Genetic tests accelerate detection and mitigate the risk of herbicide-resistant weeds in Canada

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Introduction

Crop production in Canada is significantly affected by herbicide-resistant (HR) weeds. It is estimated that HR weeds cost Canadian farmers from $43M (e.g., in ON) to about $343M (e.g., SK) annually due to increased herbicide use and decreased yield and quality. Traditional dose-response methods using seeds planted in greenhouse to confirm HR in suspected weeds can take 6-12 months. Recently developed genetic tests use weed leaf tissue samples, from which DNA is extracted to determine if a mutation conferring resistance is present. Results can be sent back to farmers within 1-2 weeks of sampling, allowing in-season timely decision making about adjustments to weed management programs.

Since 2015, several projects supported by various funding agencies, and a vast collaborative network of federal, provincial and private researchers and laboratories are continuously contributing to a growing list of genetic tests to detect HR in weed species (Tables 1-4).

Development and Adoption

From the first tests performed in 2015 on group 2 resistant common ragweed, to-date, **94 quick genetic tests** were successfully made available to assist with identifying HR in **30 weed species** addressing resistance to **5 herbicide groups** (1, 2, 5, 9, and 14). Moreover, the tests offered as a **service to farmers in the last 9 years** are now available in several regions (Ontario, Quebec, Prairies and Maritimes). Genetic test results are typically validated using traditional dose-response assays.

Since 2018, through **signed agreements**, test protocols developed by AAFC scientists have been shared with the Pest Diagnostic Lab of QC Ministry of Agriculture, Fisheries, and Food; AAFC's Harrow Research and Development Centre; Harvest Genomics and TurnKey Genomics. These service labs receive leaf samples taken from suspected weeds in cropped fields, analyze them, and report results back to submitting farmers, supporting information-based weed management decisions at the field level.

Benefits and Impact

- Thousands of tests have been commercially conducted to-date for weed samples across **7 provinces** (ON, QC, MB, AB, SK, NB, PEI);
- The protocol sharing agreement between AAFC and provincial labs enable immediate use of such tools to **directly benefit farmers**;
- The genetic tests have determined **new HR mechanisms** and enabled detection of **multiple group resistance** in many weed spp.;
- These tests led to confirming **>770 HR populations** in Canada;
- Tests differentiating pigweed species have been instrumental in confirming **new cases of waterhemp** in ON, MB and QC;
- Diagnostic services based on these tests allow extension personnel to make **science-based management** recommendations to farmers;
- By supporting informed decision making at field level, these tests have improved the ability of the sector to effectively curb HR weeds through **quickly adapting in-season best control practices**;
- Field monitoring, along with early and quick detection enabled by using these tools contributes to **limiting the spread of HR weeds**;
- Genetic tests are more economical, being **much cheaper than conventional methods**, at an estimated 1 tenth of the cost.

Farmer testimonial: ***"The rapid response is greatly appreciated early in the season because producers can adjust their herbicide use and control resistant weed populations before becoming a nuisance in the field."***

Confirmed herbicide resistance target-site mechanisms identified in respective weed spp.

Table 1. Genetic tests developed by AAFC's Saint Jean-sur-Richelieu Research and Development Centre, QC

Weed species	Resistance to herbicide group	Resistance mechanism
Large crabgrass	1	ACCase gene amplification
Common chickweed	2	P197Q & P197S
Common ragweed#	2	W574L
Eastern black nightshade#	2	A205V
Giant foxtail	2	Unpublished
Lamb's quarters	2	W574L
Pigweed spp.*#	2	S653N, W574L, A122T, A205V, D376E, & S653T
Canada fleabane#	2	P197L
Common ragweed	5	V219I
Hair fescue	5	F255I
Lamb's quarters#	5	S264G
Pigweed spp.**#	5	A251V, S264G, V219I, F274V & F274L
Canada fleabane	9	P106S
Common ragweed	9	EPSPS2 mutation
Giant ragweed	9	EPSPS2 mutation
Waterhemp#	9	P106S & EPSPS gene amplification
Brassica spp. #	9	Event G73 presence or absence of transgene
Waterhemp#	14	ΔG210 in PPX2L
Brassica spp. #	-	Species identification test
Amaranthus spp. #	-	Species identification test
Waterhemp#	-	Sex determination test

* Pigweed spp. includes green pigweed, redroot pigweed tumble pigweed, waterhemp.
** Pigweed spp. includes green pigweed, tumble pigweed, waterhemp
# Adapted from published literature

Table 2. Genetic tests* developed or adapted by AAFC's Lethbridge Research and Development Centre, AB

Weed Species	Resistance to herbicide group	Resistance mechanism
Foxtail barley	1	I2041N
Green foxtail	1	I1781L, D2078G
Yellow foxtail	1	D2078G
Common chickweed	2	W574L
False cleavers	2	W574L, S653N
Kochia#	2	D376E, P197L/S/T, W574L
Japanese brome	2	P197L, P197T, W574L
Narrowleaf hawksbeard	2	P197H, P197S, P197T, W574L
Pale smartweed	2	P197L, W574L
Redroot pigweed	2	S653T, S653N, S653I
Russian thistle#	2	W574L
Stinkweed	2	S653N
Kochia#	9	EPSPS gene amplification
Downy brome	9	EPSPS gene amplification

* These tests have not been shared or adopted by local or provincial labs yet..
# Adapted from published literature.

Table 3. Genetic tests developed or adapted by Laboratoire de diagnostic en phytoprotection, MAPAQ, QC

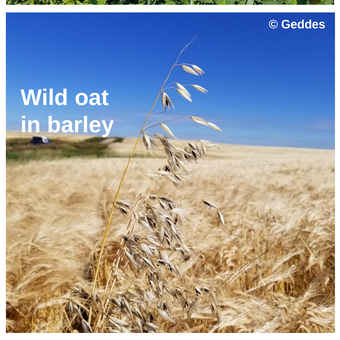
Weed Species	Resistance to herbicide group	Resistance mechanism
Wild oats#	1	I1781L, W1999C, W2027C, I2041N, I2041V, D2078G, C2088R, G2096A & G2096S
Common lamb's quarters	2	W574L
Kochia	2	P197X, A205X, D376X, W574L
Rough cocklebur	2	A122T, A205V, W574L
Canada fleabane	2	A122T, P197X, A205V, D376E, W574L, A653T
Giant ragweed	2	W574L*
Panicum spp.#	2	D376E
Wild oats#	2	A653T & A653N
Canada fleabane	5	S264G
Common ragweed	5	S264G
Giant ragweed	5	V219I*, S264G
Kochia	5	V219I, S264G
Canada fleabane	9	P106S
Kochia**	9	EPSPS gene amplification
Palmer's amaranth	9	EPSPS gene amplification
Waterhemp#	9	P106S
Pigweed spp.**#	14	R128I
Common ragweed	14	R98L, R98Q
Palmer's amaranth	14	G399A

* Adapted from the 'common ragweed' test developed by AAFC's Saint Jean-sur-Richelieu RDC, QC.
** Pigweed spp. includes waterhemp, palmer's amaranth, redroot pigweed and green pigweed.
# Adapted from published literature for all unless indicated otherwise

Table 4. Genetic Tests developed or adapted by Turnkey Genomics & Harvest Genomics

Weed Species	Resistance to herbicide group	Resistance mechanism
Italian ryegrass#	9	Pro (CCA) to Ser (TCA) mutation at Codon 106 in EPSPS (P106S)
Common ragweed	9	T102I, A103V, P106S sequencing assay
Giant ragweed	9	T102I, A103V, P106S sequencing assay
Redroot pigweed#	14	ΔG210 in PPX2L
Green pigweed#	14	ΔG210 in PPX2L
Common Ragweed#	14	Sequencing of PPX2 for R98L, R98Q
Plant Species ID#		DNA barcoding using primer set for MatK gene
Amaranth ID#		DNA barcoding using primer set for ITS gene
Amaranth spp.#	5	*psbA* sequencing for various mutations

Adapted from published literature



Conclusions

Farmers, agri-businesses and consultants who participated and/or received sample testing services and reporting back on the weed resistance situation in their fields were positive about the timely results and welcomed the in-season management recommendations. Users hope that testing service continues to be offered and expanded.

There are many more undocumented cases of HR weeds in Canada. The resistance mechanism is unknown for most of them. The major concern is their distribution and economic impact for farmers.

Widespread weed sampling and testing in various cropping systems across the country is essential to understand the status of HR, assess the threat and mitigate the risk. Knowing early where resistant biotypes are located, will improve sustainable weed management.

Contact the authors for the different references.

Acknowledgements

We greatly acknowledge all farmers, agri-businesses, consultants, research assistants and researchers who have participated in this highly valuable work. We also greatly appreciate the funding support received from the federal and provincial governments, agencies, crop protection product manufacturing companies and farmer associations.

Thank-you to our Project Supporters and Partners