Varietal susceptibility of oat to bacterial leaf streak: a field and controlled-environment study.

Introduction

Agriculture plays an important role in the Canadian economy. Oats, for example, are grown in several provinces, including Alberta, Manitoba, and Saskatchewan (Statistics Canada, 2026a). As a result, oat is an important cereal crop in Canada, as it can be used for human consumption, animal feed, and food processing industry (Canadian Grain Commission, 2025). In addition, Canada plays a significant role in international agricultural trade through the export of crops such as oat.

In 2026, Saskatchewan accounted for approximately 40% of Canada's oat production, making it the country's largest oat-producing province (Agriculture and Agri-Food Canada, n.d.; Statistics Canada, 2026b). This can be explained by the fact that oat is well adapted to the climatic conditions of Saskatchewan, including warm summers and highly variable weather conditions. However, several biotic and abiotic stresses can affect oat yield (Pretorius et al., 2025). In this project, the focus was on the evaluation of plant responses to bacterial pathogens.

Although oats are not among the cereal crops most susceptible to diseases, they can still be affected by several important pathogens that cause diseases such as Pyrenophora leaf blotch, crown rust, stem rust, and Stagonospora leaf blotch (Bailey et al., 2003). Oat may also be affected by bacterial pathogens, resulting in diseases such as bacterial leaf streak (BLS) and black chaff (Duveiller et al., 1997).

This project aimed to evaluate response of oat varieties to different bacterial pathogens. Three widely used oat varieties were evaluated: CDC Haymaker, CDC Anson, and AC Morgan.

Objective

To determine whether five bacterial species can cause disease in oats.

Materials and Methods

Experimental site and design

Three oat varieties were included in this study: CDC Haymaker, CDC Anson, and AC Morgan. Each variety was tested against 10 bacterial isolates representing five bacterial species: *Xanthomonas cerealis* (SK128a and SK128b) and *Xanthomonas translucens*, including Xtt16a (pathovar *translucens*) and Xtu6 (pathovar *undulosa*), both reported to cause BLS in oat; *Pseudomonas syringae* (AB202502 and AB202503), the causing agent of halo blight; and *Pantoea agglomerans* (SK202503, SK202505, and SK202507), *Pantoea alli* (PD-897), which are considered emerging bacterial pathogens in crops across Canada.

The study was conducted under both field and controlled-environment conditions. The field experiment was established near the BLS nursery in Aberdeen, Saskatchewan, while the controlled-environment experiment was conducted in growth chambers at the University of Saskatchewan.

The field experiment consisted of four replicates of each of the three varieties, with each variety inoculated with the 10 bacterial isolates. The experiment followed a split-plot design. Within each replicate, varieties were randomly assigned to main plots, and bacterial inoculation treatments were subsequently randomized within each variety. The plants were sowed in hills, with each hill containing 15 to 30 seeds of the corresponding variety (Figure 1). Following seeding, all plants emerged successfully and developed uniformly throughout the growing season (Appendix).



Figure 1. Field experiment was planted in hills using a split plot design. Each hill consisted of 15 to 30 seeds of a single variety.

The controlled-environment experiment followed the same split-plot design as the field trial, with four replicates of the three varieties evaluated against the 10 bacterial isolates. Each replicate consisted of one pot containing four seedlings of the corresponding variety. The entire experiment was repeated four times (Figure 2).



Figure 2. Controlled-environment experiment. Each replicate consisted of one pot with four seedlings of one variety inoculated with one bacterial isolate.

The growing conditions consisted of day and night temperatures maintained at 24°C and 17°C, respectively, with a photoperiod of 17 hours of light and 7 hours of darkness. Relative humidity was maintained at 50%. Plants were watered as needed, approximately every two days, depending on pot moisture requirements. Essential nutrients (nitrogen, phosphate and potassium) were also supplied to ensure appropriate plant growth and development.

Preparation of bacterial suspension

Cryovials containing each bacterial isolate were removed from the −80°C freezer. Using a sterile loop, an aliquot from each cryovial was streaked onto a WBC plate (Appendix) to obtain single colonies (Figure 3). The plates were then incubated at 27°C for three days.

Following the incubation, a single colony from each isolate was collected using a sterile cotton swab and streaked onto a fresh WBC plate to produce nine lawns (Figure 4). The newly prepared plates were subsequently incubated at 27°C for an additional three days to allow sufficient bacterial growth for inoculum preparation.



Figure 3. Single colony plate used to start the inoculum preparation.



Figure 4. Nine-streaks plate used to reach a concentration of 1×10^8 CFU/ml of bacterial suspension.

On the day of inoculation, bacterial suspensions were prepared and transferred into hand-spray bottles. To prepare the suspensions, a NaCl 0.85% buffer was prepared by dissolving 4.25 g of NaCl in 500 mL of distilled water. A small volume of the buffer was poured onto each nine-streaks plate, and an L-shaped spreader was used to scrape the bacterial growth and suspend the cells in the buffer. The resulting bacterial suspension was then transferred to hand-spray bottles and adjusted to a concentration of 1×10^8 CFU mL^{-1}. Ten separate hand-spray bottles were prepared, corresponding to the 10 bacterial isolates evaluate, to avoid cross contamination of the isolates (Figure 5).



Figure 5. Preparation of the bacterial suspensions for inoculation using different hand-spray bottles to avoid cross-contamination.

Inoculation

Plants were inoculated twice in the field, at two different growth stages: the flag leaf stage and the panicle emergence stage (dates in Appendix). Bacterial suspensions were prepared according to the procedure described above. Inoculations were performed under favourable environmental conditions, with no wind or rainfall occurring during the application. Following inoculation, a misting system was operated for at least two hours to increase relative humidity and promote bacterial infection.

Under controlled-environment conditions, bacterial suspensions were sprayed individually onto each plant only one time at seedling stage (Figure 7).



Figure 7. Inoculation of oat plants in the chambers using hand-spray bottles.

Following inoculation, growth chamber conditions were adjusted to favor symptom development. Relative humidity was increased to 80%, while temperature was maintained at 25°C throughout both day and night. In addition, transparent lids were placed over the plants for 24 hours immediately after inoculation to further increase humidity (Figure 8).



Figure 8. Installation of the lids in the inoculation chambers following inoculation.

Disease rating

For the field evaluations, two parameters were assessed: disease incidence, defined as the percentage of the plants showing symptoms, and disease severity, defined as the percentage of plant tissue affected by disease symptoms (Figure 9). For the controlled-environment experiment, disease severity was assessed by estimating the



Figure 9. Example of foliar symptoms observed in the field evaluation.

percentage of leaf area with bacterial symptoms on four leaves of each pot (Figure 10).



Figure 10. Example of foliar symptoms observed under the controlled-conditions evaluation.

In addition, we collected leaf samples showing these two types of symptoms in the field and cultured them on WBC medium to observe bacterial growth. This allowed us to see microorganisms present in the leaves.

Results and Discussion

We were able to observe that all three varieties developed foliar symptoms following exposure to all the bacteria under both field and controlled-environment conditions.

Because disease incidence and severity were positively correlated ($r = 0.75$, $P < 0.0001$), only disease severity data are presented in the main figures. Disease incidence results are provided in the Appendix. Disease severity varied among variety-isolate combination in the field (Figure 11) Across most isolates, CDC Haymaker exhibited greater disease severity than CDC Anson and AC Morgan, indicating increased susceptibility under field conditions. Disease severity ranged from 10% for isolate SK128a on the variety AC Morgan to 48.75% for the same isolate on CDC Haymaker. Analysis of variance

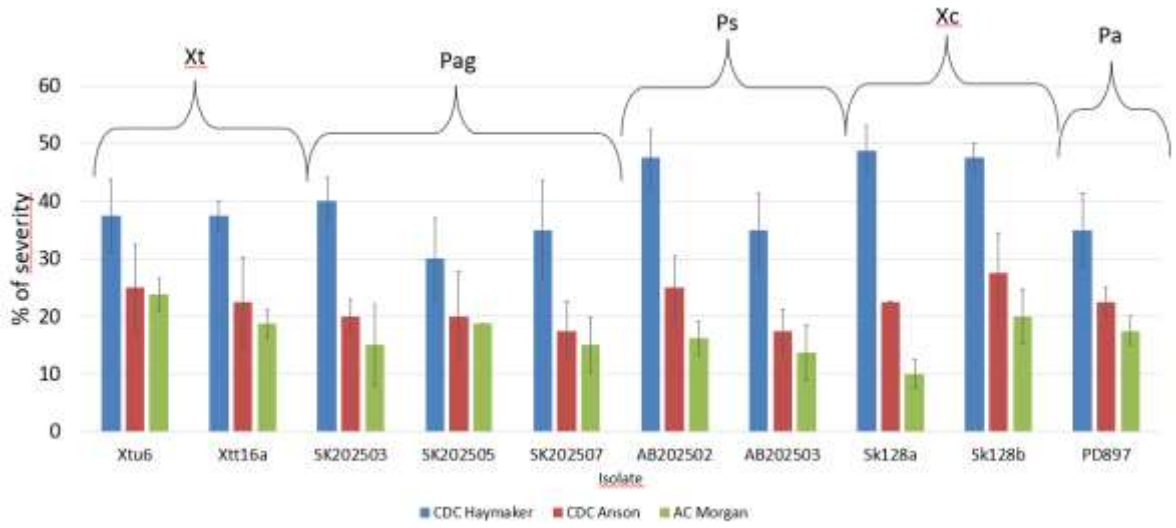


Figure 11. Disease severity (%) observed in the field

indicated that variety significantly affected disease severity(P = 0.0007), but bacterial isolates (P = 0.2491) and the variety × isolate interaction (P = 0.7498) were not significant (Table 1). These results suggest that differences in disease severity observed in the field were mostly associated with variety response rather than the isolates.

Table 1. Analysis of variance for disease severity under field conditions.

Effect	Num DF	Den DF	F value	Pr > F
Variety	2	6	30.77	0.0007
Isolate	9	81	1.30	0.2491
Variety × isolate	18	81	0.75	0.7498

Symptoms observed under field conditions were not characteristic of typical bacterial infections. Two distinct symptom types were identified. On CDC Haymaker and AC Morgan, symptoms consisted of large necrotic lesions with irregular margins that often expanded across most of the leaf area (Figure 12). In contrast, CDC Anson developed elongated, longitudinal lesions that followed the direction of the leaf veins (Figure 13).

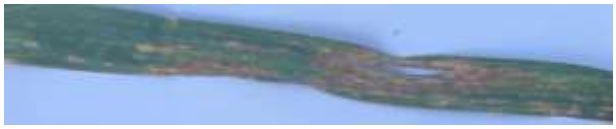


Figure 12. CDC Haymaker and AC Morgan showed dark necrotic symptoms with irregular borders that expanded across most of the leaf area.

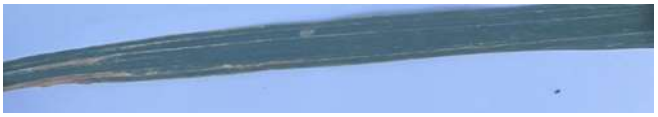


Figure 13. CDC Anson showed elongated chlorotic symptoms focused mostly on the tip of the leaves.

Isolation from symptomatic leaf tissue revealed both yellow and white bacterial colonies, as well as colonies with distinct morphologies (Figure 14). The presence of multiple microorganisms suggests that symptoms observed in the field may not have been exclusively associated with bacterial leaf streak pathogens.



Figure 14. Photos of the leaves plating

Disease severity under controlled conditions was generally lower than that observed in the field (Figure 15). Severity values ranged from 0.64% for isolate PD897 on AC Morgan to 22.19% for isolate SK202503 on CDC Haymaker.

Unlike the field evaluation, analysis of variance revealed significant effect of bacterial isolate ($P < 0.0001$) and the variety × isolate interaction ($P < 0.0001$) on disease severity, while the main effect of the variety was not significant ($P = 0.1008$) (Table

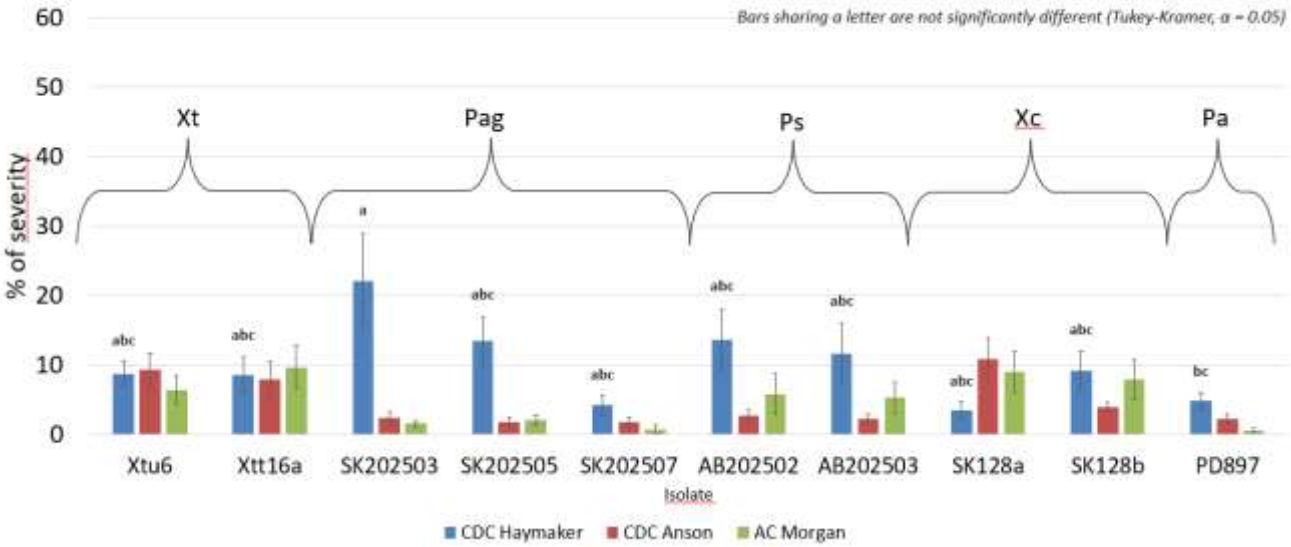


Figure 15. Disease severity (%) observed under controlled conditions. Need to define the abbreviations: Xt, Pag, Ps, Xc and Pa.

2). These results indicate that disease development under controlled conditions depended on the specific variety × isolate combination.

Table 2. Analysis of variance for disease severity under controlled-environment conditions.

Effect	Num DF	Den DF	F value	Pr > F
Variety	2	6	3.45	0.1008
Isolate	9	431	4.62	< 0.0001
Variety × isolate	18	431	2.89	< 0.0001

Under controlled-environment conditions, several symptoms characteristic of bacterial infections were observed, including water-soaking, chlorosis, greasy appearance of the leaf tissue, and elongated streaks (Figure 16). Symptoms were consistent across all three varieties.



Figure 16. Symptoms observed under controlled conditions were typical of bacterial infections.

Overall, disease severity was greater under field conditions than in the growth chambers.

Conclusion

All bacterial isolates evaluated in this study were able to induce symptoms characteristic of bacterial infection on all varieties under controlled-environment conditions. In contrast, typical bacterial symptoms were not observed under field conditions, where symptom expression differed significantly from that observed in the growth chambers.

The difference between field and controlled-environment results may be caused by several factors, including differences in plant growth stage at inoculation and assessment, as well as the potential influence of other microorganisms present in the field. Those factors may have affected symptom development and disease severity.

Across both experiments, CDC Haymaker showed higher susceptibility than CDC Anson and AC Morgan. Although all isolates were pathogenic under controlled conditions, severe BLS-like symptoms have not yet been consistently reproduced on oat. More research is needed to better understand symptoms development under field conditions and to clarify the role of these bacterial species in oat diseases.

Appendix

Wilbrink's boric acid-cephalexin (WBC)

(Duveiller *et al.*, 1997) semi-specific media for *Xanthomonas translucens* isolation

Ingredient	For 1 L	For 0.5 L (for 1 L bottles)
Bacto peptone	5.00 g	4.00 g
Sucrose	10.00 g	8.00 g
K_2HPO_4	0.50 g	0.40 g
$MgSO_4 \bullet 7H_20$	0.25 g	0.20 g
Na_2SO_3 (anhydrous)	0.05 g	0.04 g
Agar	15.00 g	12.0 g
Distilled water	850.0 ml	680.0 ml

Mix with the following solution **autoclaved separately:**

Ingredient	For 1 L	For 0.5 L (for 1 L bottles)
Boric acid	0.75 g	0.6 g
Distilled water	150.00 ml	120.0 ml

Summary of field activities schedule

Activities	Dates
Seeding	16 June
Weed control	28 July
First inoculation	4 August
Second inoculation	11 August
Disease severity and incidence evaluation	20 August

Bacterial isolates tested

Isolate	Bacterial species
SK128a	*Xanthomonas cerealis*
SK128b	*Xanthomonas cerealis*
SK202503	*Pantoea agglomerans*
SK202505	*Pantoea agglomerans*
SK202507	*Pantoea agglomerans*
PD-897	*Pantoea allii*
AB202502	*Pseudomonas syringae*
AB202503	*Pseudomonas syringae*
Xtt16a	*Xanthomonas translucens* pv. *translucens*
Xtu6	*Xanthomonas translucens* pv. *undulosa*

Split-plot design randomization

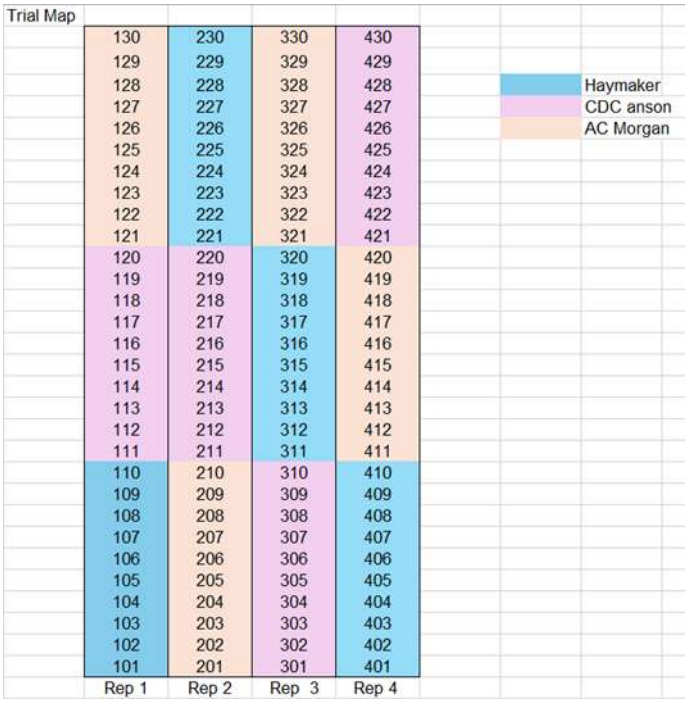


Figure 1A. Randomization of the four replicates in the field screening. Highlighted in blue are all the Haymaker hills, in pink all the CDC Anson hills, and in orange all the AC Morgan hills.

Table of incidence results

Isolate	CDC Haymaker	CDC Anson	AC Morgan
Xtu6	57.5 ± 6.3	27.5 ± 6.3	16.3 ± 5.5
Xtt16a	50.0 ± 4.1	27.5 ± 4.8	16.3 ± 5.5
SK202503	52.5 ± 6.3	32.5 ± 8.5	17.5 ± 2.5
SK202505	52.5 ± 4.8	37.5 ± 8.5	18.8 ± 7.7
SK202507	47.5 ± 8.5	32.5 ± 10.3	20.0 ± 7.1
AB202502	75.0 ± 2.9	40.0 ± 11.5	16.3 ± 8.0
AB202503	55.0 ± 2.9	17.5 ± 4.8	15.0 ± 5.0
SK128a	55.0 ± 12.6	30.0 ± 7.1	10.0 ± 0.0
SK128b	60.0 ± 4.1	25.0 ± 6.5	25.0 ± 15.0
PD897	50.0 ± 7.1	30.0 ± 9.1	27.5 ± 8.5
Mean	**55.5**	**30.0**	**18.3**

References

Agriculture and Agri-Food Canada. (n.d.). *Reports and statistics data for Canadian principal field crops*. Government of Canada. Retrieved October 5, 2026, from https://agriculture.canada.ca/en/sector/crops/reports-statistics

Bailey, K. L., Gossen, B. D., Gugel, R. K., & Morrall, R. A. A. (Eds.). (2003). *Diseases of field crops in Canada* (3rd ed.). Canadian Phytopathological Society.

Canadian Food Inspection Agency. (2023a). *CDC Anson* [Plant breeders' rights variety description: Oat]. Government of Canada. https://active.inspection.gc.ca/english/plaveg/pbrpov/cropreport/oat/app00012569e.shtml

Canadian Food Inspection Agency. (2023b). *CDC Haymaker* [Plant breeders' rights variety description: Oat]. Government of Canada. https://active.inspection.gc.ca/english/plaveg/pbrpov/cropreport/oat/app00008789e.shtml

Canadian Grain Commission. (2025). *Quality of western Canadian oats in 2025*. Government of Canada. https://grainscanada.gc.ca/en/grain-research/grain-harvest-export-quality/oats/2025/harvest-quality-report-oats-2025.html

Duveiller, E., Fucikovsky, L., & Rudolph, K. (Eds.). (1997). *The bacterial diseases of wheat: Concepts and methods of disease management*. CIMMYT.

Pretorius, C. J., Steenkamp, P. A., & Dubery, I. A. (2025). Metabolome profiling dissects the oat (*Avena sativa* L.) innate immune response to *Pseudomonas syringae* pathovars. *PLoS ONE, 20*(2), e0311226. https://doi.org/10.1371/journal.pone.0311226

Statistics Canada. (2026a, June 30). Principal field crop areas, June 2026. *The Daily*. https://www150.statcan.gc.ca/n1/daily-quotidien/260630/dq260630b-eng.htm

Statistics Canada. (2026b). *Table 32-10-0359-01: Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units* [Data table]. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210035901