual defects were categorized based on size (diameter) as prepack (<5.7 cm), medium (5.7-7.6 cm), jumbo (7.6-10.2 cm), and colossal (>10.2 cm). Unmarketable bulbs were categorized as bacterial culls or bulbs culled for reasons other than bacterial diseases, such as basal plate splitting, green shoulders, double centers, etc., and weighed separately. Harvested marketable onions were stored in a commercial onion storage facility at 1-2°C and 75-80% relative humidity for 5 months. The bulbs then were cut from the neck to the basal plate through the center and rated for incidence and severity of bacterial rot. The data were subjected to analysis of variance using R Studio v. 4.2.2. The project was funded by the Specialty Crops Research Initiative Award 2019-51181-30013 of the USDA National Institute of Food and Agriculture, the Columbia Basin Onion Research Committee, and the Washington Commission on Integrated Pest Management.

Inoculation increased the incidence of bacterial bulb rot in both the Calibra and Highlander trials, indicating the effectiveness of the inoculation method ($p < 0.0001$). There was no interaction between nitrogen application rate and inoculation treatments in terms of bulb size distribution, bacterial bulb rot incidence and severity, and total or marketable yield ($p > 0.05$). Total yield increased with increasing nitrogen application rates up to 249 kg applied N ha⁻¹ in the later maturing ‘Calibra’ ($p < 0.001$), whereas differences in total yield between treatments were less clear in the earlier maturing ‘Highlander’ ($p = 0.072$ and $p = 0.253$), though the trend was the same as in ‘Calibra’. Similarly, the weight of bacterial culls at harvest increased with increasing nitrogen application rate up to 159 kg applied N ha⁻¹ in the ‘Calibra’ trial, but differences among nitrogen application rates were not statistically significant in the ‘Highlander’ trial. Differences in the incidence of bacterial bulb rot were even more apparent after 5 months of storing the ‘Calibra’ bulbs, with bacterial bulb rot incidence increasing with increasing nitrogen application rates, up to 338 kg applied N ha⁻¹ in inoculated plots ($p = 0.016$) and non-inoculated plots ($p = 0.015$). In contrast, the incidence of bulb rot after 5 months in storage did not differ among nitrogen application rates in plots planted with ‘Highlander’ ($p = 0.414$ and 0.767 for inoculated and non-inoculated plots, respectively). In plots planted with ‘Highlander’, the incidence of bacterial rot at harvest averaged 19% in non-inoculated plots and 57% in inoculated plots and increased to 38 and 71%, respectively, after 5 months of storage. Estimated marketable yield, calculated as the product of marketable yield at harvest and the percent of stored bulbs with no bacterial rot after storage, did not differ among nitrogen application rates for either cultivar. In conclusion, increasing nitrogen application rates increased total yield at harvest, but also the incidence of bacterial bulb rots in the late maturing cultivar but not in the early maturing cultivar, ultimately rendering marketable yield statistically similar among nitrogen application rates. Therefore, under conditions that favor the development of bacterial bulb rots, such as excess irrigation, high levels of inoculum, and storage of bulbs, nitrogen application rates should be managed carefully to reduce losses to bacterial bulb rot and increase marketable yield.

Inoculation treatment	Nitrogen rate treatment ^z	Bulb (Mg ha ⁻¹)			Bacterial bulb rot incidence (%)		Bacterial rot severity index (%) ^y	
		Total yield	Bacterial culls at harvest	Marketable yield after storage ^x	Culls at harvest	At harvest plus after storage	At harvest	At harvest plus after storage
Calibra								
Non-inoculated	0 (65)	64.1 ± 4.6 ^w b	1.9 ± 0.8 b	58.4 ± 3.6	4.3 ± 1.7	8.0 ± 3.1 b	0.9 ± 0.4	2.2 ± 0.8
	69 (134)	78.1 ± 5.6 ab	4.5 ± 1.6 ab	66.6 ± 5.4	9.0 ± 3.6	16.3 ± 5.8 ab	3.0 ± 1.2	5.4 ± 1.8
	159 (224)	86.3 ± 4.5 a	15.0 ± 5.5 a	63.4 ± 7.0	17.1 ± 5.9	24.4 ± 7.6 ab	5.1 ± 1.8	8.7 ± 3.0
	249 (314)	95.4 ± 5.9 a	11.6 ± 6.1 ab	73.8 ± 12.6	15.7 ± 8.3	24.0 ± 8.1 ab	4.4 ± 2.4	6.8 ± 2.3
	338 (403)	92.4 ± 4.6 a	11.8 ± 3.1 ab	65.0 ± 1.3	15.9 ± 4.3	29.3 ± 2.7 a	4.6 ± 1.4	8.4 ± 3.0
	<i>p</i> -value	0.001	0.024	0.536	0.081 ^v	0.015	0.155	0.051
Inoculated	0 (65)	52.9 ± 4.1 b	28.3 ± 3.2 b	21.1 ± 3.5	38.7 ± 6.6	46.4 ± 4.1 b	14.3 ± 2.2	17.8 ± 1.3 b
	69 (134)	69.1 ± 8.5 a	37.4 ± 6.4 ab	24.7 ± 5.9	44.7 ± 7.4	56.8 ± 7.8 ab	18.2 ± 2.9	24.2 ± 3.6 ab
	159 (224)	74.8 ± 6.5 a	35.1 ± 3.3 ab	29.7 ± 4.0	41.3 ± 2.9	54.1 ± 2.6 ab	17.9 ± 0.9	23.1 ± 0.9 ab
	249 (314)	79.7 ± 9.5 a	43.9 ± 6.1 ab	21.7 ± 2.5	51.9 ± 6.4	66.3 ± 2.1 ab	20.2 ± 2.6	27.3 ± 1.6 a
	338 (403)	83.8 ± 7.1 a	51.7 ± 2.9 a	20.5 ± 5.5	58.9 ± 4.6	70.7 ± 4.8 a	22.5 ± 1.7	26.8 ± 2.0 ab
	<i>p</i> -value	<0.001	0.015	0.408	0.140	0.016	0.147	0.040
Highlander								
Non-inoculated	0 (65)	50.4 ± 5.2	14.9 ± 2.7	25.9 ± 4.3	24.9 ± 4.5	42.4 ± 3.6	9.4 ± 1.7 a	20.8 ± 1.6
	69 (134)	64.5 ± 10.1	12.6 ± 2.3	38.9 ± 8.6	16.8 ± 2.9	36.4 ± 7.9	4.6 ± 0.6 ab	18.2 ± 3.4
	159 (224)	73.7 ± 3.7	13.9 ± 2.4	40.3 ± 6.5	17.4 ± 4.3	38.9 ± 4.7	6.6 ± 2.1 ab	20.1 ± 2.8
	249 (314)	72.8 ± 9.7	16.1 ± 3.9	39.5 ± 7.5	21.6 ± 3.7	41.1 ± 3.7	7.2 ± 1.8 ab	19.5 ± 2.8
	338 (403)	68.5 ± 8.2	8.4 ± 1.8	43.0 ± 7.8	12.9 ± 3.0	32.0 ± 8.7	3.0 ± 0.8 b	14.5 ± 4.6
	<i>p</i> -value	0.253	0.273	0.499	0.222	0.767	0.034	0.665
Inoculated	0 (65)	43.9 ± 5.7	30.0 ± 3.4	9.2 ± 1.1	64.2 ± 2.6	71.4 ± 2.4	29.7 ± 2.8	34.1 ± 2.2
	69 (134)	61.2 ± 5.8	37.8 ± 7.0	13.1 ± 3.0	55.3 ± 8.6	74.8 ± 7.1	22.6 ± 4.8	34.1 ± 3.8
	159 (224)	70.5 ± 2.0	38.8 ± 4.1	17.6 ± 3.1	50.9 ± 4.8	65.9 ± 1.8	20.1 ± 2.0	31.9 ± 2.3
	249 (314)	59.4 ± 4.7	36.7 ± 3.7	13.4 ± 2.6	61.5 ± 4.4	77.2 ± 6.0	26.2 ± 3.1	35.6 ± 3.1
	338 (403)	60.1 ± 9.6	34.3 ± 7.4	17.1 ± 3.4	51.7 ± 2.7	66.7 ± 4.7	19.9 ± 1.9	30.0 ± 2.6
	<i>p</i> -value	0.072	0.693	0.240	0.268	0.414	0.414	0.681

^z Nitrogen rate treatment [kg N **applied** ha⁻¹ (**total available** N ha⁻¹)] where total available N includes residual soil inorganic N at planting.

^y Bacterial rot severity index was calculated by rating the area of the cut surface of each bulb as 0, 1-20, 21-40, 41-60, 61-80, or 81-100% rotten, and then calculating a weighted average based on the midpoint of each categorical rating and the number of bulbs in that category.

^x Estimated marketable yield, calculated as the product of marketable yield at harvest and the percent of stored bulbs with no bacterial rot after 5 months in storage.

^w Mean ± standard error; values followed by the same letter are not statistically different at $p < 0.05$ based on post-hoc comparisons using Tukey's Honestly Significant Difference.

^v *p* values from a square root transformation that satisfies the assumptions for analysis of variance.