Bacterial Leaf Streak in Oats: Cultivar Response and Comparison of Bactericide Control Options

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Abstract

The study evaluated eleven oat cultivars for their response to bacterial leaf streak caused by *Xanthomonas translucens (Xt)* and tested two bactericide products, $CuSO_4$ + lime (Bordeaux mixture) and *Bacillus subtilis* strain QST 713 (Rhapsody®) for their ability to reduce disease severity and prevent yield and quality loss. No typical BLS lesions were observed. Instead, necrotic dry foliar lesions developed, with field evaluations indicating low symptom severity (average ratings = 1-3 on a 0-9 scale). Among cultivars, CDC Haymaker and CDC Westgate consistently exhibited the higher end of this range, whereas AC Morgan and CDC Anson showed minimal symptoms. Despite the mild foliar expression, plating and genetic testing confirmed the presence of *Xt* in inoculated oat leaves. Bactericide treatments, $CuSO_4$ + lime and *B. subtilis* reduced foliar symptoms although no significant differences were observed in yield or grain quality.

Introduction

Bacterial leaf streak (BLS), caused by *Xanthomonas translucens* (*Xt*), is an emerging disease of concern in cereal crops across western Canada (Liu et al., 2023). This bacterium is divided into several pathovars, which are genetically distinct groups within the species that differ in host range. The two major pathovars (pv.) affecting small-grain cereals are *Xt* pv. *undulosa (Xtu),* which primarily affects wheat, triticale, and barley, and pv. *translucens (Xtt)*, which mainly infects barley and wheat (Sapkota et al., 2020; Duveiller et al., 2005). The pathogen produces translucent, water-soaked lesions that can look like streaks, reducing photosynthetic leaf area and leading to yield and quality loss (Figure 1, Sapkota et al., 2020). Under favorable conditions, especially with frequent rain or irrigation, BLS can spread rapidly within a field (Duveiller et al., 2005).

While BLS is well documented in wheat and barley, its role in oat is less clear. To date, there is very little published data confirming whether oats are naturally susceptible to BLS under prairie field conditions. Reports on oats remain rare and host interaction data is minimal (Ledman et al., 2024; Duveiller et al., 2005). This uncertainty leaves growers and breeders without clear guidance on the potential risk posed by BLS to oat crops in Saskatchewan. For SaskOats, it is important to address this knowledge gap. Determining whether BLS can infect oats, and if so, whether differences in cultivar response exist, will provide valuable direction for breeding programs and management recommendations. In addition, there is interest in evaluating bactericide products such as Bordeaux mixture ($CuSO_4$ and lime) and Rhapsody® (*Bacillus subtilis)*

to assess their potential role in integrated disease management, even though no foliar product is expected to fully control BLS.

Copper-based compounds like Bordeaux mixture have long been used to manage bacterial diseases in crops, including those caused by *Xanthomonas* spp. (Lamichhane et al., 2018). These compounds through multiple mechanisms, form a protective layer on leaf surfaces, releasing copper ions that inhibit bacterial growth, and possibly activating plant defense pathways (Yu et al., 2023). Recent studies have shown that copper oxychloride and Bordeaux mixture significantly inhibit the growth, biofilm formation, and motility of *Xt*, and reduce disease severity in wheat by up to 75% when applied preventively (Shohanipor et al., 2025). Rhapsody®, on the other hand, is a biofungicide based on *Bacillus subtilis*. It suppresses bacterial pathogens, including *Xanthomonas* spp. By competing for space and nutrients and inducing systemic resistance in the host plant (Wang et al., 2018). Although neither Bordeaux mixture nor Rhapsody® is expected to provide complete control of BLS, their evaluation may identify partial suppression tools that can be incorporated into broader disease management strategies. This is particularly relevant for oats, where cultivar resistance and effective foliar treatments for BLS are currently undefined.

Figure 1. Characteristic bacterial leaf streak (BLS) symptoms on barley leaves. Lesions appear as elongated, translucent streaks running parallel to the main vein with associated chlorosis and necrosis (leaves 1 and 2, left to right). The leaf on the right shows bacterial ooze and water soaking, typical of active *Xanthomonas translucens* infection.

Objectives

The objectives of this study were to:

1. Evaluate the response of multiple oat cultivars to BLS under field-inoculated nursery conditions.
2. Assess the efficacy of Bordeaux mixture and Rhapsody® to reduce disease symptoms and protect yield and grain quality.

Materials and methods

Field site and design

The study was conducted at the BLS nursery in Aberdeen, Saskatchewan. For both trials a mist irrigation system was installed to favour high humidity, promoting bacterial infection and symptom development. Two trials were established:

- Trial 1 – Cultivar susceptibility: 11 oat cultivars seeded in hill plots (~20 plants per hill) using a randomized complete block design (RCBD) with four replication per cultivar.
- Trial 2 – Bactericide efficacy: single oat cultivar (CDC Dancer) was used across treatments, seeded in 2 x 8m row per plot with 10 replicates per treatment.

Both trials were seeded May 26 and emergence counts were recorded on June 20 to assess plant stand. Herbicide application was conducted for weed control. A comparison of both trials is described in Table A1 and the field schedule is shown in Table A2. Weather conditions during the trial period (May-August 2025) are summarized in table A3 to document temperature and moisture conditions under which disease and yield were evaluated.

Inoculation

A 50:50 mixture of *Xtu* and *Xtt* isolates was prepared as inoculum from cultures grown on Wilbrink's Bacterial Culture (WBC) media. For each application, four backpack sprayers were used, containing 6 L of inoculum suspension. The suspension was prepared by rinsing two WBC plates of each isolate into sterile saline solution (0.85% NaCl), targeting a final concentration of approximately 10^8 CFU/mL. Inoculations were conducted at two growth stages, flag leaf and heading stage.

Mist irrigation was applied using the Fusarium Head Blight (FHB) misting system shared at the site. The system was operated only under dry conditions to maintain canopy humidity conductive to bacterial infection. On naturally humid days, misting was not applied. The exact dates and amounts of mist irrigation applied are summarized in Table A4.

Bactericide application

Bactericide treatments were applied four days after the first inoculation. Applications were made using a CO_2-pressurized backpack sprayer calibrated for uniform coverage. The treatments included:

1. Control – water only, no bactericide
2. Bordeaux mixture – copper sulphate formulation ($CuSO_4$ + lime) prepared according to label instructions
3. Rhapsody® – biological formulation containing *Bacillus subtilis* strain QST 713, applied at the recommended field rate

All treatments were applied in the morning under calm conditions to minimize drift and ensure foliar contact.

Disease assessment for foliar symptoms

Disease symptoms were evaluated approximately 10 days after each inoculation. Foliar symptoms evaluated are shown in Figure 2. A 0 to 9 scale was used, where 0 indicated no symptoms on any of the plants in the hill, and 9 indicated that all the plants were severely affected. The evaluation focused primarily on the penultimate and flag-2 leaves, considering the percentage of leaf area that appeared symptomatic. The scale was defined as 1: ≤10% of the leaf area symptomatic, 5: approximately 50% of the leaf area symptomatic, and 9: 90-100% of the leaf area symptomatic.

In the bactericide efficacy trial, both incidence (proportion of symptomatic plants in the plot) and severity (percentage of leaf area affected) were recorded separately using a 0 to 9 scale for visible foliar symptoms in each plot. Following symptom evaluation, plots were fully harvested to estimate yield and quality. Grain quality was assessed by measuring test weight (TW) and thousand kernel weight (TKW).

Figure 2. Foliar symptoms observed in oat hills and yield plots during disease evaluations.

Bacteria identification

To confirm the presence of *Xt* on oat tissue, five symptomatic leaves were collected from each of the 30 yield plots in Trial 2. Leaf sections of approximately 1 cm in length of each leaf were surface sterilized and plated on WBC media. Plates were incubated at 27°C and monitored daily for three to five days. Both yellow-pigmented and white-pigmented colonies were selected for identification. Yellow colonies were presumed to be *Xt* and selected for sub-culturing and genetic identification using the loop-mediated isothermal amplification (LAMP) protocol described by Langlois *et al.* (2017). Reaction mix composition can be found in Table A5. Reactions were incubated at 65°C for 70 minutes. A colour change from pink to yellow indicated a positive

result for *Xt* DNA. White colonies were also isolated for comparison and sent to the Alberta Health Plant Lab in Edmonton for DNA barcoding to determine species identity.

To determine whether oat seed carried surface or internal bacterial contamination, a seed wash and plating assay was conducted post-harvest using seeds from the two oat cultivars that showed contrasting foliar symptom levels: CDC Haymaker (highest score) and CDC Anson (lowest score). For each cultivar, two biological samples were prepared. Approximately 5 g of seed per sample were washed with 50 mL of sterile saline solution and shaken for 5 minutes to remove surfaced microorganisms. A 20 µL aliquot of each seed wash was plated and spread on WBC agar. Each sample also had two plates with seeds directly placed on WBC. Plates were incubated at 27°C and observed daily for colony development and morphology.

Results

Trial 1 - Oat cultivars susceptibility

Foliar symptoms evaluation from the first and second disease assessments revealed low overall symptoms development across all cultivars, with no typical BLS symptoms (such as water-soaked, translucent streaks) observed. Instead, lesions appeared as dry, elongated necrotic streaks (Figure 2). Due to this ambiguity, each hill was assigned a single overall score on a 0-9 scale for visible foliar symptoms rather than separate incidence and severity values (Figure 3). In the first evaluation, the only cultivar with foliar symptoms was CDC Haymaker. By the second evaluation, symptoms were observed on most cultivars. CDC Haymaker showed the highest mean score (3), followed by CDC Westgate (2.8). Cultivars such as AC Morgan, CD Byer, and CDC Anson remained low, with mean scores between 0.5 and 1.0.

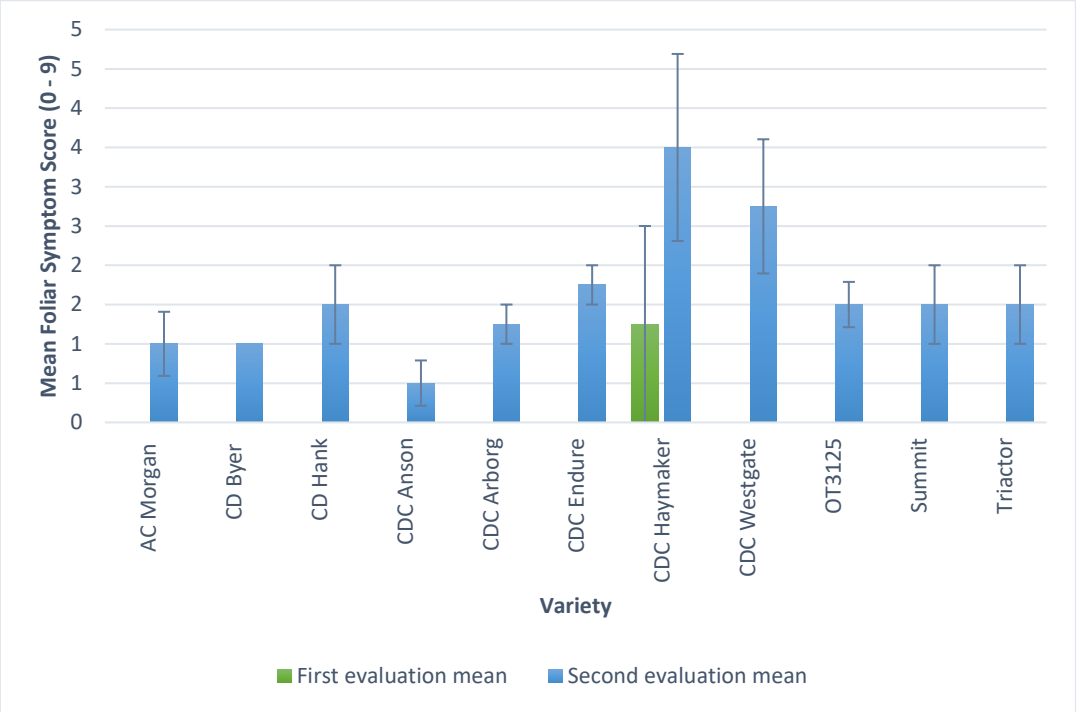

Figure 3. Mean foliar symptom scores for 11 oat cultivars assessed against BLS. Ratings were based on overall visible foliar symptoms. Green bars represent the first evaluation mean; blue bars represent the second evaluation means. Error bars indicate the standard error of the mean (n=4).

Trial 2 - Bactericide efficacy

Foliar symptom evaluations, yield, and grain quality were assessed across three different treatments: Control, Bordeaux mixture, and Rhapsody®. Evaluations were conducted approximately 10 days after each inoculation.

On the first evaluation, mean severity scores were slightly lower in treated plots compared to the control (Figure 4). By the second evaluation, symptom levels remained low across all treatments, with no significant differences in severity or incidence. Notably, no lesions with typical BLS infection (water-soaked appearance or bacterial ooze) were observed. Instead, symptoms consisted of dry, necrotic lesions (Figure 2), which were atypical bacterial expression or co-occurring stress factors.

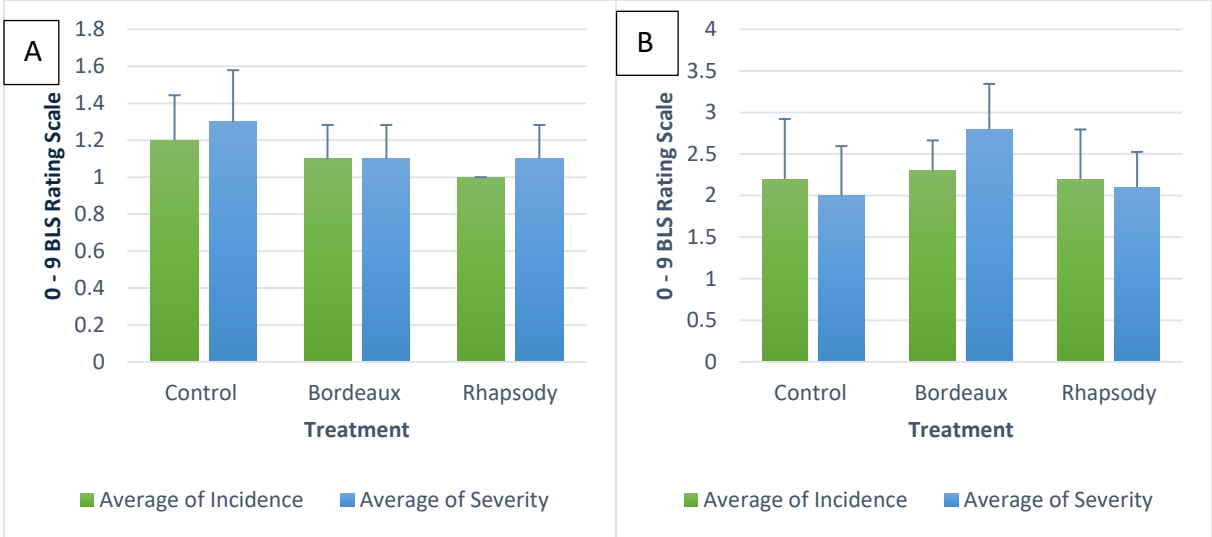

Figure 4. Mean disease incidence and severity for oat plots under three bactericide treatments (Control, Bordeaux Mixture, Rhapsody®) following *Xt* inoculation. (A) First evaluation, approximately 10 days after inoculation at flag leaf stage. (B) Second evaluation, approximately 10 days after inoculation at heading stage. Green bars represent incidence (percentage of symptomatic leaves per hill), and blue bars represent severity (0-9 scale). Error bars show standard error of the mean (n=3). No statistically significant differences among treatments were detected on either date (ANOVA, $p > 0.05$)

Corrected yield refers to grain yield adjusted for moisture content and extrapolated to kilograms per hectare. The Bordeaux mixture treatment had the highest corrected yield (1968 kg/ha), followed by Control (1884 kg/ha) and *Bacillus subtilis* application (1883 kg/ha) (Table 1). Grain quality, measured by TKW and TW, was slightly higher in the Control treatment compared to treated plots. A localized Gustnado event (a short-lived, tornado-like wind vortex) occurred on August 20-21 may have contributed to seed loss in some plots, which was noted during harvest and considered in data interpretation.

Table 1: Summary yield, and grain quality by treatments in oats. Data are mean and standard error (n=10).

Treatment	*Corrected Yield (kg/ha)*	*TKW (g)*	*TW (g/0.5 L)*
Control	1884 ± 49	30.7 ± 0.4	220.8 ± 2.1
Bordeaux Mixture	1968 ± 70	29.6 ± 0.7	218.5 ± 2.7
Rhapsody®	1883 ± 81	29.1 ± 1.0	214.5 ± 3.4

Statistical analysis

Data from both trials were analyzed using one-way analysis of variance (ANOVA) in Microsoft Excel. The cultivar susceptibility trial compared mean foliar symptom evaluations among 11 oat cultivars using a single-factor ANOVA. When significant differences were detected (p = 0.05), mean separation was performed using Tukey's honestly significant difference (HSD) test. For the second disease evaluation, the ANOVA indicated a significant difference among the 11 oat cultivars (F = 2.31, p = 0.0345), suggesting variability in symptom response. Tukey's test found that CDC Haymaker had a significantly higher score than CDC Anson and CDC Arborg ($p < 0.05$). No other cultivar pairs differed significantly.

In the bactericide efficacy trial, ANOVA was used to compare mean severity and incidence scores among treatments (Control, Bordeaux, and Rhapsody®). Neither severity (p = 0.1216) nor incidence (p = 0.9676) differed among treatments. All analyses were conducted at a 95% confidence level.

Bacteria identification results

Out of the 30 samples tested, only five were positive as identified by LAMP (Figure 5, yellow reactions), confirming the presence of *Xt* in symptomatic oat tissue.

Figure 5. LAMP results for detection of *Xanthomonas translucens* in symptomatic oat tissue.

All water controls remained negative, validating the specificity of the assay. Although *Xt* was detected, the leaf symptoms observed were not typical of BLS.

Seed wash and seed plating

Typical *Xt* colonies are yellow, convex, and mucoid in appearance, characteristics used to guide preliminary identification before molecular testing (Duveiller et al., 2005). Distinct, yellow-pigmented bacterial colonies resembling *Xt* appeared on several plates from both cultivars (Figure 6). White bacterial colonies and fungi were also observed. Representative colonies were

selected for subculturing, and samples were submitted to the Alberta Plant Health Lab to Dr. Feng for molecular identification.

Figure 6. Bacterial colonies recovered from CDC Haymaker and CDC Anson seed samples plated on WBC media.

Discussion

This study evaluated oat cultivar susceptibility to BLS and assessed the efficacy of bactericide treatments under field conditions. No typical BLS symptoms were observed in any of the oat trials; however, *X. translucens* was identified from five of 30 samples tested.

Variation among cultivars was minor and not clearly linked to infection by *Xt.* While some cultivars such as AC Morgan and CD Byer exhibited lower symptom scores, the cause of these symptoms remains uncertain and cannot be attributed to BLS. While typical BLS symptoms were not observed in the field, laboratory testing confirmed the presence of *Xt* via LAMP testing, indicating that the pathogen was present but did not express in its classical form or cause measurable effects on yield or grain quality. Despite inoculation with *Xt* isolates, no translucent, water-soaked lesions or bacterial ooze were observed during field evaluations. Instead, symptoms consisted of dry, necrotic lesions that are more consistent with plant responses to abiotic stress or infection by other foliar pathogens. Therefore, the observed leaf symptoms likely reflect non-BLS foliar stress, rather than true bacterial disease. Although plating revealed the presence of yellow-pigmented bacterial colonies and LAMP assays confirmed *Xt* DNA in symptomatic tissue, the lack of typical BLS lesion morphology suggests that the detected bacteria were either non-pathogenic or belonged to a different *Xt* pathovar not pathogenic to oat crops under these field conditions. Notably, the BLS nursery itself had moderate to high disease pressure in wheat and barley plots this year, confirming that conditions were suitable for BLS infection. Because BLS was

confirmed in the nearby plots, this suggests that oats may have resisted infection or that infection occurred without symptom expression.

It is also possible that oat is more susceptible to infection by *Xt* pathovars other than pv. *undulosa* or pv. *translucens*, such as pv. *cerealis* or related groups, which have been reported to infect multiple cereal hosts (Sapkota et al. 2020)

Bactericide treatments with Bordeaux mixture and *B. subtilis* were evaluated for their ability to suppress BLS symptoms and protect yield and grain quality relative to the untreated control. Overall disease pressure was low, and no lesions typical of BLS infection were observed. Mean severity and incidence values of other foliar symptoms on both evaluations were evaluated and resulted in slightly lower values in the Bordeaux mixture and Rhapsody® treatments compared with the control (Table 1). However, these differences were not significant ($p > 0.05$). The Bordeaux mixture treatment had the highest yield (1968 kg/ha), while the Control and Rhapsody® treatments were nearly identical (1883 kg/ha and 1882 kg/ha, respectively). Minor reductions in TKW and TW were observed among treatments compared with the control. These differences were minor and fell within the range of normal experimental variation observed among field replicates, indicating that the treatments did not have a biologically meaningful effect on yield or grain quality. The results suggest that neither Bordeaux mixture, nor Rhapsody® provided a significant benefit under the conditions tested. The bactericides may have provided slight suppression of general foliar symptoms. However, because symptoms were not typical of BLS and other pathogens may have been present, it is unclear whether these reductions were directly due to bacterial control. Additionally, a Gustnado event (short-lived, strong vortex) in late August caused physical damage and potential seed loss in some plots. The results indicate that under the 2025 field conditions, bactericide applications provided no benefit for managing foliar disease in oats.

Symptomatic leaf plating revealed both fungal and bacterial growth. Genetic confirmation for several isolates is still pending, and these results will help to clarify the identity of both yellow- and white-pigmented bacterial colonies recovered from symptomatic leaves. Molecular confirmation via LAMP assays supported the presence of *Xt* in the symptomatic tissue. The difference between field symptoms and lab results shows that field evaluations alone may miss infections when symptoms are not visible.

Even though *Xt* DNA was confirmed by LAMP testing, typical BLS symptoms were not observed. This suggests that oats may not be a strong host for *Xt* pathovars typically associated with BLS in wheat and barley (*pv. undulosa* and *pv. translucens*) under Saskatchewan field conditions. However, the possibility remains that other pathovars, such as *pv. cerealis* or less-characterized strains, could cause more pronounced symptoms or establish infection in oat. Further molecular characterization of isolates will be necessary to confirm which pathovars are present and their pathogenic potential in oat.

This study was conducted at a single site during one growing season, which limits the ability to generalize results across environments and years. Future work should expand on these findings through multi-year and multi-location testing to capture environmental variation and confirm *Xt* ability to infect oats and cause BLS. Trials under controlled-environment conditions are also recommended to clearly differentiate true BLS symptoms from those caused by other stressors. Understanding how different oat genotypes interact with *Xt* under high infection pressure will be essential for breeding programs aiming to enhance resistance and develop practical management strategies for Saskatchewan producers.

Conclusion

This study aimed to evaluate different oat cultivars in response to *Xt* infection and assess the potential of two bactericides, Bordeaux mixture and Rhapsody, for managing disease under field conditions. Although laboratory testing confirmed the presence of *Xt* in inoculated oat tissue, no typical BLS were observed. Symptoms expression was low across all cultivars and treatments, suggesting that oats may not be a strong host for *Xt* or that observed lesions were primarily responses to general abiotic stress. Bactericide treatments provided only minor reductions in visible foliar symptoms, and neither Bordeaux mixture nor Rhapsody significantly improved yield or grain quality. These findings indicate that bactericide applications offered no measurable agronomic benefit under 2025 field conditions. Further research is recommended to confirm whether *Xt* can or cannot infect oats and cause BLS.

Appendix

Table A1. Comparison of field trials in Aberdeen, Saskatchewan, 2025 evaluating oat response to *Xanthomonas translucens* (Bacterial Leaf Streak, BLS) inoculation. Trial 1 assessed cultivar susceptibility, and Trial 2 evaluated bactericide efficacy under field conditions.

Feature	**Trial 1 – Cultivar Susceptibility**	**Trial 2 – Bactericide Efficacy**
Objective	Assess variation in oat cultivar response to *Xt* infection	Evaluate effect of bactericide treatments on *Xt* infection
Plant material	11 oat cultivars	One oat cultivar (CDC Dancer)
Plot type / size	Hill plots	2 m X 8 m yield plots
Replications	Four per cultivar	10 per treatment
Treatments	Cultivars only	Control (water), Bordeaux mixture ($CuSO_4$ + lime), Rhapsody® (*Bacillus subtilis* QST 713)

Inoculum	50:50 mixture of *Xtu* and *Xtt*	50:50 mixture of *Xtu* and *Xtt*
Inoculum timing	Flag leaf and heading stages	Flag leaf and heading stages
Assessments	10 days after each inoculation Foliar symptom rating (0 – 9 scale) One overall rating	10 days after each inoculation Foliar symptom rating (0 – 9 scale) Separate incidence and severity ratings

Table A2. Timeline of field trials in Aberdeen, SK, 2025 during the 2025 oat-*Xanthomonas translucens* (Bacterial Leaf Streak) susceptibility and bactericide efficacy trials at Aberdeen, Saskatchewan.

Date	**Activity**	**Details**
May 26, 2025	Seeding	Plots established in BLS disease nursery in Aberdeen, SK.
June 20, 2025	Emergence counts	Recorded plant stand.
June 9 + 27, 2025	Herbicide spray	Applied pre-trial weed control.
July 11, 2025	First BLS inoculation	Applied at flag leaf stage using four backpack sprayers (6 L each) with a mixed inoculum of two *Xt* strains (*Xtu* and *Xtt*); two agar plates of each strain used per application.
July 15, 2025	Bactericide applications	Applied Rhapsody® and Bordeaux mixture to designated plots. Control plots received water only.
July 21, 2025	Second BLS inoculation	Applied at heading stage using the same method as first inoculation (4 × 6 L backpacks, 2 plates each of *Xtu* and *Xtt*).
July 25, 2025	First disease rating	Incidence and severity recorded for all plots (front and back) ~10 days after first inoculation.
August 1, 2025	Second disease rating	Incidence and severity recorded for all plots (front and back) ~10 days after second inoculation.
Throughout	Irrigation	Mist irrigation is applied to promote disease development.
	Combine harvest	Harvested plot material.
Post-harvest	Quality testing	TW (g/0.5 L) and TKW (g) measured.
Post-harvest	Data analysis	ANOVA for treatment and cultivar comparisons.
October 31, 2025	Final report submission	Results prepared for SaskOats.

Table A3. Monthly weather summary for Aberdeen, Saskatchewan, May – August 2025, showing mean temperature and precipitation from the Aberdeen weather station during the oat bacterial leaf streak (BLS) trials.

	TEMPERATURE °C				***Precipitation (mm)***	
Month	**Maximum**	**Minimum**	**Average**	**Avg Dew Pt**	**Water equivalent**	**LTA**
May	21.5	5.1	14.1	4.4	8.8	11.8
June	22.4	8.0	15.5	9.2	54.8	16.1
July	23.6	10.1	17.2	12.6	39.8	19.0
August	23.4	12.0	17.6	14.4	98.0	18.2

LTA: 1981-2010, 30-year long-term average values(mm) (Environment Canada, 2020).

Table A4: Dates and measurements of mist irrigation applied through misting system (Aberdeen, Saskatchewan, July – August 2025)

Date	*Millimeters*
10-JUL	5.1
13-Jul	10.2
16-Jul	10.2
17-Jul	5.1
18-Jul	5.1
29-Jul	10.2
30-Jul	5.1
31-Jul	10.2
01-Aug	10.2
03-Aug	15.2

Table A5. Reaction mix composition for *Xanthomonas translucens* LAMP assay.

Component	*Volume per reaction (µL)*
2x LAMP master mix	12.0
10x primer mix	2.5
DNA template	1.0
Sterile distilled water	9.0
Total volume	25.0

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