Available Genetic Testing Enables Early Detection and Mitigation of Herbicide-Resistant Weeds

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Introduction

Crop production in Canada is significantly affected by herbicide-resistant (HR) weeds. It was estimated that HR weeds cost Western Canada growers about $530 million annually due to increased herbicide use and decreased yield and quality. Traditional methods using seeds planted in greenhouse pots to confirm HR in suspected weeds can take 6-12 month. Genetic tests use leaf tissue, from which DNA is extracted to determine if a mutation conferring resistance is present. Results can be sent to growers within 1-2 weeks of sampling, allowing in-season adjustments to weed management programs.

Since 2015, several multi-partner projects supported by various funding agencies, and a vast collaborative network of federal, provincial and private researchers and laboratory technicians are continuously contributing to a growing list of genetic tests to detect HR in weed species (Table 1, 2, 3, 4).

Development and Adoption

From the first tests performed in 2015 on group 2 resistant common ragweed, to-date, **64 genetic quick tests** were successfully made available to assist with identifying HR in **17 weed species** covering resistance to **5 herbicide groups** (1, 2, 5, 9, and 14) (Tables 1 to 4). Moreover, the tests offered as a **service to growers in the last 7 years** are now available in several regions (ON, QC, Prairies and Maritimes). Test results are typically validated using greenhouse dose-response assays.

Since 2018, through a **mutually signed agreement**, test protocols developed by AAFC, have been regularly shared with the Pest Diagnostic Lab of the QC Ministry of Agriculture, Fisheries, and Food; Harvest Genomics Lab in ON; and AAFC's Harrow Research and Development Centre. Leaf samples collected from suspected weeds in cropped fields are sent to these regional labs for analyses, and **growers are informed about their test results within 1-2 weeks.**

Benefits and Impact

- Over **3,900 genetic tests** have been conducted successfully to-date for weed samples across **6 provinces** (ON, QC, MB, AB, NB, PEI);
- The protocol sharing agreement between AAFC and provincial labs enabled immediate use of such tools to **directly benefit growers**;
- These tests have determined **new mechanisms of HR** and enabled detection of **multiple group resistance** in many weed spp.;
- These tests led to confirming **771 new 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 growers;
- By supporting informed decision making at field level, these tests have improved the ability of the sector to effectively address HR weeds through **quickly adapting in-season control practices**;
- Field monitoring, along with early and quick detection enabled by the use of these tools contributes to **limiting the spread of HR weeds**;
- Genetic tests are also more economical, as these are **much cheaper than conventional methods**, at an estimated 1 tenth of the cost.

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
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
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 Harvest Genomics Inc. Guelph, ON

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

Adapted from published literature

Table 3. Genetic Tests developed or adapted by Laboratoire d'expertise et de diagnostic en phytoprotection, MAPAQ, QC

Weed Species	Resistance to herbicide group	Resistance mechanism
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*
Canada fleabane	5	S264G
Common ragweed	5	S264G
Giant ragweed	5	V219I*, S264G
Kochia	5	V219I, S264G
Kochia**	9	EPSPS gene amplification
Palmer's amaranth	9	EPSPS gene amplification
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 Research and Development Centre, 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 AAFC's Lethbridge Research and Development Centre, AB

Weed Species	Resistance to herbicide group	Resistance mechanism
Russian thistle#	2	W574L
Pale smartweed	2	P197L, W574L
Kochia#	2	D376E, P197L/S/T, W574L
Kochia#	9	EPSPS gene amplification
Downy brome	9	EPSPS gene amplification

* These tests are recently made available and are ready to be handed over for adoption by local or provincial labs.
# Adapted from published literature.

Producer 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."***

Conclusions

Growers, agri-business and consultants who participated and received sample testing services and communication 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 continued testing is offered in the long term.

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 growers.

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.

Acknowledgements

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

Thank-you to our Project Supporters and Partners