ONION (*Allium cepa*, 12 cultivars)
Center rot; *Pantoea agglomerans*
Slippery skin; *Burkholderia gladioli* pv. *alliicola*

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**Susceptibility of 12 onion cultivars to bacterial leaf blight and bulb rot in Pasco, WA, 2022-23.**

A field trial was planted on 29 Mar 21 at the Washington State University Pasco Vegetable Extension Farm, using pelleted seed of 12 onion cultivars (210,000 seeds/A), to evaluate their susceptibility to bacterial leaf blight and bacterial bulb rot caused by *Pantoea agglomerans* and *Burkholderia gladioli* pv. *alliicola* in storage bulb crops grown with overhead irrigation in the Columbia Basin of Washington and Oregon. The trial was a split-split plot, randomized complete block design with five replications of a nested treatment design: two inoculation treatments (inoculated or not inoculated) were applied to main plots, four onion maturity groups (MG) were applied to split plots, and three onion cultivars nested within each MG were planted in split-split plots. Each split-split plot was a 34-in.-wide bed (2 double-rows of onion) x 15 ft long, including 5 ft of bed as a buffer between adjacent plots. Cultivars in MG 1, 2, 3, and 4 ranged from 103-107, 112-115, 117-118, and 119-125 days to maturity, respectively. Plants were irrigated using sprinklers so that irrigation could be terminated when plants in each MG reached ~50% tops down (8, 15, 22, and 29 Aug for MG 1 to 4, respectively), and to minimize inter-plot interference from irrigation. To avoid confounding plant maturity with time of inoculation, inoculum consisting of an equal ratio of the two pathogens, produced as overnight shake cultures in nutrient broth yeast extract medium and diluted to $10^8$ CFU/ml in 0.0125M phosphate buffer plus 0.01% Tween 20, was applied to relevant main plots when plants in a MG reached 5% and 50% tops down: 21 Jul and 4 Aug for MG 1, 28 Jul and 11 Aug for MG 2, 4 and 18 Aug for MG 3, and 11 and 25 Aug for MG 4, respectively. Inoculum was applied in the evening with a $CO_2$-pressurized backpack sprayer and 3-nozzle boom (XR8003 tips, 34.65 gpa, 20 psi), shortly after irrigating split plots with 0.12 in. water to favor bacterial infection. Plots in each MG continued to be irrigated briefly in the late afternoon every other day from mid-Jul until a week after the final inoculation to favor bacterial disease development. The trial was otherwise managed with typical practices for the region. Plots in each MG were rated four times at weekly intervals for incidence (percentage of plants with symptoms) and severity of bacterial leaf blight (percentage of canopy with symptoms), starting 5 days after the first inoculation. Plots were rated for percentage tops down on 25 Jul, and 2 and 9 Aug. Plants were undercut on 16, 24, and 31 Aug, and 7 Sep for plots in MG 1 to 4, respectively. Bulbs in a 5-ft section/split-split plot were topped and harvested manually on 26 Aug, and 12, 22, and 27 Sep for MG 1 to 4, respectively. Bulbs were sorted into those culled because of external symptoms of bacterial rot, those culled for other reasons (split bulbs, green shoulders, double-bulbs, or bolted), and marketable bulbs. Marketable bulbs were sized (pre-pack, medium, jumbo, and colossal), counted, and weighed by size to calculate marketable yield (t/A). Marketable bulbs were placed in a commercial storage facility (40°F, 70% relative humidity) for 5 months. On 2 Feb 23, bulbs were cut vertically and rated for incidence (%) of bulbs with bacterial rot and severity of bacterial rot (% of cut surface area of each bulb with symptoms). Data were subjected to analyses of variance (ANOVAs) and means comparisons using Fisher's protected least significant difference (LSD). The project was funded by Specialty Crops Research Initiative Award 2019-51181-30013 of the USDA National Institute of Food and Agriculture.

The range in maturity of cultivars within MG reflected the percentage tops down on 9 Aug: 87.0, 60.3, and 34.0% for MG 1 to 3, respectively (Table 1); accidental mechanical injury precluded tops down ratings of MG 4 plots. Inoculation increased the percentage tops down to 62.4% vs. 58.4% for non-inoculated plots. There were also significant differences in tops down ratings among cultivars within MGs, with greatest differences among cultivars in MG 3 (13.0 to 62.0%). Similar trends were observed when results were analyzed separately for inoculated vs. non-inoculated plots (Table 2). Bacterial leaf blight was observed less than a week after the first inoculation and increased in severity thereafter. Two weeks after inoculation, 85.3% of plants in inoculated plots had symptoms vs. 22.5% in non-inoculated plots, with a severity of 47.2 vs. 9.9%, respectively (Table 1). The incidence of symptomatic plants was greater for cultivars in MG 4 (71.7%) than MGs 3 (54.7%) and 2 (48.0%), and least for MG 1 (41.3%). Similarly for severity ratings. However, incidence and severity of bacterial leaf blight differed significantly among cultivars within MGs 3 and 4, when averaged over inoculated and non-inoculated plots (Table 1). In inoculated plots, bacterial leaf blight was so prevalent that only MG 1 plots had less incidence, with no significant effect of cultivars nested in MGs for foliar incidence, only severity (Table 2). In non-inoculated plots, the incidence of foliar disease increased from MG 1 to 4, and only MGs 3 and 4 had significant differences among cultivars. Inoculations reduced marketable bulb yield by 14.9 t/A, largely as a result of an 11.9 t/A increase in weight of bulbs culled because of bacterial rot; and increased the incidence and severity of bacterial bulb rot at harvest and after 5 months in storage. An average of 50.5% of bulbs was lost to bacterial rot (harvest + storage) in inoculated plots vs. 12.0% of bulbs in non-inoculated plots (Table 1). MG 3 cultivars had greater marketable yields than those in MGs 1 and 2. Yields also differed among cultivars within MGs. Legend and XP0188-16000 in MG 3 had the highest yields (>40 t/A), followed by Anillo in MG 3 and Hamilton, Crockett, and Joaquin in MG 4. Frontier (MG 1) had the lowest yield (16.6 t/A), followed by the other two cultivars in MG 1 and those in MG 2. In inoculated plots, marketable yield results showed a similar trend (Table 2), with highest yields in MGs 3 and 4 (Table 2), and a significant effect of cultivars nested in MGs. In non-inoculated plots, XP0188-16000 (MG 3) had the highest yield (53.6 t/A), followed by Legend and Anillo (MG 3) plus all three cultivars in MG 4, and Calibra (MG 2) and SV0106-NG (MG 1). The yield of bacterial culls at harvest and the incidence of bulbs with bacterial rot did not differ among MGs but differed among cultivars in MGs (Tables 1 and 2). In contrast, the incidence of bacterial bulb rot after 5 months in storage was greater for MGs 3 (10.4%) and 4 (11.7%) vs. 1 (7.5%) and 2 (8.6%). The total incidence of bacterial bulb rot (harvest + storage) also did not differ among MGs but was affected by cultivars in MGs in both inoculated and non-inoculated plots (Tables 1 and 2). Legend (MG 3) had the least bulb rot (10.5%), followed by Traverse (MG 1, 22.7%), XP0188-16000 (MG 3, 24.8%), and Crockett (MG 4, 29.6%). Joaquin (MG 4) had the most bulb rot (46.1%), followed by seven cultivars spread across all four MGs (between 30.0 and 39.2% bulb rot). In inoculated plots, Legend again had the least total bulb rot (18.5%), while the other 11 cultivars averaged 40.7 to 70.4% bulb rot. In non-inoculated plots, six cultivars had <10% total bulb rot (Traverse and SV0106-NG in MG 1, Tamara and Calibra in MG 2, and Legend and XP0188-16000 in MG 3). The three cultivars in MG 4 had the most bulb rot (Crockett with 18.4%, Hamilton with 23.5%, and Joaquin with 28.7%). In summary, timing inoculations based on cultivar maturity facilitated screening onion cultivars for susceptibility to bacterial infection. Including both inoculated and non-inoculated plots also enabled screening of cultivars at different levels of disease pressure. However, accidental, late season mechanical injury to the tops of MG 4 cultivars could have increased the risk of neck and bulb infections in those plots.

Table 1.

| Main plot, split plot, and split-split plot treatments | Tops down on 9 Aug (%) | Bacterial leaf blight 2 weeks after inoculation[z] | | Bulb yield at harvest (t/A) | | Bulbs culled at harvest from bacterial rot | | Bacterial bulb rot 5 months after storage | | Bacterial bulb rot incidence at harvest + storage (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Incidence (% of plants) | Severity (% of canopy) | Marketable bulbs | Bacterial culls | Incidence (% of bulbs) | Severity per bulb (%) | Incidence of bulbs (%) | Severity per bulb (%) | |
| Main plots | | | | | | | | | | |
| Inoculated | 62.4 a[y] | 85.3 a | 47.2 a | 25.0 b | 14.5 a | 37.6 a | 48.6 a | 12.9 a | 12.3 a | 50.5 a |
| Non-inoculated | 58.4 b | 22.5 b | 9.9 b | 39.9 a | 2.6 b | 5.8 b | 14.4 b | 6.2 b | 3.4 b | 12.0 b |
| LSD | Rank[x] | Rank | Rank | 3.7 | 2.5 | Rank | 4.7 | Rank | Rank | Rank |
| *P* value | 0.0109 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| Split plots | | | | | | | | | | |
| MG 1 | 87.0 a | 41.3 c | 23.6 c | 25.3 b | 8.7 | 25.9 | 26.0 b | 7.5 b | 7.2 | 33.4 |
| MG 2 | 60.3 b | 48.0 b | 25.9 bc | 28.0 b | 8.4 | 23.3 | 37.7 a | 8.6 b | 7.1 | 31.9 |
| MG 3 | 34.0 c | 54.7 b | 29.2 b | 40.7 a | 6.1 | 12.7 | 27.6 b | 10.4 ab | 7.8 | 23.1 |
| MG 4 | -----[w] | 71.7 a | 35.6 a | 35.3 ab | 11.2 | 25.4 | 35.7 a | 11.7 a | 9.2 | 37.1 |
| LSD | Rank | Rank | Rank | 5.2 | 3.5 | Rank | 6.7 | Rank | Rank | Rank |
| *P* value | 0.0001 | 0.0001 | 0.0006 | 0.0390 | 0.5279 | 0.2908 | 0.0012 | 0.0099 | 0.0627 | 0.2532 |
| Split-split plots (cultivars nested in MG) | | | | | | | | | | |
| MG 1 | | | | | | | | | | |
| Frontier | 84.5 b | 45.0 bc | 25.3 bcd | 16.6 d | 7.2 def | 29.5 abc | 30.1 c | 8.8 b-e | 5.8 bc | 38.3 abc |
| SV0106-NG | 85.0 b | 41.0 bc | 27.0 bcd | 29.9 bc | 13.4 abc | 34.0 ab | 33.4 bc | 5.2 de | 10.2 b | 39.2 abc |
| Traverse | 91.5 a | 38.0 c | 18.6 d | 29.4 bc | 5.5 def | 14.2 de | 14.4 d | 8.5 cde | 5.7 bc | 22.7 de |
| MG 2 | | | | | | | | | | |
| Tamara | 49.5 d | 47.0 b | 27.7 b | 25.9 cd | 7.3 b-e | 23.7 a-e | 33.2 bc | 7.4 cde | 7.5 b | 31.1 bcd |
| Talon | 61.0 c | 47.0 b | 25.9 b | 26.9 cd | 6.6 c-f | 20.2 a-d | 45.5 a | 9.8 bcd | 5.9 b | 30.0 bcd |
| Calibra | 70.5 c | 50.0 b | 24.3 bcd | 31.6 bc | 11.6 a-e | 26.2 a-d | 34.2 bc | 8.5 b-e | 8.0 b | 34.7 bcd |
| MG 3 | | | | | | | | | | |
| Legend | 62.0 c | 43.0 bc | 16.1 cd | 43.0 a | 2.9 ef | 5.6 e | 14.4 d | 4.9 e | 2.9 c | 10.5 e |
| XP0188-16000 | 27.0 e | 45.0 bc | 23.6 bcd | 44.0 a | 7.5 bcd | 14.0 cd | 30.4 c | 10.8 b-e | 8.0 b | 24.8 cd |
| Anillo | 13.0 f | 76.0 a | 48.0 a | 35.2 bc | 7.9 bcd | 18.6 a-d | 37.9 abc | 15.3 a | 12.6 a | 33.9 bc |
| MG 4 | | | | | | | | | | |
| Hamilton | -----[w] | 79.0 a | 39.2 a | 35.7 abc | 9.1 b-e | 23.7 a-d | 31.0 c | 12.0 abc | 6.7 b | 35.7 bc |
| Crockett | -----[w] | 88.0 a | 44.7 a | 35.1 bc | 7.8 b-e | 17.7 b-e | 33.1 bc | 11.9 abc | 6.9 b | 29.6 bcd |
| Joaquin | -----[w] | 48.0 bc | 22.8 bc | 35.1 bc | 16.7 a | 34.8 a | 42.9 ab | 11.3 abc | 14.0 a | 46.1 a |
| LSD | Rank | Rank | Rank | 9.0 | 6.1 | Rank | 11.6 | Rank | Rank | Rank |
| *P* value | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0113 | 0.0003 | 0.0001 |

[z] 2 weeks post-inoculation rating for bacterial leaf blight = 18, 24, and 31 Aug, and 6 Sep for cultivars in MG 1 to 4, respectively.

[y] Within main plot, split plot, and split-split plot treatments, means in a column followed by the same letter are not significantly different based on Fisher's protected least significant difference (LSD, $P < 0.05$). If the ANOVA F-test was not significant, means separation letters are not shown.

[x] Rank = data subjected to Friedman's non-parametric rank test. Original means are shown but means separation is based on transformed data.

[w] Ratings for tops down were not taken due to mechanical damage to foliage in plots for MG 4.

Table 2.

| Inoculated plots | Tops down on 9 Aug (%) | Bacterial leaf blight 2 weeks after inoculation[z] | | Bulb yield at harvest (t/A) | | Bulbs culled at harvest from bacterial rot | | Bacterial bulb rot after 5 months in storage | | Bacterial bulb rot incidence at harvest + storage (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Incidence (% of plants) | Severity (% of canopy) | Marketable bulbs | Bacterial culls | Incidence (% of bulbs) | Severity per bulb (%) | Incidence of bulbs (%) | Severity per bulb (%) | |
| Split plots | | | | | | | | | | |
| MG 1 | 90.7 a[y] | 78.0 b | 46.0 | 16.6 c | 16.4 | 48.8 | 42.8 b | 10.9 | 12.2 | 59.7 |
| MG 2 | 63.3 b | 86.7 a | 48.3 | 19.6 bc | 15.3 | 42.7 | 59.3 a | 11.2 | 11.1 | 53.9 |
| MG 3 | 33.3 c | 85.3 ab | 47.2 | 34.8 a | 10.8 | 22.7 | 43.0 b | 14.9 | 12.1 | 37.6 |
| MG 4 | -----[x] | 91.3 a | 47.4 | 29.0 ab | 15.6 | 36.2 | 49.4 b | 14.5 | 13.8 | 50.7 |
| LSD | Rank[w] | Rank | 7.8 | Rank | Rank | Rank | 8.4 | 4.4 | Rank | Rank |
| *P* value | 0.0001 | 0.0357 | 0.9607 | 0.0039 | 0.5251 | 0.0911 | 0.0004 | 0.1394 | 0.5694 | 0.2176 |
| Split-split plots (cultivars nested in MG) | | | | | | | | | | |
| MG 1 | | | | | | | | | | |
| Frontier | 89.0 a | 84.0 | 50.2 b | 9.9 f | 13.7 abc | 56.4 ab | 47.4 b | 8.8 | 8.8 bcd | 65.2 ab |
| SV0106-NG | 90.0 a | 80.0 | 53.8 ab | 16.7 def | 24.4 a | 62.4 a | 53.3 ab | 8.0 | 16.6 abc | 70.4 ab |
| Traverse | 93.0 a | 70.0 | 33.9 cd | 23.3 cde | 10.9 cd | 27.7 c-f | 27.8 c | 15.9 | 11.2 bcd | 43.6 cde |
| MG 2 | | | | | | | | | | |
| Tamara | 53.0 cd | 84.0 | 50.2 b | 16.3 ef | 14.1 abc | 46.5 abc | 62.4 a | 12.0 | 13.5 abc | 58.5 a-d |
| Talon | 62.0 bc | 88.0 | 50.0 b | 20.5 c-f | 11.4 cd | 35.6 b-e | 62.6 a | 9.1 | 7.1 cd | 44.7 b-e |
| Calibra | 75.0 b | 88.0 | 44.6 bc | 22.1 c-f | 20.3 ab | 45.9 abc | 52.9 ab | 12.5 | 12.6 abc | 58.4 a-d |
| MG 3 | | | | | | | | | | |
| Legend | 56.0 c | 78.0 | 30.1 d | 41.9 a | 5.3 d | 10.5 f | 27.2 c | 8.0 | 4.3 d | 18.5 f |
| XP0188-16000 | 30.0 de | 82.0 | 44.7 bc | 34.4 ab | 13.1 abc | 25.3 cde | 47.9 b | 18.5 | 15.0 abc | 43.8 a-d |
| Anillo | 14.0 e | 96.0 | 66.8 a | 28.0 bcd | 13.9 abc | 32.4 a-d | 53.9 ab | 18.1 | 16.9 ab | 50.5 a-d |
| MG 4 | | | | | | | | | | |
| Hamilton | -----[x] | 98.0 | 52.4 b | 30.3 bc | 12.6 bcd | 32.5 a-d | 44.5 b | 15.5 | 10.8 bcd | 48.0 a-d |
| Crockett | -----[x] | 92.0 | 48.1 b | 30.1 abc | 10.9 cd | 26.4 def | 47.1 b | 14.3 | 9.8 bcd | 40.7 def |
| Joaquin | -----[x] | 84.0 | 41.7 bcd | 26.4 b-e | 23.4 a | 49.6 abc | 56.6 ab | 13.8 | 20.8 a | 63.4 abc |
| LSD | Rank | Rank | 13.5 | Rank | Rank | Rank | 14.6 | 7.6 | Rank | Rank |
| *P* value | 0.0012 | 0.0586 | 0.0001 | 0.0191 | 0.0002 | 0.0001 | 0.0003 | 0.0585 | 0.0152 | 0.0004 |
| Non-inoculated plots | | | | | | | | | | |
| Split plots | | | | | | | | | | |
| MG 1 | 83.3 a | 4.7 c | 1.2 c | 33.9 | 1.1 | 2.9 | 9.1 | 4.1 | 2.3 | 7.0 |
| MG 2 | 57.3 b | 9.3 bc | 3.6 c | 37.0 | 0.9 | 2.5 | 14.7 | 5.9 | 3.2 | 8.4 |
| MG 3 | 34.7 c | 24.0 b | 11.2 b | 46.7 | 1.4 | 2.7 | 12.1 | 5.8 | 3.6 | 8.5 |
| MG 4 | -----[x] | 52.0 a | 23.7 a | 41.7 | 6.8 | 14.7 | 21.9 | 8.9 | 4.6 | 23.6 |
| LSD | Rank | Rank | Rank | Rank | Rank | Rank | 9.8 | 3.7 | 2.9 | 9.0 |
| *P* value | 0.0002 | 0.0001 | 0.0001 | 0.0867 | 0.0863 | 0.0965 | 0.0657 | 0.2633 | 0.6091 | 0.1298 |
| Split-split plots (cultivars nested in MG) | | | | | | | | | | |
| MG 1 | | | | | | | | | | |
| Frontier | 80.0 bc | 6.0 c | 0.3 b | 23.3 f | 0.7 | 2.7 | 12.8 abc | 8.9 abc | 2.8 bc | 11.6 a-d |
| SV0106-NG | 80.0 bc | 2.0 c | 0.1 b | 43.1 abc | 2.4 | 5.6 | 13.5 abc | 2.4 de | 3.8 abc | 8.0 b-e |
| Traverse | 90.0 a | 6.0 c | 3.3 b | 35.5 c-e | 0.1 | 0.6 | 1.0 c | 1.1 e | 0.3 c | 1.7 efg |
| MG 2 | | | | | | | | | | |
| Tamara | 46.0 ef | 10.0 c | 5.1 b | 35.6 bcd | 0.4 | 0.9 | 4.0 bc | 2.8 cde | 1.4 c | 3.7 d-g |
| Talon | 60.0 de | 6.0 c | 1.7 b | 33.2 def | 1.7 | 4.8 | 28.4 a | 10.5 a | 4.7 abc | 15.3 a-d |
| Calibra | 66.0 cd | 12.0 c | 4.0 b | 43.4 abc | 0.6 | 1.6 | 10.8 abc | 4.5 b-e | 3.5 abc | 6.1 c-f |
| MG 3 | | | | | | | | | | |
| Legend | 68.0 bcd | 8.0 c | 2.0 b | 44.1 bcd | 0.4 | 0.7 | 1.6 c | 1.8 e | 1.4 c | 2.5 c-g |
| XP0188-16000 | 24.0 fg | 8.0 c | 2.4 b | 53.6 a | 1.8 | 2.6 | 12.9 abc | 3.1 b-e | 1.1 c | 5.7 c-g |
| Anillo | 12.0 g | 56.0 b | 29.2 a | 42.3 bcd | 1.8 | 4.8 | 21.8 a | 12.6 a | 8.2 a | 17.4 a-f |
| MG 4 | | | | | | | | | | |
| Hamilton | -----[x] | 60.0 b | 26.0 a | 41.1 a-d | 5.6 | 14.9 | 17.5 abc | 8.6 a-d | 2.6 bc | 23.5 ab |
| Crockett | -----[x] | 84.0 a | 41.3 a | 40.1 a-d | 4.7 | 9.0 | 19.1 ab | 9.4 ab | 4.0 abc | 18.4 b-e |
| Joaquin | -----[x] | 12.0 c | 3.9 b | 43.7 a-d | 9.9 | 20.0 | 29.3 a | 8.7 a-d | 7.3 ab | 28.7 a |
| LSD | Rank | Rank | Rank | Rank | Rank | Rank | 17.0 | 6.4 | 5.0 | 15.6 |
| *P* value | 0.0001 | 0.0003 | 0.0003 | 0.0001 | 0.0869 | 0.1040 | 0.0260 | 0.0014 | 0.0238 | 0.0067 |

[z] 2 weeks post-inoculation rating for bacterial leaf blight = 18, 24, and 31 Aug, and 6 Sep for cultivars in MG 1 to 4, respectively.

[y] Within main plot, split plot, and split-split plot treatments, means in a column followed by the same letter are not significantly different based on Fisher's protected least significant difference (LSD, $P < 0.05$). If the ANOVA F-test was not significant, means separation letters are not shown.

[x] Foliar ratings for tops down were not taken due to mechanical damage to onion foliage in cultivar maturity group 4.

[w] Rank = data subjected to Friedman's non-parametric rank test. Original means are shown but means separation is based on transformed data.