Crop Profile for Spring Wheat in Canada, 2016

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Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Canada

Third Edition – 2019
Crop Profile for Spring Wheat in Canada, 2016
Catalogue No.: A118-10/30-2016E-PDF
ISBN: 978-0-660-30862-3
AAFC No.: 12904E

Second Edition –2012
Crop Profile for Spring Wheat in Canada, 2010
Catalogue No.: A118-10/30-2012E-PDF
ISBN: 978-1-100-20032-3
AAFC No.: 11695E

First Edition –2005
Crop Profile for Wheat in Canada
Catalogue No.: A118-10/16-2005E-PDF
ISBN: 978-1-100-20032-3

Electronic version available at www.agr.gc.ca/pmc-cropprofiles

Paru également en français sous le titre: « Profil de la culture du blé de printemps au Canada, 2016 »

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Preface

National crop profiles are developed by the Pest Management Program of Agriculture and Agri-Food Canada (AAFC). The national crop profiles provide baseline information on crop production and pest management practices and document the pest management needs and issues faced by growers. This information is developed through extensive consultation with stakeholders.

Information on pest management practices and pesticides is provided for information purposes only. No endorsement of any pesticide or pest control technique, discussed, is implied. Product names may be included and are meant as an aid for the reader, to facilitate the identification of pesticides in general use. The use of product names does not imply endorsement of a particular product by the authors or any of the organizations represented in this publication.

For detailed information on growing this crop, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile.

Every effort has been made to ensure that the information in this publication is complete and accurate. Agriculture and Agri-Food Canada does not assume liability for errors, omissions, or representations, expressed or implied, contained in any written or oral communication associated with this publication. Errors brought to the attention of the authors will be corrected in subsequent updates.

Agriculture and Agri-Food Canada gratefully acknowledges the contributions of provincial crop specialists, industry specialists and growers in the gathering of information for this publication.

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Crop Profile for Spring Wheat in Canada

Wheats (*Triticum* spp.) are grasses in the Poaceae family that are cultivated for their seed. The predominant wheats grown in Canada include common wheat or bread wheat, *Triticum aestivum*, and durum wheat, *Triticum turgidum* ssp. *durum*. Wheats may be classified into "spring" and "winter" types, depending on the season in which they are grown. "Spring" wheats are seeded in the spring and harvested in the fall. "Winter" wheats are seeded in the fall and harvested the following summer or early fall. Durum wheats are grown as spring wheat. This crop profile addresses spring wheat.

Spring wheat (*Triticum aestivum* and *T. turgidum* ssp. *durum*) is an iconic Canadian crop, first having been grown by pioneers in eastern Canada and Upper Canada, and later by those who opened the Canadian Prairie regions to agriculture. Currently, it remains one of the most important crops in Canada, and is grown on about 8.9 million hectares (including durum wheat).

All spring wheat varieties grown in Canada are assigned to "classes" by the Canadian Grain Commission based on protein content, milling quality, colour of the grain and other characteristics. (https://www.grainscanada.gc.ca/). Over 175 varieties, categorized into 12 spring wheat classes are grown in Canada. As the characteristics of each variety dictates the end use of the wheat, assigning a variety to a class enables marketing and sale of wheat for specific purposes and ensures the quality of grain shipments meet the needs of end users.

Wheat is a staple food, consumed throughout Canada and in about 125 countries worldwide. Wheat is processed into flour, cereal food and feed, bread, pasta and bakery products. Wheats with lower protein (gluten) content are considered to be "soft wheats" and are used for the baking of cookies, cakes and pastries. Wheats with a higher gluten content, are called hard wheats. Gluten is a protein which gives dough elasticity making it suitable for breads. Durum wheat has high protein content and is most suitable for processing into semolina flour that is used to make pasta and couscous. Certain wheat varieties with high starch and low protein content, that do not meet the quality requirements of milling classes, are used for animal feed or in the production of ethanol.

Wheat originated in Southwest Asia in the regions bordering Iran, Iraq, Syria and Turkey. Natural crosses among grasses and subsequent selection by humans resulted in the development of modern wheat. It's cultivation eventually spread across Europe, Asia and Africa.

Wheat was likely first introduced into Canada at Port Royal Nova Scotia in 1605 by European settlers. Throughout the 17th and 18th centuries, wheat was grown for food (subsistence) by settlers in Eastern Canada. Wheat was a dominant crop in Ontario (Upper Canada) from 1800 to 1860 and was exported both to Lower Canada (Quebec) and Britain. Wheat was introduced into western Canada in 1812 with the Selkirk settlers at the Red River Colony (Manitoba). European varieties of both winter and spring wheats were cultivated on the prairies throughout the 19th centuries with limited success due to severe winters and short growing seasons and the poor winter hardiness of available varieties. Throughout the 19th an early 20th centuries, the expansion of agricultural development in the west lead to the increased importance of wheat. In 1909, the cultivar 'Marquis', which was high yielding and superior to

other varieties available at the time, was released by Agriculture and Agri-Food Canada. 'Marquis' was considered the industry standard for hard red spring wheat and it remained so until 1988. The high quality of Marquis wheat gave Canada the reputation of being source of consistent superior quality wheat. A detailed history of wheat production in Canada is available from https://www.thecanadianencyclopedia.ca/en/article/history-of-agriculture.

Crop Production

Industry Overview

Spring wheat is Canada's largest crop being grown with a total production of 20.7 million metric tonnes in 2016. The total, gross, production value of Canadian wheat, (including spring wheat, durum classes and winter wheat) in 2016 was 7.045 billion dollars (FAOSTAT - http://www.fao.org/faostat/en/#data/QV). The wheat industry applies quality standards or grading classes that are recognized worldwide. Canada is the largest producer of high-protein milling wheat and its Canada Western Red Spring (CWRS) wheat class is recognized as a premium wheat for bread and pasta production.

Table 1. General production information, 2016

	All wheat[4]	All wheat except durum	Spring wheat	Durum wheat
Canadian Production[1]	32,139,900 metric tonnes 9,624,800 hectares (seeded)	24,378,000 metric tonnes 7,156,000 hectares (seeded)	20,705,200 metric tonnes 6,422,500 seeded (hectares)	7,761,800 metric tonnes 2,469,200 hectares (seeded)
Gross production value[2]	$7.1 billion	-	-	-
Total domestic use[3]	10,416,000 metric tonnes	7,905,000 metric tonnes	-	2,511,000 metric tonnes
Exports[3]	20,155,000 metric tonnes	15,621,000 metric tonnes	-	4,534,000 metric tonnes
Imports[3]	110,000 metric tonnes	99,000 metric tonnes	-	11,000 metric tonnes

[1]Statistics Canada. Table 32-10-0359-01 (Formerly CANSIM 001-0017) - Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units, annual, CANSIM (database accessed February 28, 2019).

[2]Food and Agriculture Organization of the United Nations. Value of Agricultural Production. FAOSTAT www.fao.org/faostat/en#data/QV

[3]Agriculture and Agri-Food Canada. Canada: Outlook for Principal Field Crops- Grains and oilseeds supply and disposition (October 19, 2018)

[4]All wheat includes spring wheat, durum wheat and winter wheat.

Production Regions

Spring wheat is grown in almost all provinces in Canada with the main areas of production being the prairie provinces. In 2016, 97% of the national area of production of spring wheat was located in the three prairie provinces, with Saskatchewan, Alberta and Manitoba responsible for 43%, 36% and 13% seeded area, respectively. The distribution of national production is presented in table 2.

Table 2. Distribution of Spring Wheat production in Canada, 2016[1]

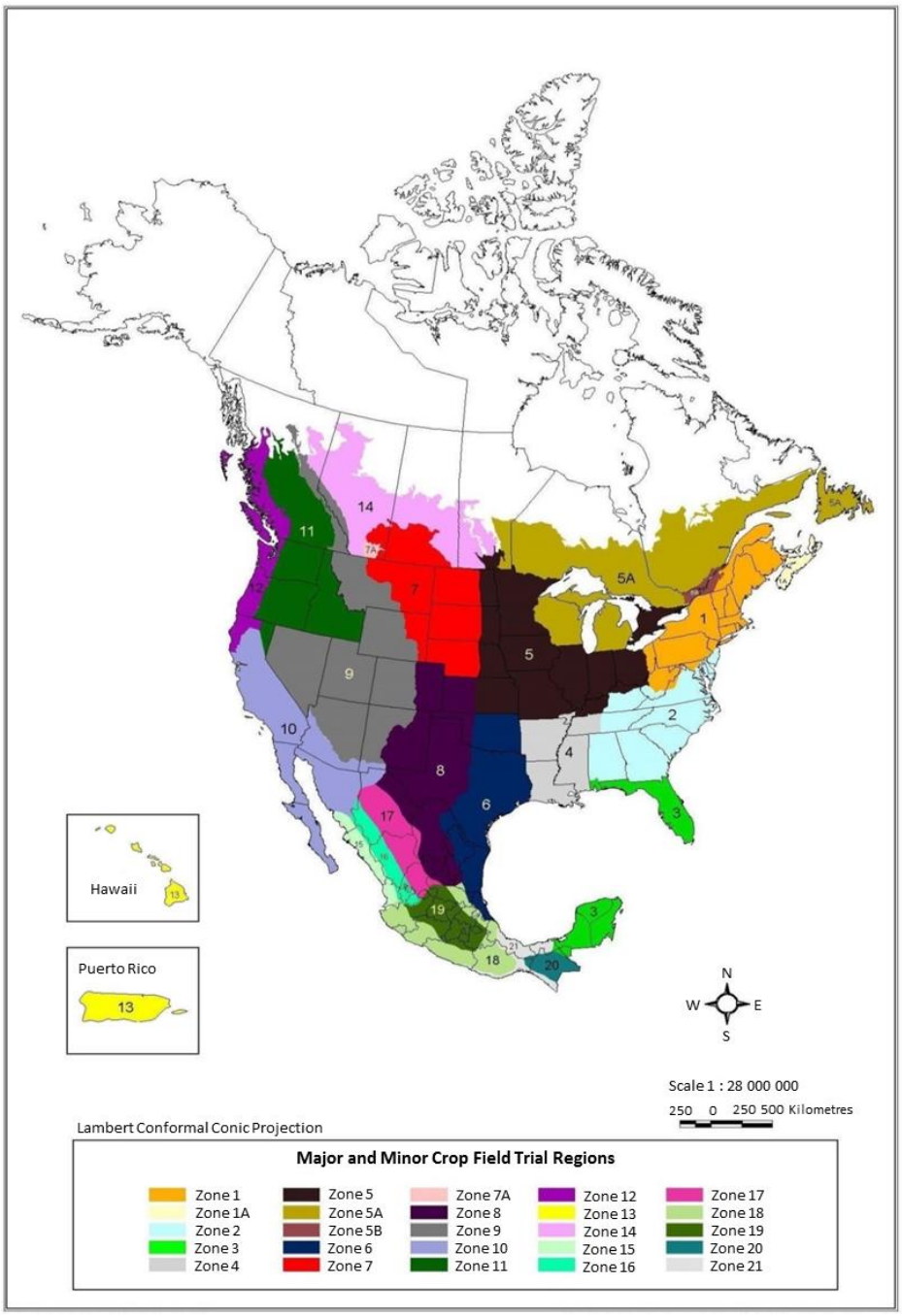
Production Regions	Spring wheat seeded area (2016) (hectares) (%)	Durum wheat (hectares) (%)	Winter wheat (seeded in fall) (hectares) (%)	Wheat, all (hectares) (%)
British Columbia	40,900 (<1%)	-	-	40,900 (<1%)
Alberta	2,318,300 (36%)	445,800 (18%)	78,00 (11%)	2,842,600 (29%)
Saskatchewan	2,780,200 (43%)	2,023,400 (81%)	101,200 (14%)	4,904,800 (51%)
Manitoba	1,143,700 (18%)	-	66,800 (9%)	1,210,500 (13%)
Prairie Provinces	6,242,200 (97%)	2,469,200 (100%)	246,500 (34%)	8,957,900 (93%)
Ontario	48,800 (1%)	-	459,800 (63%)	508,600 (5%)
Quebec	76,000 (1.1%)	-	19,800 (3%)	95,800 (1%)
New Brunswick	3,800 (<1%)	-	-	3,800 (<1%)
Nova Scotia	-	-	3,200 (<1%)	3,200 (<1%)
Prince Edward Island	10,800 (<1%)	-	3,800 (<1%)	14,600 (<1%)
Maritimes	14,600 (<1%)	-	7,000 (1%)	21,600 (<1%)
Newfoundland and Labrador	-	-	-	-
Canada	**6,422,500**	**2,469,200**	**733,100**	**9,624,800**

[1]Statistics Canada. Table 32-10-0359-01 Estimated areas, yield, production, average farm price and total farm value of principle field crops, in metric and imperial units (accessed: February 28, 2018).

North American major and minor field trial regions

Major and minor crop field trial regions (Figure1) were developed following stakeholder consultation and are used by the Pest Management Regulatory Agency (PMRA) in Canada and the United States (US) Environmental Protection Agency (EPA) to identify the regions where residue chemistry crop field trials are required to support the registration of new pesticide uses. The regions are based on a number of parameters, including soil type and climate but they do not correspond to plant hardiness zones. For additional information, please consult the PMRA Regulatory Directive 2010-05 "*Revisions to the Residue Chemistry Crop Field Trial Requirements"* (www.hc-sc.gc.ca/cps-spc/pubs/pest/_pol-guide/dir2010-05/index-eng.php).

Figure 1. Common zone map: North American major and minor field trial regions[1]



[1]Produced by: Spatial Analysis and Geomatics Applications, Agriculture Division, Statistics Canada, February 2001.

Cultural Practices

In the prairie region, spring wheat is typically grown as part of diverse crop rotations that include canola, pulse crops (e.g. dry bean, chickpea, field pea or lentil) and other cereal crops (e.g. barley, rye or oats). Spring wheat on the prairies is typically grown using no-till management.

Outside the prairie region, spring wheat is typically grown under a conventional tillage system. In central and Atlantic Canada, spring wheat is grown as a rotational crop in a variety of cropping systems including small grain-oilseed rotations, forage-based rotations, corn-soybean rotations and potato/vegetable-based rotations.

Spring wheat is a widely adapted crop and can be grown on various soil types, ranging from well drained sandy loam to heavy clay, and does best when planted in fields that have not been seeded to a wheat crop in the previous year. Varietal selection is based on desired wheat class, performance under local conditions and other agronomic factors. Spring wheat is seeded as early as possible to maximize yield potential. The availability of soil moisture in the spring, longer spring days and avoidance of mid-summer heat and drought stress all contribute to improved yield in early seeded wheat. Optimum seeding rates vary with the class of wheat being grown and with seed characteristics (size, germination percentage) and available moisture. Higher seeding rates increase plant densities which results in fewer tillers and more uniform flowering and maturation of the crop and higher yield potential. However higher plant densities have an increased risk of lodging and disease development.

Fertilizer is applied in below-surface bands that give the crop preferential access to the nutrients with rates based on soil analyses. The availability of sufficient nitrogen affects both yield and protein content of wheat.

Wheat may be harvested by swathing when kernels have 35% or less moisture content or can be directly combine harvested if moisture content is 14%. Wheat may be stored at 14.5% moisture.

Table 3. Spring wheat production and pest management schedule in Canada

TIME OF YEAR	ACTIVITY	ACTION
Winter (November to late March)	Planning	Crop planning; sourcing of seed supplies
April	Weed Management	Calibration of application equipment
	Plant Care	Preparation of seed and fertilizer for planting; calibration of seeding equipment
	Soil Care	Soil testing (if not done the previous fall)
May	Weed Management	Pre-seeding herbicide application or cultivation prior to seeding for weed control
	Plant Care	Seeding
	Soil Care	Fertilization according to soil test
June	Weed Management	Field scouting for weeds; application of herbicide as required
July	Plant care	Monitoring crop development
	Disease Management	Field scouting for all diseases; application of fungicides as required
	Insect Management	Field scouting for all insects; application of insecticides as required
August	Plant Care	Monitoring of seed set to estimate yield potential
	Disease Management	Continuation of field scouting for all diseases; fungicide application as required
	Weed Management	Scouting of fields for perennial weeds; application of pre-harvest herbicide treatments as required
September	Plant Care	Crop harvest when 75 percent of seeds have reached maturity
	Soil care	Harrowing of fields after harvest for residue management
October	Soil care	Soil testing
	Weed Management	Field scouting for weeds; herbicide application as required

Abiotic Factors Limiting Production

Moisture

Sufficient moisture is required throughout the growing season to achieve maximum yields of wheat. Insufficient moisture at critical periods can result in reduced growth and tillering, flower abortion and poor head filling. Seeding at the proper depth and seeding early will facilitate the efficient use of soil moisture reserves and allow for crop growth before the hotter and drier growing conditions of summer occur. No-till farming practices will reduce evaporation rates and conserve soil moisture. In regions where irrigation is used, proper irrigation management will ensure the maximum yield response based on nutrient and moisture availability.

Fall frost

Fall frost can adversely affect seed yield and quality of immature spring wheat crops, with the degree of damage depending on both the maturity of the crop and the severity of the frost. Seed in affected heads may show no visible injury, injury to the bran or shrivelling of the whole seed. Seed damaged by frost produces seedlings with reduced vigour that are more susceptible to seedling diseases and are more susceptible to weed competition throughout the growing season.

Lodging

Lodging, or a falling over of the crop prior to harvest, results from physical characteristics of the plants in combination with environmental conditions such as wind, strong rain or hail. Tall, weak stemmed cultivars are more prone to lodging than shorter, semi-dwarf varieties that have stiffer straw. Depending on variety, the condition may be more severe under high nitrogen fertilization, high moisture and high plant densities. Lodging most commonly occurs early in the season. At this time affected plants form “elbow” joints at lower stem nodes and resume upright growth. Stem breakage is typical of lodging that occurs later in the season as the stems tend to be more brittle during that period.

Lodging affects grain filling and plant maturation and can have a significant effect on yield. Harvesting costs may be increased as a result of having to slow the combine speed due to green, immature kernels. The potential for lodging can be reduced through the use of semi-dwarf varieties (if suited to the region) and ensuring the crop is sown at recommended plant spacing and depth.

Physiological leaf spot

Wheat varieties differ in their susceptibility to physiological leaf spot, a condition that most commonly occurs on winter wheat. Symptoms begin as small yellow (chlorotic) spots, one to-three millimeters in diameter, on the upper leaves, that eventually develop dark brown centers. Physiological leaf spot is often confused with leaf spot diseases like tanspot and stagonospora or septoria leaf spots.

Physiological leaf spots develop from the interaction of genetic factors with environmental conditions during the growing season. A low chloride level in the soil appears to be a contributing factor. Physiological leaf spots often occur following extended cloudy periods interspersed with few sunny days.

Diseases

Key issues

- Alternatives to triazole fungicides are required to facilitate resistance management for Fusarium head blight (FHB) pathogens.
- Producers require access to integrated approaches for more robust and effective disease management.
- There is a need for alternative cropping options that provide economic returns, fit into producer's cropping programs and which make adherence to good crop rotation for disease management more economically attractive.

Table 4. Occurrence of diseases in spring wheat production in Canada[1,2]

Disease	Alberta	Saskatchewan	Manitoba
Seedling blights, root rots			
Seedling blight, common root rot, spot blotch			
Tan spot			
Septoria/ Stagonospora leaf blotch			
Stem rust			
Leaf rust			
Stripe rust			
Ergot			
Fusarium head blight (scab)			

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest is present and of concern, however little is known of its distribution, frequency and importance.

Pest not present.

Data not reported.

[1]Source: Spring wheat stakeholders in reporting provinces (Alberta, Manitoba and Saskatchewan); the data reflect the 2016, 2015 and 2014 production years.

[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 5. Adoption of disease management practices in spring wheat production in Canada[1]

Practice / Pest		Seedling blights	Leaf spot diseases	Rust diseases	Fusarium head blight (scab)
Avoidance	Varietal selection / use of resistant or tolerant varieties				
	Planting / harvest date adjustment				
	Rotation with non-host crops				
	Choice of planting site				
	Optimizing fertilization for balanced growth and to minimize stress				
	Minimizing wounding and insect damage to limit infection sites				
	Use of disease-free propagative materials (seed, cuttings or transplants)				
Prevention	Equipment sanitation				
	Canopy management (thinning, pruning, row or plant spacing, etc.)				
	Manipulating seeding / planting depth				
	Irrigation management (timing, duration, amount) to minimize disease infection periods and manage plant growth				
	Management of soil moisture (improvements in drainage, use of raised beds, hilling, mounds, etc.)				
	End of season or pre-planting crop residue removal / management				
	Pruning out / removal of infected material throughout the growing season				
	Removal of other hosts (weeds / volunteers / wild plants) in field and vicinity				

…continued

Table 5. Adoption of disease management practices in spring wheat production in Canada[1] (continued)

Practice / Pest		Seedling blights	Leaf spot diseases	Rust diseases	Fusarium head blight (scab)
Monitoring	Scouting / spore trapping				
	Maintaining records to track diseases				
	Soil analysis for the presence of pathogens				
	Weather monitoring for disease forecasting				
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of diseases				
Decision making tools	Economic threshold				
	Use of predictive model for management decisions				
	Crop specialist recommendation or advisory bulletin				
	Decision to treat based on observed disease symptoms				
	Use of portable electronic devices in the field to access pathogen / disease identification / management information				

…continued

Table 5. Adoption of disease management practices in spring wheat production in Canada[1] (continued)

	Practice / Pest	Seedling blights	Leaf spot diseases	Rust diseases	Fusarium head blight (scab)
Suppression	Use of diverse product modes of action for resistance management				
	Soil amendments and green manuring involving soil incorporation as biofumigants, to reduce pathogen populations				
	Biopesticides (microbial and non-conventional pesticides)				
	Controlled atmosphere storage				
	Targeted pesticide applications (banding, spot treatments, use of variable rate sprayers, etc.)				
	Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms				

This practice is used to manage this pest by at least some growers in the province.

This practice is not used by growers in the province to manage this pest.

This practice is not applicable for the management of this pest

Information regarding the practice for this pest is unknown.

[1]Source: Spring wheat stakeholders in reporting provinces (Alberta, Saskatchewan and Manitoba); the data reflect the 2016, 2015 and 2014 production years.

Fusarium Head Blight (*Fusarium graminearum and Fusarium* spp.)

Pest Information

Damage: Fusarium head blight (FHB) kills florets and causes poor filling of seeds, resulting in a loss in yield. FHB reduces seed germination and affects milling quality of the grain, and thus is a serious concern in grain marketing. Infected spikelets become bleached, and a pink discolouration may develop at the base of the glumes. FHB may also contaminate the grain with deoxynivalenol (DON) a mycotoxin to which livestock are highly sensitive.

Life Cycle: Several fusarium species contribute to FHB, however *F. graminearum* is the most important species involved. FHB affects many hosts including wheat, barley, oats, corn, rye and wild grasses. FHB pathogens overwinter in crop residue and in infected seed. Seedlings can be infected at emergence. Both ascospores (sexually produced spores) and conidia (asexual spores) are produced in overwintered crop debris and are spread by rain or wind to florets and cause new infections. The disease thrives under warm, humid conditions during flowering. FHB may be introduced into new areas on contaminated seed.

Pest Management

Cultural Controls: The use of disease-free seed and seed treatments favours seed germination, reduces the potential for seedling blights and reduces the likelihood of introducing the disease to new fields. Crop rotation out of cereal crops for one to two years enables the breakdown of crop residue and helps reduce disease carry-over between crops. The avoidance of planting wheat in close proximity to fields which had significant FHB the previous year will also help to reduce disease carry-over. Eliminating susceptible weeds such as quack grass and barnyard grass will eliminate potential sources of disease. Restricting irrigation during flowering will help reduce humidity in the crop canopy creating conditions less favourable to infection. Higher seeding rates which result in less tillering and shorter flowering periods will reduce the period during which a crop is susceptible to infection. Additional management practices for fusarium head blight are listed in *Table 5. Adoption of disease management practices in spring wheat production in Canada.*

Resistant Cultivars: Wheat varieties vary in their susceptibility to FHB. Information on susceptibility is available from Provincial Ministries of Agriculture.

Issues for Fusarium Head Blight

1. New cultivars with resistance to FHB are required for use as part of an over-all integrated disease management approach.
2. There is a need for reduced risk pesticide alternatives for control of the foliar phase of the disease.
3. Producers need new fungicides with modes of action that differ from those of the triazole family for resistance management.

4. There is a need to facilitate grower adoption of an integrated approach to this disease including: the use of rotations, early seeding, the use of resistant cultivars and timely harvesting.

Seed Rots, Seedling Blights, and Root Rots (*Fusarium* spp., *Pythium* spp., and *Rhizoctonia* spp.)

Pest Information

Damage: This group of diseases affects seeds and seedlings early in the growing season. Infected seeds may not germinate and seedlings fail to emerge or emerge discoloured and of low vigour. Plants attacked at later stages of growth develop root rot. Uneven emergence and poor stands are typical of this group of diseases. Information about rots and blights caused by Fusarium is also provided under the Fusarium head blight section above.

Life Cycle: Seedling blights are more prevalent during cool, wet conditions in spring that slow seed germination and seedling growth. The pathogens survive in infected crop debris and in soil and invade plant tissues under suitable conditions of moisture and temperature. Pathogens may be spread through the movement of infested soils and on infected seeds.

Pest Management

Cultural Controls: Delaying seeding until soils have warmed up to the point where rapid emergence can occur, may be used to avoid early infection. The use of clean, disease-free seed helps minimize the incidence of the diseases. Several non-cereal crops are also hosts for fusarium so rotating out of these crops will help reduce these pathogenic species. Maintenance of adequate fertility levels can help to reduce disease impact. Additional management practices for seedling blights are listed in *Table 5. Adoption of disease management practices in spring wheat production in Canada.*

Resistant Cultivars: None available.

Issues for Seed Rots, Seedling Blights, and Root Rots

1. There is concern that the continued use of triazole fungicides may result in resistance development in some pathogens. There is a need to develop fungicidal treatments with modes of action that differ from that of the triazole fungicides, for resistance management.
2. There is a need for the development of cultivars with resistance to seedling blight diseases.

Seedling Blight, Common Root Rot and Spot Blotch (*Cochliobolus sativus*)

Pest Information

Damage Cochliobolus sativus causes root and crown rots, leaf spots (spot blotch) and seedling blights. Brown spots develop on the coleoptiles of seedlings which may eventually be killed. On more mature plants, lesions develop on lower stems and leaf sheaths, roots, crowns and sub-crown internodes. Yields are reduced as infections result in premature ripening of the plants, fewer tillers, fewer heads and poorly filled seed.

Life Cycle: The pathogens survive on seed and as spores in soil and crop residues. Spores remain viable in the soil for many years and may be spread by wind, water and the movement of soil. Spores germinate in the presence of root exudates of host plants and infect plant tissues. Spores are produced in infected tissues and contribute to further spread of the disease. The disease is more prevalent under hot, dry conditions.

Pest Management

Cultural Controls: Disease can be reduced through the planting of disease-free seed and by following crop rotations with non-host crops. Infection of the sub-crown internode can be reduced by shallow seeding. Planting into warm, well drained soils that favour germination and ensuring adequate nutrient levels will also help in minimizing the impact of this disease. Additional management practices for seedling blights are listed in *Table 5. Adoption of disease management practices in spring wheat production in Canada.*

Resistant Cultivars: Wheat cultivars vary in their susceptibility to this disease.

Issues for Seedling Blight, Common Root Rot and Spot Blotch

None identified

Septoria / Stagonospora Leaf Blotch [*Septoria tritici* (*Mycospaerella graminicola)* and *Stagonospora nodorum*]

Pest Information

Damage: Septoria tritici symptoms first appear as yellow flecks on lower leaves. The flecks enlarge to become yellow, greyish white or brown blotches with chlorotic halos that are delimited by veins. Infected leaves may be killed. Leaf spots caused by Stagonospora are light coloured with a dark margin, encircled with a chlorotic halo. *S. nodorum* may also infect glumes and nodes. Disease is more severe during wet seasons.

Life Cycle: The pathogens overwinter on crop residue and on winter wheat plants. *S. nodorum* may be seedborne. Conidia (asexual spores) and ascospores (sexual spores) produced in crop residues, give rise to new infections on seedlings in the fall (winter wheat) or spring (spring wheat). Disease spread is by wind (ascospores) and rain splash (conidia). Throughout the growing season, conidia produced in pycnidia on diseased tissues may be rain-splashed to new tissues where they initiate new infections. Disease development is favoured by warm wet weather.

Pest Management

Cultural Controls: Disease carry-over between crops can be reduced by including non-host crops in crop rotations and by burying crop residue. Delaying the planting of winter wheat in the fall may reduce early infections by avoiding fall periods of ascospore release. Additional management practices for leaf spot diseases are listed in *Table 5. Adoption of disease management practices in spring wheat production in Canada.*

Resistant Cultivars: Wheat varieties differ in their susceptibility to septoria diseases.

Issues for Leaf Spot Complex

1. There is a need for the development of resistant varieties for all spring wheat classes.
2. There is a need to establish optimal crop stage and timing for fungicide application to improve treatment efficacy.

Tan Spot (*Pyrenophora tritici-repentis*)

Pest Information

Damage: The first symptoms of tan spot are small dark lesions on lower leaves. The spots eventually become tan and oval with dark centres and may develop a yellow halo. Lesions may coalesce to form irregular blotches and leaf tissues may be killed. Heavy infections of the flag leave and head tissues can result in yield reductions. Infected seed develop red discolouration and become shrivelled.

Life Cycle: In the early spring, spores are produced in crop residue and winter wheat plants, the overwintering sites of the pathogen. The spores are windblown to new wheat plants where under suitable conditions of leaf moisture and temperature, new infections occur. Warm, humid (wet) weather is favourable for infection. Spores produced in mature infections are spread to new leaves through wind or rain splash.

Pest Management

Cultural Controls: Planting of non-host crops such as other cereals (rye and barley are affected to a much lesser extent and oats are resistant), corn, soybeans and alfalfa, for at least two

years following wheat will facilitate the breakdown of crop debris and reduce carry-over of the disease. Seeding wheat with a wider row-spacing will reduce humidity in the crop canopy, creating conditions less suitable for disease development. Additional management practices for leaf spot diseases are listed in *Table 5. Adoption of disease management practices in spring wheat production in Canada1*.

Resistant Cultivars: Most wheat cultivars grown in Canada are susceptible to tan spot.

Issues for Tan Spot Complex

1. There is a need for the development of resistant cultivars for all spring wheat classes. There is a need to establish the ideal crop stage and timing for fungicide application to optimize treatment efficacy.

Stem Rust (*Puccinia graminis* f. sp*. tritici*)

Pest Information

Damage: Stem rust causes the development of brick-red pustules of urediniospores on the stems of wheat. Leaves may also be affected. The pustules eventually darken with the production of teliospores. Stem rust has the potential to reduce crop yields as infection results in fewer tillers and fewer seeds per head. Stem rust results in a reduction in quality (shrivelled seed) to a greater degree than leaf rust. Historically, stem rust has been one of the most devastating diseases of wheat in Canada.

Life Cycle: Stem rust overwinters as mycelium or uredinia on wheat plants in the southern United States. The disease progresses northward by successively infecting susceptible winter and spring wheat. Spores are carried into Canada on wind currents with the first symptoms of disease developing usually in mid to late June. Urediniospores are produced in pustules in infected foliage and stems. When the pustules rupture, spores are released into the air and spread to other plants. High moisture and humidity levels causes the disease to spread more quickly. Barberry is the alternate host for stem rust and is required for the completion of sexual reproduction of *Puccinia graminis*. Sexual reproduction involves the development of the pathogen through five spore stages and is important because it provides an opportunity for new pathogenic strains to develop. Spore types produced on barberry can also cause early season infections of wheat crops.

Pest Management

Cultural Controls: Programs to eradicate common barberry, an ornamental introduced into North America from Europe, since the early 1900's has helped to reduce early season infections and the potential for the development of new races of the pathogen. Early seeding will facilitate crop growth early in the season and aid in avoiding rust infection early in wheat plant

development. Additional management practices for rust diseases are listed in *Table 5. Adoption of disease management practices in spring wheat production in Canada*..

Resistant Cultivars: Public breeding programs historically targeted the development of rust resistant varieties. The use of varieties that are resistant to races of stem rust is a key component to managing the disease. Most spring wheat varieties in all wheat classes are rated to have good or very good resistance to stem rust.

Issues for Stem Rust

1. The potential introduction of the stem rust pathogen, strain Ug99, is a major concern. Varieties resistant to this new strain are required.
2. New, virulent forms of rust constantly render current resistant genes ineffective. The continued development of resistant varieties is important.
3. There is a need to provide producer education concerning rust diseases.

Leaf Rust (*Puccinia triticina*)

Pest information

Damage: Leaf rust produces scattered, small, circular pustules on leaves and leaf sheaths (stems are not affected). The pustules are yellowish-red due to the production of urediniospores but eventually darken with the production of teliospores. Heavy infections of leaf rust can result in the death of the whole leaf and reduced crop yields and crop quality.

Life Cycle: Leaf rust overwinters as mycelium or uredinia on wheat plants in the southern United States. It is blown northward, eventually into Canada with first signs of the disease in Western Canada, developing in June. Rust spores are produced in pustules in infected leaves. When the pustules rupture, spores are released into the air and spread to other plants. A species of *Thalictrum* (meadow rue) is the alternate host for leaf rust and is required for sexual reproduction of the pathogen; however, this plant is not present in North America.

Pest management

Cultural Controls: The use of resistant varieties is the key approach to managing this disease. Crop rotations are not effective in the management of leaf rust as the spores are wind blown over wide areas. Early planting and conditions which favour the early emergence of the crop can reduce the impact of rust on the crop. Additional management practices for rust diseases are listed in *Table 5. Adoption of disease management practices in spring wheat production in Canada.*

Resistant Cultivars: The use of varieties that are resistant to races of leaf rust is critical to managing this disease, however growers must know the predominant rust races in their region in order to select the appropriate variety, as resistance genes vary with variety.

Issues for Leaf Rust

1. New, virulent forms of rust constantly render current resistant genes ineffective. The continued development of resistant varieties is important.
2. There is a need to provide producer education concerning rust diseases.

Stripe Rust (*Puccinia striiformis*)

Pest Information

Damage: Stripe rust produces yellow-orange pustules of uredinia on leaves and heads of wheat. Pustules rupture the cuticle of the leaves making them very susceptible to desiccation. The pustules develop in stripes that are parallel to the leaf veins. Defoliation, shrivelled seed and significant yield reductions occur under heavy infections.

Life Cycle: Stripe rust infections are initiated in the spring by urediniospores that have been carried northward from infected wheat crops in the United States. The pathogen may also survive in winter wheat in some parts of Canada during mild winters. When this occurs, spring crop infections occur earlier than when due to spores blown in from the south, and the potential for damage is greater. Infection is favoured by cool temperatures (9 to 12 degrees Celsius) and moisture on foliage. Urediniospores continue to be produced and released from rust pustules and are windblown to new plants where new infections occur. Summer temperatures above 20 degrees Celsius inhibit spore production. Barberry has been determined to be the alternate host of stripe rust and is required for sexual reproduction. However, since the alternative host is rare in North America, asexual reproduction is responsible for the majority of rust infections. During mild winters, stripe rust can overwinter on winter wheat in parts of Canada.

Pest Management

Cultural Controls: Regular scouting of fields and early detection is important for managing the disease. Crop rotations are not effective in the management of stripe rust as the spores are wind blown over wide areas. It is important to control stripe rust on winter wheat to minimize chances of disease spread to spring wheat. Conditions which favour early emergence of the crop can help to reduce the impact of rusts on the crop. Additional management practices for rust diseases are listed in *Table 5. Adoption of disease management practices in spring wheat production in Canada.*

Resistant Cultivars: The use of varieties that are resistant to races of stripe rust is a key component to managing the disease. Only a few varieties are rated to have good resistance.

Issues for Stripe Rust

1. The continued development of improved, varieties resistant to stripe rust is needed as new virulent forms of rust constantly render current resistant genes ineffective. The presence of new virulent forms of this disease is suspected.
2. There is a need to provide producer education concerning rust diseases.

Ergot (*Claviceps purpurea*)

Pest Information

Damage: Ergot symptoms become evident during kernel formation, when ergot bodies (sclerotia) are formed in place of kernels. The ergot bodies are often larger than the seed they replace and protrude from the glumes of the maturing head. Ergot bodies contain alkaloids that are toxic to humans and livestock. Contamination levels greater than 0.01% ergot will result in downgrading of the grain.

Life Cycle: Ergot can affect many cereal crops and grasses. Sclerotia on or near the soil surface germinate and release ascospores that are wind-blown to wheat florets where they infect the ovary. Infected florets produce honeydew which contains conidia. Secondary infection occurs when conidia in honeydew is spread by insects or rain splash to other florets. Ergot bodies develop in the infected florets and these may drop to the soil during harvest or be harvested with the mature grain.

Pest Management

Cultural Controls: Planting clean, ergot-free seed, crop rotation away from susceptible crops and tillage that buries the sclerotia will reduce inoculum levels. Mowing perennial grasses in adjacent fields and roadsides before they flower eliminates a potential source of disease. Avoiding planting spring wheat adjacent to winter cereals, especially fall rye will reduce the spread of disease to the new crop. Following management practices that favour uniform stand development and even flowering will generally result in less disease. Copper fertilization on copper deficient soils will reduce ergot infections.

Resistant Cultivars: None available.

Issues for Ergot

1. This disease can pose serious problems in some regions with few management options available to growers.
2. Reduced pollen fertility caused by factors such as low soil-available copper and late applications of herbicides may cause normally self-pollinated flowers to open and become more susceptible to ergot.

Fungicides and biofungicides registered for disease management in spring wheat production in Canada

Active ingredients registered for the management of **diseases** in spring wheat are listed below in Table 6 *Fungicides and biofungicides registered for disease management in spring wheat production in Canada*. This table also provides registration numbers for **products registered on spring** wheat **as of February 14, 2019** for each active ingredient, in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific **diseases**, the reader is referred to individual product labels available on the PMRA label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
azoxystrobin	26153, 30254, 30489, 32263, 32416, 32417, 32418	methoxy-acrylate	11	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	RE
azoxystrobin + propiconazole	28328, 30256, 31074, 31126, 32878, 32184, 32185, 33022	methoxy-acrylate + triazole	11 + 3	C3: respiration + G1: sterol biosynthesis in membranes	complex III: cytochrome bc1 (ubiquinol oxidase) at Q0site (cyt b gene)C14- demethylase in sterol biosynthesis (erg11/cyp51)	R + R
azoxystrobin + propiconizole + pydiflumetofen (including durum wheat)	33022	methoxy-acrylate + triazole + N-methoxy-(phenyl-ethyl)-pyrazole-carboxamide	11 + 3 + 7	C3: respiration + G1: sterol biosynthesis in membranes + C2: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + C14- demethylase in sterol biosynthesis (erg11/cyp51) + complex II: succinate dehydrogenase	R + R + R
benzovindiflupyr	31522, 32185	pyrazole-4- carboxamide	7	C2: respiration	complex II: succinate dehydrogenase	R

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Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
benzovindiflupyr + propiconazole	31525	pyrazole-4- carboxamide + triazole	7 + 3	C2: respiration + G1: sterol biosynthesis in membranes	complex II: succinate dehydrogenase + C14-demethylase in sterol biosynthesis (erg11/cyp51)	R +R
carbathiin	27550	succinate dehydrogenase inhibitor	7	C2: respiration	complex II: succinate dehydrogenase	R
carbathiin + ipconazole	32667	succinate dehydrogenase inhibitor + triazole	7 + 3	C2: respiration + G1:sterol biosynthesis in membranes	complex II: succinate dehydrogenase + C-14demethylase in sterol biosynthesis (erg11/cyp51	R + R
carbathiin + ipconazole + metalaxyl	32668	succinate dehydrogenase inhibitor + triazole + acylalanine	7 + 3 + 4	C2: respiration + G1:sterol biosynthesis in membranes + A1: nucleic acids synthesis	complex II: succinate dehydrogenase + C-14 demethylase in sterol biosynthesis (erg11/cyp51) + RNA polymerase I	R + R + R

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Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
carbathiin + thiram	11423, 27555, 30380, 30381, 30547	succinate dehydrogenase inhibitor + dithio-carbamate and relatives	7 + M03	C2: respiration + multi-site contact activity	complex II: succinate dehydrogenase + multi-site contact activity	R + RE
chlorothalonil	15723, 28900, 29225, 29306, 29355, 29356	chloronitrile (phthalonitrile)	M05	multi-site contact activity	multi-site contact activity	R (RVD2018-11)
difenoconazole + fludioxonil + metalaxyl-M and S-isomer + sedaxane	31408, 32625	triazole + pheylpyrrole + acylalanine + pyrazole-4-carboxamide	3 + 12 + 4 + 7	G1: sterol biosynthesis in membranes + E2: signal transduction + A1: nucleic acids synthesis + C2: respiration	C14-demethylase in sterol biosynthesis (erg11/cyp51) + MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1) + RNA polymerase I + complex II: succinate-dehydrogenase	RE + R (RVD2018-04) + R + R

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Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
difenoconazole + fludioxonil + metalaxyl-M and S-isomer + sedaxane + thiamethoxam	31453	triazole + pheylpyrrole + acylalanine + pyrazole-4-carboxamide + neonicotinoid[4]	3 + 12 + 4 + 7 + 4A[4]	G1: sterol biosynthesis in membranes + E2: signal transduction + A1: nucleic acids synthesis + C2: respiration + nicotinic acetylcholine receptor (nAChR) competitive modulator[4]	C14-demethylase in sterol biosynthesis (erg11/cyp51) + MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1) + RNA polymerase I + complex II: succinate-dehydrogenase + nicotinic acetylcholine receptor (nAChR) competitive modulator[4]	RE + R (RVD2018-04) + R + R + RES*
difenoconazole + metalaxyl-M and S-isomer + sedaxane + thiamethoxam	30436	triazole + acylalanine + pyrazole-4-carboxamide + neonicotinoid[4]	3 + 4 + 7 + 4A[4]	G1: sterol biosynthesis in membranes + A1: nucleic acids synthesis + C2: respiration + nicotinic acetylcholine receptor (nAChR) competitive modulator[4]	C14-demethylase in sterol biosynthesis (erg11/cyp51) + RNA polymerase I + complex II: succinate-dehydrogenase + nicotinic acetylcholine receptor (nAChR) competitive modulator[4]	RE + R + R + RES*

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Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
difenoconazole + metalaxyl-M and S-isomer + sedaxane	30437	triazole + acylalanine + pyrazole-4-carboxamide	3 + 4 + 7	G1: sterol biosynthesis in membranes + A1: nucleic acids synthesis + C2: respiration	C14-demethylase in sterol biosynthesis (erg11/cyp51) + RNA polymerase I + complex II: succinate-dehydrogenase	RE + R + R
difenoconazole + metalaxyl-M and S-isomer + thiamethoxam	29127, 29192	triazole + acylalanine + neonicotinoid[4]	3 + 4 + 4A[4]	G1: sterol biosynthesis in membranes + A1: nucleic acids synthesis + nicotinic acetylcholine receptor (nAChR) competitive modulator[4]	C14-demethylase in sterol biosynthesis (erg11/cyp51) + RNA polymerase I + nicotinic acetylcholine receptor (nAChR) competitive modulator[4]	RE + R + RES*
difenoconazole + metalaxyl-M and S-isomer	25777, 29490	triazole + acylalanine	3 + 4	G1: sterol biosynthesis in membranes + A1: nucleic acid synthesis	C14-demethylase in sterol biosynthesis (erg11/cyp51) + RNA polymerase I	RES + R
ethaboxam	31324	ethylamino-thiazole-carboxamide	22	B3: cytoskeleton and motor proteins	ß-tubulin assembly in mitosis	R

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Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
fludioxonil	27001	phenylpyrrole	12	E2: signal transduction	MAP/histidine- kinase in osmotic signal transduction (os-2, HOG1)	R (RVD2018-04)
fluopyram	30509	pyridinyl-ethyl-benzamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
fluxapyroxad	30562, 30565	pyrazole-4- carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
fluxapyroxad + pyraclostrobin	30567	pyrazole-4- carboxamide + methoxy-carbamate	7 + 11	C2: respiration + C3: respiration	complex II: succinate-dehydrogenase + complex III:cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R + R

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Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
fluxapyroxad + pyraclostrobin + propiconazole	32678	pyrazole-4- carboxamide + methoxy-carbamate + triazole	7 + 11 + 3	C2: respiration + C3: respiration + A1:nucleic acids synthesis + G1: sterol biosynthesis in membranes	complex II: succinate-dehydrogenase + complex III:cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + C14- demethylase in sterol biosynthesis (erg11/cyp51)	R + R + R
fluxapyroxad + pyraclostrobin + metalaxyl + trticonazole	33210	pyrazole-4- carboxamide + methoxy-carbamate + acelalanine + triazole	7 + 11 + 4 + 3	C2: respiration + C3: respiration + A1:nucleic acids synthesis + G1: sterol biosynthesis in membranes	complex II: succinate-dehydrogenase + complex III:cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + RNA polymerase I + C14- demethylase in sterol biosynthesis (erg11/cyp51)	R + R + R + RE
ipconazole	29175, 29176	triazole	3	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	R

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Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
iprodione	30769, 32950	dicarboximide	2	E3: signal transduction	MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	R (RVD2018-16)
mancozeb (including durum wheat)	numerous products	dithiocarbamate and relatives (electrophile)	M03	multi-site contact activity	multi-site contact activity	RE (see PRVD2018-17)
metalaxyl	30246	acylalanine	4	A1: nucleic acids synthesis	RNA polymerase I	R
metalaxyl-M and S isomer	25585, 26674	acylalanine	4	A1: nucleic acids synthesis	RNA polymerase I	R
metalaxyl + metconazole	32371	acelalanine + triazole	4 + 3	A1: nucleic acid synthesis + G1: sterol biosynthesis in membranes	RNA polymerase I + C14-demethylase in sterol biosynthesis (erg11/cyp51)	R + R

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Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
metalaxyl + metconazole + clothianidin (seed treatment commercial treaters only)	31357	acelalanine + triazole + neonicotinoid[4]	4 + 3 + 4A[4]	A1: nucleic acid synthesis + G1: sterol biosynthesis in membranes + nicotinic acetylcholine receptor (nAChR) competitive modulator[4]	RNA polymerase I + C14-demethylase in sterol biosynthesis (erg11/cyp51) + nicotinic acetylcholine receptor (nAChR) competitive modulator[4]	R + R + RES*
metalaxyl + penflufen + prothioconazole	30364	acylalanine + pyrazole-4-carboxamide + triazolinthione	4 + 7 + 3	A1: nucleic acids synthesis + C2:respiration + G1: sterol biosynthesis in membranes	RNA polymerase I + complex II: succinate-dehydrogenase + c14-demethylase in sterol biosynthesis (erg11/cyp51)	R + R + R
metalaxyl + prothioconazole + tebuconazole	30102, 30687,	acylalanine + triazolinthione + triazole	4 + 3 + 3	A1: nucleic acids synthesis + G1: sterol biosynthesis in membranes + G1: sterol biosynthesis in membranes	RNA polymerase I + C14- demethylase in sterol biosynthesis (erg11/cyp51) + C14-demethylase in sterol biosynthesis (erg11/cyp51)	R + R + RE

…continued

Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
metalaxyl + pyraclostrobin + triticonazole	30685	acylalanine + methoxy-carbamate + triazole	4 + 11 + 3	A1: nucleic acids synthesis + C3: respiration + G1: sterol biosynthesis in membranes	RNA polymerase I + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + C14-demethylase in sterol biosynthesis (erg11/cyp51)	R + R + RE
metalaxyl + tebuconazole	27692, 32073	acylalanine + triazole	4 + 3	A1: nucleic acids synthesis + G1: sterol biosynthesis in membranes	RNA polymerase I + C14-demethylase in sterol biosynthesis (erg11/cyp51)	R + RE
metconazole	29767, 31356	triazole	3	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	R
metconazole + pyraclostrobin	30337, 32189	triazole + methoxy-carbamate	3 + 11	G1: sterol biosynthesis in membranes + C3: respiration	C14-demethylase in sterol biosynthesis (erg11/cyp51) + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R + R

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Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
oriental mustard seed meal (oil) (*Brassica juncea*)	30263	diverse	N/C	not classified	unknown	R
penflufen	30359, 30360	pyrazole-4-carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
penthiopyrad	30332	pyrazole-4- carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
picoxystrobin	30470	methoxy-acrylate	11	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R
propiconazole	numerous products	triazole	3	G1: sterol biosynthesis in membranes	C14- demethylase in sterol biosynthesis (erg11/cyp51)	R
propiconazole + trifloxystrobin	27528	triazole + oximino-acetate	3 + 11	G1: sterol biosynthesis in membranes + C3: respiration	C14- demethylase in sterol biosynthesis (erg11/cyp51) + mplex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R + R

…continued

Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
prothioconazole	28359, 30101, 31839, 32888	triazolinthione	3	G1: sterol biosynthesis in membranes	C14- demethylase in sterol biosynthesis (erg11/cyp51)	R
prothioconazole + tebuconazole	29819, 29821, 32824	triazolinthione + triazole	3 + 3	G1: sterol biosynthesis in membranes + G1: sterol biosynthesis in membranes	C14- demethylase in sterol biosynthesis (erg11/cyp51) + 4-demethylase in sterol biosynthesis (erg11/cyp51)	R + RE
prothioconazole + trifloxystrobin	31435, 31436	triazolinthione + oximino-acetate	3 + 11	G1: sterol biosynthesis in membranes + C3: respiration	C14- demethylase in sterol biosynthesis (erg11/cyp51) + complex III: ytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R + R
pydiflumetofen	33018, 33213	N-methoxy-(phenyl-ethyl)-pyrazole-carboxamide	7	C2: respiration	complex II: succinate dehydrogenase	R

…continued

Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
pyraclostrobin	27322, 30182, 30567	methoxy-carbamate	11	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R
Reynoutria sachalinensis (extract)	30199, 32350	complex mixture, ethanol extract (anthraquinones resveratrol)	P05	P5: host plant defence induction	anthraquinone elicitors	R
sedaxane	30438	pyrazole-4-carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
tetraconazole	25762, 25940, 26137, 26138, 29820, 30491, 30492,32500	triazole	3	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	R
tebuconazole + thiram	27566	triazole + dithiocarbamate and relatives (electrophile)	3 + M03	G1: sterol biosynthesis in membranes + multi-site contact activity	C14- demethylase in sterol biosynthesis (erg11/cyp51) + multi-site contact activity	RE + R (RVD2018-38)

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Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
tebuconazole + trifloxystrobin	29818	triazole + oximino-acetate	3 + 11	G1: sterol biosynthesis in membranes + C3: respiration	C14- demethylase in sterol biosynthesis (erg11/cyp51) + complex III: ytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	RE + R
trifloxystrobin	27529, 30427	oximino-acetate	11	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R

…continued

Table 6. Fungicides and biofungicides registered for disease management in spring wheat in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
triticonazole	29400, 30226	triazole	3	G1: sterol biosynthesis in membranes	C14- demethylase in sterol biosynthesis (erg11/cyp51)	RE

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). **The list includes all active ingredients registered as of February 14, 2019.** While every effort has been made to ensure all fungicides, bactericides and biofungicides registered in Canada on spring wheat have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Fungicide Resistance Action Committee. *FRAC Code List 2018: Fungicides sorted by mode of action (including FRAC code numbering).* February 2018. (www.frac.info/) (accessed March 1, 2019).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2018-06 Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023, Re-evaluation Note REV2018-17 Initiation of Cumulative Health Risk Assessment-N-Methyl Carbamates **and other re-evaluation documents**: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[4] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 9.1; December 2018)* (excluding pheromones) (www.irac-online.org) (accessed January 28, 2019).

[5]As published by Government of Canada: *Notice to anyone engaged in the use of methyl bromide: June 2017 https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/notice-use-methyl-bromide-june-2017.html*.

Insects and Mites

Key issues

- There is a need for pest management strategies that target specific insect or mite pests but do not harm beneficial insects.
- Growers need registration of new products for management of insect and mite pest species.
- There is concern that the potential loss of neonicotinoid insecticides as a result of regulatory review could leave few options for the management of insect pests with seed treatments.
- There is concern that Canadian growers may experience a loss of competitiveness without access to equivalent seed treatment options as producers in other jurisdictions.

Table 7. Occurrence of insect pests in Canadian spring wheat production[1,2]

Insect	Alberta	Saskatchewan	Manitoba
Grasshoppers			
Lesser migratory grasshopper			
Two striped grasshopper			
Clear-winged grasshopper			
Cutworms			
Redbacked cutworm			
Pale western cutworm			
Darksided cutworm			
Armyworm			
Cereal leaf beetle			
Wheat midge			
Cereal aphids			
English grain aphid			
Oat bird cherry aphid			
Wireworms			
Thrips			

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Data not reported.

[1]Source: Spring wheat stakeholders in reporting provinces (Alberta, Manitoba and Saskatchewan); the data reflect the 2016, 2015 and 2014 production years.

[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 8. Adoption of insect pest management practices in spring wheat production in Canada[1]

	Practice / Pest	Grasshoppers	Cutworms	Cereal leaf beetle	Wheat midge	Cereal aphids
Avoidance	Varietal selection / use of resistant or tolerant varieties					
	Planting / harvest date adjustment					
	Rotation with non-host crops					
	Choice of planting site					
	Optimizing fertilization for balanced growth					
	Minimizing wounding to reduce attractiveness to pests					
	Reducing pest populations at field perimeters					
	Use of physical barriers (e.g. mulches, netting, floating row covers)					
	Use of pest-free propagative materials (seeds, cuttings and transplants)					
Prevention	Equipment sanitation					
	Canopy management (thinning, pruning, row or plant spacing, etc.)					
	Manipulating seeding / planting depth					
	Irrigation management (timing, duration, amount) to manage plant growth					
	Management of soil moisture (improvements in drainage, use of raised beds, hilling, mounds)					
	End of season or pre-planting crop residue removal / management					
	Pruning out / removal of infested material throughout the growing season					
	Tillage / cultivation to expose soil insect pests					
	Removal of other hosts (weeds / volunteers / wild plants) in field and vicinity					

…continued

Table 8. Adoption of insect pest management practices in spring wheat production in Canada[1] (continued)

Practice / Pest		Grasshoppers	Cutworms	Cereal leaf beetle	Wheat midge	Cereal aphids
Monitoring	Scouting / trapping					
	Maintaining records to track pests					
	Soil analysis for pests					
	Weather monitoring for degree day modelling					
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of pests					
Decision making tools	Economic threshold					
	Use of predictive model for management decisions					
	Crop specialist recommendation or advisory bulletin					
	Decision to treat based on observed presence of pest at susceptible stage of life cycle					
	Use of portable electronic devices in the field to access pest identification / management information					

…continued

Table 8. Adoption of insect pest management practices in spring wheat production in Canada[1] (continued)

	Practice / Pest	Grasshoppers	Cutworms	Cereal leaf beetle	Wheat midge	Cereal aphids
Suppression	Use of diverse pesticide modes of action for resistance management					
	Soil amendments and green manuring involving soil incorporation as biofumigants, to reduce pest populations					
	Biopesticides (microbial and non-conventional pesticides)					
	Release of arthropod biological control agents					
	Preservation or development of habitat to conserve or augment natural controls (e.g. preserve natural areas and hedgerows, adjust crop swathing height, etc.)					
	Mating disruption through the use of pheromones					
	Mating disruption through the release of sterile insects					
	Trapping					
	Targeted pesticide applications (banding, spot treatments, variable rate sprayers, etc.)					
	Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms					

This practice is used to manage this pest by at least some growers in the province.

This practice is not used by growers in the province to manage this pest.

This practice is not applicable for the management of this pest

Information regarding the practice for this pest is unknown.

[1]Source: Spring wheat stakeholders in reporting provinces (Alberta, Saskatchewan and Manitoba); the data reflect the 2016, 2015 and 2014 production years.

Grasshoppers: Lesser Migratory Grasshopper *(Melanoplus sanguinipes),* Two Striped Grasshopper *(Melanoplus bivitattus),* Clear-winged Grasshopper (*Camnula pellucida*)

Pest Information

Damage: Grasshoppers attack all of the above ground portions of the plant. The migratory grasshopper feeds on broadleaved weeds, grasses, barley and wheat. It may clip the heads of wheat as the crop matures. The two striped grasshopper has a broad host range including pulses, forages, grasses and wheat. The clear-winged grasshoppers prefer cereals and grasses. Grasshopper damage is strongly correlated to weather conditions. Under dry, hot conditions a small grasshopper population may do as much damage as a large grasshopper population will under cool, wet conditions.

Life Cycle: Pest species of grasshoppers lay eggs in late summer and fall in field margins, pastures, or any area with green vegetation. Eggs laid in the soil are encased in a pod formed from a foamy secretion. When conditions are optimum, female grasshoppers can produce egg pods every two to four days. The numbers of eggs per pod varies with species of grasshopper. Eggs hatch in the spring. Grasshoppers develop through five instars in the spring and early summer, taking between 35 and 50 days to become adults. Newly hatched grasshoppers feed in the vicinity of the egg laying site, moving to preferred crops as they increase in size and mobility. Grasshoppers have one generation per year. Temperatures during the spring and summer and fall weather conditions significantly affect the reproduction of grasshoppers and influence the severity of outbreak the following season. Hot, dry conditions in the spring favour early hatch and quick development of grasshoppers. Cool, wet weather will slow grasshopper development.

Pest Management

Cultural Controls: Many grasshopper species are not pests; therefore, it is important to identify the species of grasshopper present and to determine whether control is warranted before initiating treatments. Early seeding will result in larger plants earlier in the season that are better able to withstand grasshopper feeding. Avoiding stubble fields infested with grasshoppers also reduces the potential for grasshopper damage. Tillage to eliminate weeds in the fall will discourage egg laying. The elimination of weeds in the spring through tillage will remove a food source for newly hatched grasshoppers resulting in their starvation. The pros and cons of tillage must be carefully considered when choosing this management option. Leaving non-tilled strips with weeds (trap strips) during tillage operations that attract and concentrate grasshopper populations and subsequent treatment of strips with insecticide can help to reduce grasshopper populations. Grasshopper forecast maps are produced annually by provincial agriculture ministries. Scouting in spring and early summer is important in areas where high populations of grasshoppers have been forecast. Many natural enemies including parasites and predators of eggs, nymphs and adults can help control grasshopper populations.

Additional management practices for grasshoppers are listed in *Table 8. Adoption of insect pest management practices in spring wheat production in Canada.*

Resistant Cultivars: None available.

Issues for Grasshoppers

1. There is a need for an integrated management program for grasshoppers in wheat.
2. There is a need for reduced risk alternatives to the organophosphate insecticides that will function under high temperatures.

Cutworms: Red-backed (*Euxoa ochrogaster*), Pale Western (*Agrotis orthogonia*), and Dark-sided (*Euxoa messoria*)

Pest Information

Damage: Cutworms attack a variety of crops including cereals, canola, sunflower, flax, legumes and others. Preferred crops, habitats and timing of development differs among species. Cutworms are generally present at low levels in fields but can cause economic damage to wheat and other crops in "outbreak" years. Young larvae of the pale western and red-backed cutworms feed on leaves and stems below ground, often severing leaves and young plants. The dark-sided cutworm feeds on seedlings at night. The severity of damage to the crop varies from a few small patches to loss of the entire crop. Sites with early season weed growth, heavy plant residue or dense foliage near the crop, are likely to sustain more injury.

Life Cycle: Adult moths lay eggs on or near the soil surface in the fall. The red-backed, pale western and dark-sided cutworms overwinter as eggs. Once hatched, the larvae live in the soil, venturing above-ground to feed. Larvae pupate in the late spring. The new moths emerge in the summer. There is one generation per year.

Pest Management

Cultural Controls: Many predators, parasitoids and pathogens play a significant role in controlling cutworms. For this reason, practices that favour the survival of natural enemies including limiting the use of pesticides, and preserving natural habitat such as areas along field margins will help to reduce cutworm populations. Additional management practices for cutworms are listed in *Table 8. Adoption of insect pest management practices in spring wheat production in Canada.*

Resistant Cultivars: None available.

Issues for Cutworms

1. There is a need for improved resources to assist in the identification of cutworm larvae to facilitate scouting for these pests. In addition, there is a need to understand the differences in biology among cutworms and their naturally occurring parasites and predators for future management considerations.

True Armyworm [*Mythimna* (*Pseudaletia) unipuncta*]

Pest Information

Damage: True armyworms feed primarily on grasses, corn and grains including wheat, oats, fall rye and barley. Larvae are nocturnal and feed on the leaf margins of wheat, gradually moving up the plants to feed on flowers, awns and kernels.

Life Cycle: Armyworm moths are carried into Canada on air currents from the south. Female moths lay eggs in groups of about 100 at the base of host plants. Larvae feed at night or on overcast days for three to four weeks, developing through six instars. When feeding is complete, the larvae pupate a few centimetres below the surface of the soil. Adults emerge in about two weeks and lay eggs to initiate a second generation which feeds in the fall. There are two generations per year in Canada with the first (spring) generation responsible for the greatest damage to spring wheat.

Pest Management

Cultural Controls: Controlling grassy weeds prior to seeding will minimize the risk of attracting egg-laying moths in the spring. The arrival of moths can be monitored through the use of light or pheromone traps. The presence of larvae can be detected by scouting areas of fields showing damage or where there are birds, as birds are common predators of armyworm. Egg and larval parasitoids and predators provide some natural control of armyworm.

Resistant Cultivars: None available.

Issues for True Armyworm

1. There is limited producer knowledge about armyworm.
2. There is a need for the registration of microbial insecticides for the control of armyworms.

Cereal Leaf Beetle (*Oulema melanopus*)

Pest Information

Damage: Cereal leaf beetle adults and larvae damage wheat by chewing long strips of tissue between the leaf veins. This creates a "skeletonizing" effect. Most of the injury is caused by the larvae in June. Heavily damaged fields appear silver. Yield reductions of 55% in spring wheat have been recorded.

Life Cycle: Adult beetles overwinter along the margins of grain fields in protected places such as in crop residues and tree litter. They favour sites adjacent to shelterbelts and forests. They emerge in the spring and are active for about six weeks. Eggs are laid singly or in pairs along leaf margins and the mid-vein on the upper side of the leaf. Each female may lay several hundred eggs. The larvae feed for about two weeks, passing through four instars before pupating. The pupal stage lasts two to three weeks. Adult beetles emerge and feed for a few weeks before seeking overwintering sites. There is one generation per year.

Pest Management

Cultural Controls: Monitoring can be done by looking for adult leaf beetle feeding injury in the spring and by checking for eggs and larvae at random sites throughout the crop. Populations of cereal leaf beetle have successfully been maintained below economic thresholds by the introduction of the parasitic wasp, *Tetrastichus julis.* Other natural enemies of the pest include lady beetles, mites and some birds. For the safety of these natural enemies and continued effective biological control, it is helpful to minimize chemical pest management treatments to the crop as much as possible. Areas of the prairies where cereal leaf beetle is present, but the parasitoid *T. julis* is not, can be targeted for releases of the parasitoid. Additional management practices for cereal leaf beetle are listed in *Table 8. Adoption of insect pest management practices in spring wheat production in Canada.*.

Resistant Cultivars: None available

Issues for Cereal Leaf Beetle

1. The known range for the cereal leaf beetle is expanding across the Prairie Provinces and growers need more information on the management of this pest.
2. There is a need for the registration of insecticides that are not harmful to the parasitoid, *Tetrastichus julis*, which has been released to manage this pest in some provinces.

Wheat Midge (*Sitodiplosis mosellana*)

Pest information

Damage: Wheat midge larvae feed on the developing wheat kernel. Affected kernels may become cracked, shrivelled or scarred resulting in reduced yield and quality and downgrading of the grain. The severity of damage is dependent on variety, stage of kernel development at feeding and the number of larvae present.

Life Cycle: Adults emerge from the soil mid-June to mid-July, timing that corresponds with the emergence of wheat heads from the sheath and flowering. Eggs are laid on the developing wheat kernels and after hatching, the young larvae feed on the developing wheat kernels for two to three weeks before dropping to the soil where they spin a cocoon and overwinter. Pupation occurs in the spring and adults emerge if there is adequate soil moisture. If moisture conditions are too low, pupation does not occur and the larvae remain in the soil. Larvae can remain in the soil for several years until moisture conditions become more suitable. There is one generation per year.

Pest Management

Cultural Controls: Monitoring for wheat midge takes place between heading and flowering, in the evening when the wheat midge is most active. Crop rotation and the avoidance of continuous wheat cropping, will prevent the build-up of pest populations. Varying the date of seeding, to prevent midge emergence and egg laying coinciding with flowering, can be effective in reducing damage but the impact will vary with wheat variety and soil types. Pest populations can be reduced by a small, naturally occurring parasitic wasp called *Macroglenes penetrans.* Additional management practices for wheat midge are listed in *Table 8. Adoption of insect pest management practices in spring wheat production in Canada.*

Resistant Cultivars: Several midge-resistant cultivars of red spring wheat are available as "varietal blends" (VB). These VB's are a blend of both resistant (90%) and susceptible (10%) varieties. The susceptible varieties are included as refuge crops to prevent the evolution of genes to overcome the wheat resistance within the pest populations.

Issues for Wheat Midge

1. Midge resistance in wheat is based on a single gene, increasing the risk that the resistance will breakdown in a few years. New lines of resistance are needed.
2. More information is required on the economic impact of wheat midge. There is a need for the development of economic thresholds and simple scouting techniques for wheat midge.
3. There is a need for the registration of alternatives to organophosphate insecticides, including biological controls, for the management of this insect. Insecticides that are not harmful to the parasitoid, *Macroglenes penetrans* are required.

Cereal Aphids (*Aphididae*): English Grain aphid [*Sitobion* (*Macrosiphum*) *avenae*] and Oat-bird Cherry aphid (*Rhopalosiphum padi*)

Pest Information

Damage: Aphids feed on wheat by sucking sap. The English grain aphid feeds on the kernels of cereal crops resulting in a shrivelling of the seed. The oat-bird cherry aphid tends to feed on stems and lower leaves. Heavy infestations of the oat-bird cherry aphid can affect grain quality. In the fall, aphids move to winter wheat to feed. Both aphids can transmit barley yellow dwarf virus, however the oat-bird cherry aphid is a more efficient vector.

Life Cycle: Female aphids are wind blown into Canada from the United States. Throughout the summer successive generations of female nymphs are produced asexually. Aphids feed on spring wheat and other cereal crops and move to winter cereals in the fall. Populations die-out in the fall.

Pest Management

Cultural Controls: Early seeding will enable the spring wheat crop to reach a level of growth that is less attractive to the aphids and less likely to be infected with barley yellow dwarf virus. Aphid populations can be reduced by naturally occurring fungal pathogens and parasitoids as well as lacewings and ladybird beetles. Treatment thresholds have been established for aphids in wheat. Additional management practices for cereal aphids are listed in *Table 8. Adoption of insect pest management practices in spring wheat production in Canada.*

Resistant Cultivars: Tolerant varieties are available.

Issues for Aphids

1. Growers need selective insecticides for the control of aphids that are not harmful to natural parasitoids and predators.

Wireworms (*Elateridae*)

Pest Information

Damage: A number of wireworm species can attack field crops with the prairie grain wireworm (*Ctenicera destructor*) and the click beetle (*Hypnoidus bicolor*) being the most common on the prairies. Wireworms feed on seeds, roots and seedlings in the spring, resulting in reduced crop emergence and thinned stands. Wireworms can affect successive crops due to the extended lifespan of the larvae. Wireworms are often found more abundantly in medium

textured, well-drained soils and in fields that are recently broken sod. All field crops may be attacked with the exception of the fall seeded crops.

Life Cycle: Wireworms are the larvae of click beetles. Eggs are laid in the soil near the roots of their host plants in the spring. Larvae remain in the soil feeding on roots. When soil temperatures become too warm in the summer, they move deeper into cooler soil. Depending on species, the larval stage can last up to 11 years before pupation and adult emergence. Larvae pupate about five to ten centimetres below the soil surface. Pupation lasts for less than a month, but adults do not emerge until the following spring.

Pest Management

Cultural Controls: In the spring, the presence of wireworms can be detected by placing bait stations containing a corn-wheat mixture, potato pieces or oatmeal in a field, two to three weeks before planting. Seeding practices that promote rapid germination and vigorous seedlings will enable plants to better withstand wireworm attack. Eliminating green growth from fallow fields in June and July will starve recently hatched larvae.

Resistant Cultivars: None available.

Issues for Wireworms

1. There is a need to develop monitoring techniques and establish economic thresholds for wireworms.
2. Further research is required into the use of crop rotation for wireworm management.
3. Problems with wireworms are increasing in many Canadian farming systems, likely due to changes in available chemical insecticides and changes to field cultivation practices. Producers need insecticides that provide both stand protection and wireworm population reduction.

Hessian Fly (*Mayetiola destructor*)

Pest Information

Damage: Hessian fly attacks both spring and winter wheat. Larvae feed on the stem where the leaf blade meets the stem. Feeding weakens the stem, predisposing it to breakage, improper elongation of the plant and yield loss. Damage is often confused with sawfly injury.

Life Cycle: The Hessian fly has two generations per year, one in the spring and one in the fall. The insect overwinters in old plant crowns as pupae, often called “flaxseed” due to its similar appearance. In June, adults emerge and lay eggs at the base of young spring wheat seedlings. Larvae feed at the base of the plants for two to three weeks and then pupate. Adults emerge and lay eggs on late maturing plants. Larvae feed between the stem and the leaf sheath at upper nodes.

Pest Management

Cultural Controls: Since the insect is a weak flier, crop rotation will help control the insect. Early seeding will result in larger and more vigorous plants that are better able to withstand Hessian fly feeding, by the time the insects are present. Avoiding planting spring wheat adjacent to winter wheat fields will reduce the opportunity for Hessian flies to migrate between crops. Fall tillage to bury infested stubble will help to eliminate the overwintering population. At least six species of Hymenoptera are parasitoids of the Hessian fly, and these insects help to manage this pest, especially the second generation.

Resistant Cultivars: Some spring wheat varieties are less susceptible to injury caused by the Hessian fly

Issues for Hessian Fly

1. Growers lack chemical controls for Hessian fly, including seed treatments.
2. There is a need to evaluate the economic impact of Hessian fly in some regions.

Thrips (*Thripidae*)

Pest Information

Damage: Thrips feed by rasping the leaves and other tissues of plants to release sap that they feed on. Tissues with heavy feeding turn white and stems and heads may develop a goose-necked shape. Heavy feeding on the flag leaf may result in shrivelled seed or the failure of seeds to develop. Adult thrips may be found on spring and winter wheat; larvae are found on barley. Thrips may attack leaves, stem or heads.

Life Cycle: Females overwinter on grasses and in protected sites. In the spring, thrips fly or are carried by wind to cereal hosts. Adults lay eggs on the host plant. The generation time is very short with several generations each year.

Pest Management

Cultural Controls: Thrips rarely cause serious damage to wheat. It is unusual to find infestations that warrant control. Many predatory insects will feed on thrips and suppress their numbers.

Resistant Cultivars: None available.

Issues for Thrips

None identified.

Insecticides, miticides and bio-insecticides registered for the management of insect and mite pests in spring wheat production in Canada

Active ingredients registered for the management of **insects and mites** in spring wheat are listed below in Table 9 *Insecticides, miticides and bio-insecticides registered for the management of insect and mite pests in spring wheat production in Canada*. This table also provides registration numbers for **products registered on spring wheat as of February 15, 2019** for each active ingredient in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific **insects and mites**, the reader is referred to individual product labels on the PMRA label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 9. Insecticides, miticides and bio-insecticides for insect management in spring wheat production in Canada

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
carbaryl	25815	carbamate	1A	acetylcholinesterase (AChE) inhibitor	RE (REV2018-17)
chlorantraniliprole	28982	diamide	28	ryanodine receptor modulator	R
chlorpyrifos	numerous products	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	RE
clothianidin	28975	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES*
clothianidin + metalaxyl + metconazole	31357	neonicotinoid + acelalanine[4] + triazole[4]	4A + 4[4]+ 3[4]	nicotinic acetylcholine receptor (nAChR) competitive modulator + A1: nucleic acid synthesis[4] + G1: sterol biosynthesis in membranes[4]	RES* + R + R
cypermethrin	15738, 28795, 30316	pyrethroid, pyrethrin	3A	sodium channel modulator	R (RVD2018-22)

…continued

Table 9. Insecticides, miticides and bio-insecticides for insect management in spring wheat production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
deltamethrin	17734, 20078, 22478, 25573, 32446, 32447	pyrethroid, pyrethrin	3A	sodium channel modulator	R (RVD2018-27)
dimethoate	8277, 9382, 9807, 25651	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	R
imidacloprid	28475, 29609, 29610, 30505, 30668	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES*
lambda-cyhalothrin	24984, 26837, 29052, 32427	pyrethroid, pyrethrin	3A	sodium channel modulator	RE
malathion	4590, 5821, 8372, 9337, 15896, 17222, 25638	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	R
permethrin	14882, 16688, 28877, 30316	pyrethroid, pyrethrin	3A	sodium channel modulator	RE

…continued

Table 9. Insecticides, miticides and bio-insecticides for insect management in spring wheat production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
silica aerogel (amorpohus silica gel)	24259	not classified	N/A	unknown	R
silicon dioxide (present as 100% diatomaceous earth)	27265, 22489	not specified	UNM	UNM Non-specific mechanical chain disruptor	R
spinetoram	28777, 28778	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator - site 1	R
spiromesifin	28905	tetronic and tetramic acid derivative	23	inhibitor of acetyl CoA carboxylase	R
sulfoxaflor	30825	sulfoximine	4C	nicotinic acetylcholine receptor (nAChR) competitive modulator	R

…continued

Table 9. Insecticides, miticides and bio-insecticides for insect management in spring wheat production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
Storage Treatment					
aluminum phosphide (for wheat seed destined for planting only)	numerous products	phosphide	24A	mitochondrial complex IV electron transport inhibitor	R
silicon dioxide (present as 100% diatomaceous earth)	22489	N/A	N/A	UNM non-specific mechanical disruptor	R
silicon dioxide (present as 100% diatomaceous earth) + silica aerogel	24259	N/A	N/A	UNM non-specific mechanical disruptor	R

…continued

Table 9. Insecticides, miticides and bio-insecticides for insect management in spring wheat production in Canada (continued)

Footnotes:

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). **The list includes all active ingredients registered as of February 15, 2019.** While every effort has been made to ensure all insecticides, miticides and biopesticides registered in Canada on spring wheat have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. The information in this table should not be relied upon for pesticide application decisions and use.

[2] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 9.1; December 2018)* (excluding pheromones) (www.irac-online.org) (accessed January 28, 2019).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2018-06 Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023, Re-evaluation Note REV2018-17 Initiation of Cumulative Health Risk Assessment-N-Methyl Carbamates **and other re-evaluation documents**: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[4]Source: Fungicide Resistance Action Committee. *FRAC Code List 2018: Fungicides sorted by mode of action (including FRAC code numbering).* February 2018. (www.frac.info/) (accessed March 1, 2019).

[5]As published by Government of Canada: *Notice to anyone engaged in the use of methyl bromide: June 2017 https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/notice-use-methyl-bromide-june-2017.html*

Weeds

Key Issues

- Resistance to numerous classes of herbicides within weed populations is a concern.
- Rotational strategies that incorporate non-chemical weed management approaches are needed to limit the development of herbicide resistance within weed populations.

Table 10. Occurrence of weeds in Canadian spring wheat production[1,2]

Weed	Alberta	Saskatchewan	Manitoba
Annual broadleaf weeds			
Annual grass weeds			
Perennial broadleaf weeds			
Perennial grass weeds			

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest not present.

Data not reported

[1]Source: Spring wheat stakeholders in reporting provinces (Alberta, Manitoba and Saskatchewan); the data reflect the 2016, 2015 and 2014 production years.

[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 11. Adoption of weed management practices in spring wheat production in Canada[1]

Practice / Pest		Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds
Avoidance	Varietal selection / use of competitive varieties				
	Planting / harvest date adjustment				
	Crop rotation				
	Choice of planting site				
	Optimizing fertilization for balanced crop growth				
	Use of weed-free propagative materials (seed, cuttings or transplants)				
	No till or low disturbance seeding to minimize weed seed germination				
	Use of physical barriers (e.g. mulches)				
Prevention	Equipment sanitation				
	Canopy management (thinning, pruning, row or plant spacing, etc.)				
	Manipulating seeding / planting depth				
	Irrigation management (timing, duration, amount) to maximize crop growth				
	Management of soil moisture (improvements in drainage, use of raised beds, hilling, mounds)				
	Weed management in non-crop lands				

…continued

Table 11. Adoption of weed management practices in spring wheat production in Canada[1] (continued)

Practice / Pest		Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds
Monitoring	Scouting / field inspection				
	Maintaining records of weed incidence including herbicide resistant weeds				
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of weeds				
Decision making tools	Economic threshold				
	Crop specialist recommendation or advisory bulletin				
	Decision to treat based on observed presence of weed at susceptible stage of development				
	Decision to treat based on observed crop damage				
	Use of portable electronic devices in the field to access weed identification / management information				

…continued

Table 11. Adoption of weed management practices in spring wheat production in Canada[1] (continued)

Practice / Pest		Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds
Suppression	Use of diverse herbicide modes of action for resistance management				
	Soil amendments and green manuring involving soil incorporation as biofumigants to reduce weed populations				
	Biopesticides (microbial and non-conventional pesticides)				
	Release of arthropod biological control agents				
	Mechanical weed control (cultivation / tillage)				
	Manual weed control (hand pulling, hoeing, flaming)				
	Use of stale seedbed technique				
	Targeted pesticide applications (banding, spot treatments, variable rate sprayers, etc.)				
	Selection of herbicides that are soft on beneficial insects, pollinators and other non-target organisms				
New practices (by province)	CombCut – use of a mower based on Swedish technology that selectively mows weeds (Alberta)				

This practice is used to manage this pest by at least some growers in the province

This practice is not used by growers in the province to manage this pest

This practice is not applicable for the management of this pest

Information regarding the practice for this pest is unknown

[1]Source: Spring wheat stakeholders in reporting provinces (Alberta, Saskatchewan and Manitoba); the data reflect the 2016, 2015 and 2014 production years.

Annual Grass and Broadleaf Weeds

Pest Information

Damage: Competition from weeds for light, nutrients and moisture can result in yield loss. The severity of yield losses increases with weed density. Weeds that germinate and establish before the emergence of the crop will out-compete the crop. Vegetative weed growth at time of harvest may slow harvesting and increase harvest costs. There may be dockage losses, loss in grade and cleaning costs associated with the presence of weed seeds in the harvested grain.

Life Cycle: Annual weeds reproduce from seeds which are produced annually in great numbers. Annual weeds complete their development from seed germination, through vegetative growth, flowering and seed development, in one growing season. Some annual weeds exhibit a winter annual growth habit, germinating in the fall, overwintering and completing their life cycle in the spring. Seed can remain viable in the soil for many years.

Pest Management

Cultural Controls: Integrated weed management that uses a variety of approaches provides the most effective weed control. Crop rotations with other crops can prevent the build-up of weeds through the use of different cultural practices and herbicides. The use of weed-free seed (including when using farm-saved seed) and thorough cleaning of farm machinery when it is moved to new fields will reduce the chances of introducing new weeds into fields. Early seeding will enable the wheat to emerge and establish ahead of the weeds and reduce the potential for yield loss. Subsurface banding of fertilizers increases crop competition by providing preferential access to nutrients. Additional management practices for annual broadleaf and grass weeds are listed in *Table 11. Adoption of weed management practices in spring wheat production in Canada.*

Resistant Cultivars: None available.

Issues for Annual Broadleaf and Grass Weeds

1. Resistance to commonly used herbicides is a growing concern, especially since the number of herbicide groups registered on wheat is very limited. Examples of herbicide resistance include: resistance to Group 1 herbicides [acetyl-CoA carboxylase (ACCase) inhibitors] od wild oat (*Avena fatua*) and foxtails *Setaria* spp.; wild oat is also resistant to Group 2 herbicides [acetolactate synthase/ actohydroxyacid synthase (ALS/AHAS) inhibitors], as well as the now less-widely used, thiocarbamate herbicides (Group 8); widespread resistance to the dinitroaniline herbicides (Group 3) in foxtails; resistance to commonly used herbicides, such as ALS/AHAS (Group 2) inhibitors in kochia (*Kochia scoparia*); Some kochia biotypes are resistancet to herbicides in Group 4-pyridine carboxylic acid herbicides of some kochia biotypes; seventeen broadleaf weed species have developed resistance to Group 2 herbicides. The potential for the further development of herbicide resistant weeds is a concern. Sustainable approaches to

herbicide resistance management must continue to be developed and promoted to facilitate the adoption of these practices among producers.

2. Cross-resistance and multiple-resistance to a range of herbicides and herbicide groups is well documented. Some biotypes of wild oat in Manitoba may have evolved multiple resistance to up to four or five different herbicidal modes-of-action.
3. There is a need for improved control measures for spiny annual sow thistle *(Sonchus asper)* as a result of widespread resistance to Group 2 herbicides and its misidentification as perennial sow-thistle (*Sonchus arvensis*).
4. The trend to wider row spacing could increase dependence on herbicides, increasing the potential for the development of resistance in annual weeds.
5. Greater resources are required to monitor and map resistant weeds. There is a need for faster and less costly techniques for the diagnosis of herbicide resistance in weeds.
6. There are few herbicides available for the management of downy brome (*Bromus tectorum*) and Japanese brome (*B. japonicus*), which are difficult to control weeds.
7. Weed surveys are required in a number of regions to establish levels of weed infestations.

Perennial Grass and Broadleaf Weeds

Pest Information

Damage: Perennial weeds compete with the crop for moisture and nutrients and can affect both yield and quality.

Life Cycle: Perennial weeds can live for one to many years. They reproduce both by seed and by vegetative means including extensive creeping root systems, stolons and tubers. The weeds may readily regenerate through root fragments. Most perennial weed seeds will germinate within a year, but some may remain viable in the soil for 20 years or more.

Pest Management

Cultural Controls: The selection of fields with low perennial weed pressure is important in perennial weed management. The use of weed free seed and cleaning of farm machinery when moving between fields, will reduce the chances of introducing new weeds to new fields. Perennial weeds may be reduced by post-harvest tillage. Diverse crop rotations with crops such as barley, canola or forages which are more competitive with weeds and for which different herbicides might be available, can prevent the build-up of weed problems. Additional management practices for perennial broadleaf and grass weeds are listed in *Table 11. Adoption of weed management practices in spring wheat production in Canada.*

Resistant Cultivars: None available.

Issues for Perennial Weeds

1. Minimum tillage systems have led to increased problems with perennial weeds.
2. The trend to wider row spacing could increase dependence on herbicides – increasing the rate of development of resistant perennial weeds.
3. Weed surveys are required in a number of regions to establish levels of weed infestations.
4. There is a need for improved controls for Canada thistle (*Cirsium arvense*).

Volunteer Crops

Pest Information

Damage: Volunteer crops compete with the crop for moisture and nutrients and can affect the quality of the seeds harvested. When different wheat classes such as western red spring and amber durum, are grown in rotation, high levels of volunteer off-type wheat in the grain sample may result in downgrading. Winter wheat volunteers can act as a "green bridge" for disease and insect pests in spring wheat.

Life Cycle: Volunteer crops grow from seeds that are the result of harvest and shattering losses. Similar to other annual weeds, they complete their development from seed germination, through vegetative growth, flowering and seed development, in one growing season.

Pest Management

Cultural Controls: Volunteer crops typically do not exhibit significant seed dormancy so most seeds germinate within one year of harvesting the crop. Integrated crop management using diverse crop rotations and increased seeding rates can help reduce problems with volunteers. Using practices that favour rapid seed germination and emergence before that of the volunteers, reduces yield losses. Subsurface banding of fertilizers increases crop competition by providing preferential access to nutrients.

Resistant Cultivars: None available.

Issues for Volunteer Crops

1. Herbicide-tolerant cultivars of volunteer canola, soybean and corn can be difficult to eradicate.
2. Volunteers of other wheat classes or cereal grain species cannot be controlled with herbicides in spring wheat.

Herbicides and bioherbicides registered for weed management in spring wheat production in Canada

Active ingredients registered for the management of **weeds** in spring wheat are listed in *Table 12 Herbicides and bioherbicides registered for weed management in spring wheat production in Canada*. This table also provides registration numbers for **products registered on spring wheat as of February 27, 2019** for each active ingredient, in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific **weeds**, the reader is referred to individual product labels available on the PMRA label database, https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
2,4-D	numerous products	phenoxy-carboxylic-acid	4	synthetic auxin	R (REV2017-08)
2,4-D (including durum wheat)	30061	phenoxy-carboxylic-acid	4	synthetic auxin	R (REV2017-08)
2,4-D + bromoxynil	28123, 30372	phenoxy-carboxylic-acid + nitrile	4 + 6	synthetic auxin + inhibition of photosynthesis at photosystem II site B	R (REV2017-08) + RES
2,4-D + bromoxynil (including durum wheat)	22659, 28779, 28853, 28947, 29513, 30005	phenoxy-carboxylic-acid + nitrile	4 + 6	synthetic auxin + inhibition of photosynthesis at photosystem II site B	R (REV2017-08) + RES
2,4-D + bromoxynil + fluroxypyr (including durum wheat)	30690	phenoxy-carboxylic-acid + nitrile + pyridine carboxilic acid	4 + 6 + 4	synthetic auxin + inhibition of photosynthesis at photosystem II site B + synthetic auxin	R (REV2017-08) + RES + RE
2,4-D + dicamba + mecoprop-P	27856, 27987	phenoxy-carboxylic-acid + benzoic acid + phenoxy-carboxylic-acid	4 + 4 + 4	synthetic auxin + synthetic auxin + synthetic auxin	R (REV2017-08) + R + R
2,4-D + dichlorprop-P	29660, 29664, 30103, 30111, 30112	phenoxy-carboxylic-acid + phenoxy-carboxylic-acid	4 + 4	synthetic auxin + synthetic auxin	R (REV2017-08) + R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Family[2]	Resistance Group[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
2,4-D + fluroxypyr	30077, 31626, 31673	phenoxy-carboxylic-acid + pyridine carboxilic acid	4 + 4	synthetic auxin + synthetic auxin	R (REV2017-08) + RE
2,4-D + glyphosate (including durum wheat)	25898, 30958, 30960	phenoxy-carboxylic-acid + glycine	4 + 9	synthetic auxin + inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R (REV2017-08) + R
2,4-D + imazamox (for use on on Clearfield® wheat only)	27879	phenoxy-carboxylic-acid + imidazolinone	4 + 2	synthetic auxin + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R (REV2017-08) + R
2,4-D + picloram	14167	phenoxy carboxylic acid + pyridine carboxylic acid	4 + 4	synthetic auxin + synthetic auxin	R (REV2017-08) + R
2,4-D + pyraflufen-ethyl (including durum wheat)	32111, 29051	phenoxy-carboxylic-acid + phenylpyrazole	4 + 14	synthetic auxin + inhibition of protoporphyrinogen oxidase (Protox, PPO)	R (REV2017-08) + R
2,4-DB	27910, 27911, 27912	phenoxy-carboxylic-acid	4	synthetic auxin	R (RVD2019-01)
bentazon (bendioxide) (excluding durum wheat)	12221, 32661, 32827, 33011, 33282	benzothiadiazinone	6	inhibition of photosynthesis at photosystem II site B	R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
bicyclopyrone + bromoxynil (including durum wheat)	32681	triketone + nitrile	27 + 6	inhibition of 4-hydroxyphenyl-pyruvate-dioxygenase (4-HPPD) + inhibition of photosynthesis at photosystem II site B	R + RES
bromoxynil (including durum)	18001, 25791	nitrile	6	inhibition of photosynthesis at photosystem II site B	RES
bromoxynil	numerous products	nitrile	6	inhibition of photosynthesis at photosystem II site B	RES
bromoxynil + fluroxypyr + MCPA (including durum wheat	30691	nitrile + pyridine carboxilic acid + phenoxy-carboxylic-acid	6 + 4 + 4	inhibition of photosynthesis at photosystem II site B + synthetic auxin + synthetic auxin	RES + R + RE
bromoxynil + MCPA (including durum wheat)	numerous products	nitrile + phenoxy-carboxylic-acid	6 + 4	inhibition of photosynthesis at photosystem II site B + synthetic auxin	RES + RE

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Family[2]	Resistance Group[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
bromoxynil + fenoxaprop-p-ethyl + pyrasulfotole (including durum wheat)	29367	nitrile + aryloxyphenoxy-propionate 'FOP' + pyrazole[6]	6 + 1 + 27[6]	inhibition of photosynthesis at photosystem II site B + inhibition of acetyl CoA carboxylase (ACCase) + inhibition of 4-hydroxyphenyl-pyruvate-dioxygenase (4-HPPD)[6]	RES + R + R
bromoxynil + fluroxypyr + pyrasulfotole (including durum wheat)	33248	nitrile + pyridine carboxilic acid + pyrazole[6]	6 + 4 + 27[6]	inhibition of photosynthesis at photosystem II site B + synthetic auxin + inhibition of 4-hydroxyphenyl-pyruvate-dioxygenase (4-HPPD)[6]	RES + RE + R
bromoxynil + pyrasulfotole (including durum wheat)	28738, 29051, 29214, 32260	nitrile + pyrazole[6]	6 + 27[6]	inhibition of photosynthesis at photosystem II site B + inhibition of 4-hydroxyphenyl-pyruvate-dioxygenase (4-HPPD)[6]	RES + R
bromoxynil + pyraflufen-ethyl	32528	nitrile + phenylpyrazole	6 + 14	inhibition of photosynthesis at photosystem II site B + inhibition of protoporphyrinogen oxidase (Protox, PPO)	RES + R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
bromoxynil + pyrasulfotole + thiencarbazone-methyl (including durum wheat)	29584, 31992, 32607, 33239	nitrile + triketone + sulfonylaminocarbonyl-triazolinone	6 + 27 + 2	inhibition of photosynthesis at photosystem II site B + inhibition of 4-hydroxyphenyl-pyruvate-dioxygenase (4-HPPD) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	RES + R + R
carfentrazone-ethyl	28573, 33127	triazolinone	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	R
carfentrazone-ethyl + florasulam + flucarbazone (excluding durum wheat)	33273	triazolinone + triazolopyrimidine + sulfonylaminocarbonyl-triazolinone	14 + 2 + 2	inhibition of protoporphyrinogen oxidase (Protox, PPO) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + RE + RE
carfentrazone-ethyl + pyroxasulfone (excluding durum wheat)	32292	triazolinone + isoxazoline	14 + 15	inhibition of protoporphyrinogen oxidase (Protox, PPO) + inhibition of mitosis	R + R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Family[2]	Resistance Group[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
chlorsulfuron (including durum wheat)	17245	sulfonylurea	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R
clodinafop-propargyl (including durum wheat)	numerous products	aryloxyphenoxy-propionate 'FOP'	1	inhibition of acetyl CoA carboxylase (ACCase)	RE
clodinafop-propargyl + fluroxypyr (including durum wheat)	31434	aryloxyphenoxy-propionate 'FOP' + pyridine carboxilic acid	1 + 4	inhibition of acetyl CoA carboxylase (ACCase) + synthetic auxin	RE + RE
clodinafop-propargyl + pinoxaden (including durum wheat)	29855, 31674	aryloxyphenoxy-propionate 'FOP' + phenylpyrazoline ('DEN')	1 + 1	inhibition of acetyl CoA carboxylase (ACCase) + inhibition of acetyl CoA carboxylase (ACCase)	RE + R
clopyralid	23545, 32265, 32336, 32415, 32422, 32423, 32795, 32898, 33114	pyridine carboxylic acid	4	synthetic auxin	R
clopyralid + fluroxpyr (including durum wheat)	30456, 32359	pyridine carboxylic acid + pyridine carboxylic acid	4 + 4	synthetic auxin + synthetic auxin	R + RE

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
clopyralid + fluroxpyr + MCPA (including durum wheat)	31727	pyridine carboxylic acid + pyridine carboxylic acid + phenoxy-carboxylic acid	4 + 4 + 4	synthetic auxin + synthetic auxin + synthetic auxin	R + RE + R
clopyralid + MCPA (including durum wheat)	22764, 25464, 27032, 29465, 30914, 31428	pyridine carboxylic acid + phenoxy-carboxylic acid	4 + 4	synthetic auxin + synthetic auxin	R + R
dicamba	numerous products	benzoic acid	4	synthetic auxin	R
dicamba + fluroxypyr (including durum wheat)	29450	benzoic acid + pyridine carboxilic acid	4 + 4	synthetic auxin + synthetic auxin	R + RE
dicamba + glyphosate	21572, 27200, 30870	benzoic acid + glycine	4 + 9	synthetic auxin + inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R + R
dicamba + MCPA	16545, 27856	benzoic acid + phenoxy-carboxylic-acid	4 + 4	synthetic auxin + synthetic auxin	R + R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
dicamba + MCPA + mecoprop	27790, 27856, 27892, 28028, 28761	benzoic acid + phenoxy-carboxylic-acid + phenoxy-carboxylic-acid	4 + 4 + 4	synthetic auxin + synthetic auxin + synthetic auxin	R + R + R
dicamba + thifensulfuron-methyl (including durum wheat)	29515	benzoic acid + sulfonylurea	4 + 2	synthetic auxin + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R
dicamba + thifensulfuron-methyl + tribenuron methyl (including durum wheat)	28836, 28894, 29556, 30027, 29939	benzoic acid + sulfonylurea + sulfonylurea	4 + 2 + 2	synthetic auxin + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R + R
dicamba + tribenuron methyl (including durum wheat)	28872, 29989, 32995, 33039	benzoic acid + sulfonylurea	4 + 2	synthetic auxin + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R
dichlorprop-P + MCPA + mecoprop-P (including durum wheat)	29662	phenoxy-carboxylic-acid + phenoxy-carboxylic-acid + phenoxy-carboxylic-acid	4 + 4 + 4	synthetic auxin + synthetic auxin + synthetic auxin	R + R + R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
fenoxaprop-p-ethyl (including durum wheat)	numerous products	aryloxyphenoxy-propionate 'FOP'	1	inhibition of acetyl CoA carboxylase (ACCase)	R
florasulam (including durum wheat)	numerous products	triazolopyrimidine	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	RE
florasulam + halauxifen (including durum wheat)	31304	triazolopyrimidine + arylpicolinate	2 + 4	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + synthetic auxin	RE + R
florasulam + MCPA (including durum wheat)	28804	triazolopyrimidine + phenoxy-carboxylic-acid	2 + 4	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + synthetic auxin	RE + R
florasulam + fluroxypyr (including durum wheat)	29286, 29953, 31646, 33289	triazolopyrimidine + pyridine carboxilic acid	2 + 4	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + synthetic auxin	RE + RE

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
florasulam + fluroxypyr + MCPA (including durum wheat)	32099	triazolopyrimidine + pyridine carboxilic acid + phenoxy-carboxylic-acid	2 + 4 + 4	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + synthetic auxin + v	RE + RE + R
florasulam + pinoxaden (excluding durum wheat)	29138	triazolopyrimidine + phenylpyrazoline ('DEN')	2 + 1	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetyl CoA carboxylase (ACCase)	RE + R
florasulam + tribenuron-methyl (including durum wheat)	32758	triazolopyrimidine + sulfonyurea	2 + 2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	RE + R
flucarbazone -sodium (including durum wheat)	26447, 26448, 29558, 30342, 30430, 32602, 32941, 33258	sulfonylaminocarbonyl-triazolinone	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	RE

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
flucarbazone -sodium (excluding durum wheat)	29500	sulfonylaminocarbonyl-triazolinone	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	RE
flucarbazone-sodium + fluroxypyr (including durum wheat)	30580	sulfonylaminocarbonyl-triazolinone + pyridine carboxilic acid	2 + 4	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + synthetic auxin	RE + RE
flucarbazone - sodium + tribenuron methyl (excluding durum wheat	30663	sulfonylaminocarbonyl-triazolinone + sulfonyurea	2 + 2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	RE + R
flumioxazin	29230, 29235	N-phenylphthalimide	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	R
flumioxazin + pyroxasulfone	31117, 33116	N-phenylphthalimide + isoxazoline	14 + 15	inhibition of protoporphyrinogen oxidase (Protox, PPO) + inhibition of mitosis	R + R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Family[2]	Resistance Group[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
fluroxypyr (including durum wheat)	numerous products	pyridine carboxilic acid	4	synthetic auxin	RE
fluroxypyr + halauxifen (including durum wheat)	31303, 33262	pyridine carboxilic acid + arylpicolinate	4 + 4	synthetic auxin + synthetic auxin	RE + RE
fluroxypyr + pinoxaden	30391	pyridine carboxilic acid + phenylpyrazoline ('DEN')	4 + 1	synthetic auxin + inhibition of acetyl CoA carboxylase (ACCase)	RE + R
fluroxypyr + pyroxsulam (including durum wheat)	33028	pyridine carboxilic acidb + triazolopyrimidine	4 + 2	synthetic auxin + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	RE + R
fluroxypyr + thifensulfuron-methyl (including durum wheat)	32143	pyridine carboxilic acid + sulfonylurea	4 + 2	synthetic auxin + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	RE + R
glyphosate (present as dimethylamine salt)	numerous products	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
glyphosate (present as isopropylamine salt)	numerous products	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
glyphosate (present as isopropylamine salt and potassium salt)	numerous products	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
glyphosate (present as potassium salt	numerous products	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
halauxifen (including durum wheat)	31304, 31305	arylpicolinate	4	synthetic auxin	R
halauxifen + pyroxsulam (including durum wheat)	32520	arylpicolinate + triazolopyrimidine	4 + 2	synthetic auxin + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R
imazamethabenz-methyl (including durum wheat)	21032, 29618	imidazolinone	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
imazamox (for use on Clearfield® wheat only)	26705	imidazolinone	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R
linuron	15544, 16279, 20193	urea	7	inhibition of photosynthesis at photosystem II site A (different behavior from group 5)	RES*
MCPA (present as amine salts: diethanolamine, dimethylamine or mixed amines) (including durum wheat)	8211, 27030	phenoxy-carboxylic-acid	4	synthetic auxin	R
MCPA (present as amine salts: diethanolamine, dimethylamine or mixed amines)	numerous products	phenoxy-carboxylic-acid	4	synthetic auxin	R
MCPA (present as potassium salt) + MCPB (present as sodium salt)	22003, 24336, 26488, 29582	phenoxy-carboxylic-acid	4	synthetic auxin	R + R

….continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
MCPA + pyraflufen-ethyl	32112	phenoxy-carboxylic-acid + phenylpyrazole	4 + 14	synthetic auxin + inhibition of protoporphyrinogen oxidase (Protox, PPO)	R + R
mecoprop-p	27824, 27891, 28563	phenoxy-carboxylic-acid	4	synthetic auxin	R
mesosulfuron methyl (including durum wheat)	29707	sulfonylurea	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R
metribuzin	numerous products	triazinone	5	inhibition of photosynthesis at photosystem II site A	R
metsulfuron-methyl (including durum wheat)	numerous products	sulfonylurea	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
metsulfuron-methyl + flouroxypyr + thifensulfuron methyl (including durum wheat)	31685	sulfonylurea + pyridine carboxilic acid + sulfonylurea	2 + 4 + 2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + synthetic auxin + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + RE + R
metsulfuron-methyl + pyroxsulam + thifensulfuron-methyl + tribenuron-methyl (including durum wheat)	32575, 32576, 32579, 32580	sulfonylurea + triazolopyrimidine + sulfonylurea + sulfonylurea	2 + 2 + 2 + 2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R + R + R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
metsulfuron-methyl + quinclorac + thifensulfuron-methyl + tribenuron-methyl (including durum wheat)	30583	sulfonylurea + quinoline carboxylic acid + sulfonylurea + sulfonylurea	2 + 4 + 2 + 2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + synthetic auxin + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R + R + R
metsulfuron-methyl + thifensulfuron-methyl + tribenuron-methyl (including durum wheat)	29262, 29579	sulfonylurea + sulfonylurea + sulfonylurea	2 + 2 + 2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R + R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
metsulfuron-methyl + tribenuron-methyl (including durum wheat)	29212, 29929, 31873	sulfonylurea + sulfonylurea	2 + 2 + 2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R
picolinafen (including durum wheat)	27291	pyridinecarboxamide	12	inhibition of phytoene desaturase (PDS)	R
pinoxaden (including durum wheat)	28150, 28642	phenylpyrazoline ('DEN')	1	inhibition of acetyl CoA carboxylase (ACCase)	R
pinoxaden	32448	phenylpyrazoline ('DEN')	1	inhibition of acetyl CoA carboxylase (ACCase)	R
pinoxaden (excluding durum wheat)	30341	phenylpyrazoline ('DEN')	1	inhibition of acetyl CoA carboxylase (ACCase)	R
pyrasulfotole (including durum wheat)	28736	pyrazole[6]	276	inhibition of 4-hydroxyphenyl-pyruvate-dioxygenase (4-HPPD)[6]	R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
pyroxsulam (including durum wheat)	28887, 29985, 31061, 31916, 31932, 32068, 33290	triazolopyrimidine	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R
pyroxsulam + thifensulfuron-methyl (including durum wheat)	33015, 33016	triazolopyrimidine + sulfonylurea	2 + 2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R
pyroxsulam + thifensulfuron-methyl + tribenuron-methyl (including durum wheat)	32120, 32121, 32577, 32578	triazolopyrimidine + sulfonylurea + sulfonylurea	2 + 2 +2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R + R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
pyroxsulam + tribenuron-methyl (including durum wheat)	32739, 32740	triazolopyrimidine + sulfonyurea	2 + 2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R
pyroxasulfone (excluding durum wheat)	30572	isoxazoline	15	inhibition of mitosis	R
quinclorac (including durum wheat)	25118, 31365, 31539, 31753, 32138, 32213, 33322	quinoline carboxylic acid	4	synthetic auxin	R
quinclorac + thifensulfuron methyl + tribenuron methyl (including durum wheat)	28349, 28622	quinoline carboxylic acid + sulfonylurea + sulfonylurea	4 + 2 + 2	synthetic auxin + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R + R
salflufenacil (including durum wheat)	29368, 31468, 31469	pyrimidinedione	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
thiencarbazone-methyl (including durum wheat)	29070, 29213, 29511, 29512, 31735, 31894, 31990, 32908	sulfonylaminocarbonyl-triazolinone	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R
thifensulfron methyl + tribenuron methyl (including durum wheat)	numerous products	sulfonylurea + sulfonylurea	2 + 2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) + inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R + R
tralkoxydim (including durum wheat)	numerous products	cyclohexanedione 'DIM'	1	inhibition of acetyl CoA carboxylase (ACCase)	R
triallate (including durum wheat)	16759, 25112	thiocarbamate	8	inhibition of lipid synthesis; not ACCase inhibition	R
triallate + trifluralin (including durum wheat)	19521	thiocarbamate + dinitroaniline	8 + 3	inhibition of lipid synthesis; not ACCase inhibition + microtubule assembly inhibition	R + R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
tribenuron-methyl (including durum wheat)	numerous products	sulfonyurea	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R
trifluralin (for use in the Heritage wheat production system)	14545	dinitroaniline	3	microtubule assembly inhibition	R
trifluralin	17223	dinitroaniline	3	microtubule assembly inhibition	R
trifluralim (including durum wheat)	18612, 19521, 21742, 22744, 28289	dinitroaniline	3	microtubule assembly inhibition	R
Plant Growth Regulators (PGR)					
chlormequat PLANT GROWTH REGULATOR (including durum wheat)	31462	plant growth regulator	N / A	for treatment of wheat to produce shorter, thicker, stronger stems for improved lodging resistance	R

…continued

Table 12. Herbicides and bioherbicides for weed management in spring wheat production in Canada (continued)

Footnotes:

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). **The list includes all active ingredients registered as of February 15, 2019.** While every effort has been made to ensure all herbicides, bioherbicides and plant growth regulators registered in Canada on spring wheat have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Weed Science Society of America (WSSA). Herbicide Site of Action Classification list (last modified December 5, 2018) http://wssa.net (accessed January 28, 2019)

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2018-06 Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023, Re-evaluation Note REV2018-17 Initiation of Cumulative Health Risk Assessment-N-Methyl Carbamates **and other re-evaluation documents**: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[4] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 9.1; December 2018)* (excluding pheromones) (www.irac-online.org) (accessed January 28, 2019).

[5]As published by Government of Canada: *Notice to anyone engaged in the use of methyl bromide: June 2017 https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/notice-use-methyl-bromide-june-2017.html*

[6] Source: National Center for Biotechnology Information: Pyrasulfotole https://pubchem.ncbi.nlm.nih.gov/compound/Pyrasulfotole#section=Top; not yet classified under the Weed Science Society of Americal Herbicide Site of Action (SOA) Classification list.

Resources

Integrated pest management / integrated crop management resources for spring wheat production in Canada

Alberta Agriculture and Forestry. Crops Publications.
www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3882

Centre de référence en agriculture et agroalimentaire du Québec (CRAAQ). www.craaq.qc.ca

Canadian Grain Commission. *Canadian Wheat Classes*.
https://www.grainscanada.gc.ca/en/grain-quality/official-grain-grading-guide/

Food and Agriculture Organization of the United Nations. FAOSTAT. *Value of Agricultural Production: Canada.* http://www.fao.org/faostat/en/#data/QV

Government of Canada. *From a single seed: tracing the Marquis Wheat success story in Canada to its roots in the Ukraine* / by Stephan Symko. ISBN: 978-0-660-03585-7. Cat. No. A22-197/1999E-PDF. 85 pp. http://publications.gc.ca/site/eng/9.804661/publication.html

Health Canada. Pest Management Regulatory Agency. *Pesticides and Pest Management*.
www.hc-sc.gc.ca/cps-spc/pest/index-eng.php

Manitoba Agriculture. *Field Crop Production Guide.* 90 pp.
https://www.gov.mb.ca/agriculture/crops/guides-and-publications/#fcpg

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http://www.gocereals.ca/index.php

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https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/crops-and-irrigation/crop-guides-and-publications/varieties-of-grain-crops

Saskatchewan Agriculture. *Crop Guides and Publications*.
https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/crops-and-irrigation/crop-guides-and-publications

Statistics Canada. www.statcan.gc.ca

USDA Regional IPM Centres. www.ipmcenters.org

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
Alberta	Alberta Agriculture and Forestry www.alberta.ca/ministry-agriculture-forestry.aspx	Clair Langlois, Crop Extension Specialist clair.langlois@gov.ab.ca	Gayah Sieusahai gayah.sieusahai@gov.ab.ca Ron Pidskalny Prairie Minor Use Consortium (Alberta, Saskatchewan and Manitoba) pidskaln@gmail.com
Saskatchewan	Saskatchewan Ministry of Agriculture www.saskatchewan.ca/government/government-structure/ministries/agriculture	Mitchell Japp, Cereal Crop Specialist mitchell.japp@gov.sk.ca	Carter Peru carter.peru@gov.sk.ca
Manitoba	Manitoba Agriculture www.gov.mb.ca/agriculture/	Anne Kirk, Cereal Crop Specialist anne.kirk@gov.mb.ca Earl Bergen, Farm Production Extension Specialist earl.bergen@gov.mb.ca Rejean Picard, Farm Production Extension Specialist rejean.picard@gov.mb.ca	Pratisara Bajracharya pratisara.bajracharya@gov.mb.ca

Provincial Wheat Grower Organizations

Agricultural Producers Association of Saskatchewan: https://apas.ca/

Alberta Wheat commission (AWC): http://www.albertawheat.com/

Atlantic Grains Council: http://www.atlanticgrainscouncil.ca/

British Columbia Grain Producers Association: www.bcgrain.com

Centre de recherche sur les grains (CEROM) : www.cerom.qc.ca

Grain Farmers of Ontario: www.gfo.ca

Manitoba Wheat and Barley Growers Association: http://www.mbwheatandbarley.ca/

Ontario Federation of Agriculture: www.ofa.on.ca

Ontario Soils and Crop Improvement Association (OSCIA): www.ontariosoilcrop.org

Producteurs de Grains du Québec: http://www.pgq.ca/

The Midge Tolerant Wheat Stewardship Team: www.midgetolerantwheat.ca

Western Canadian Wheat Growers Association: https://wheatgrowers.ca/

National Wheat Grower Organizations

Canadian Federation of Agriculture: www.cfa-fca.ca

Canada Grain Commission: https://www.grainscanada.gc.ca/en/

Canadian Grains Council: https://canadagrainscouncil.ca/

G3 Canada Limited: http://www.g3.ca/

Grain Growers of Canada (GGC): www.ggc-pgc.ca

Appendix 1

Definition of terms and colour coding for pest occurrence table of the crop profiles.

Information on the occurrence of disease, insect and mite and weed pests in each province is provided in Tables 4, 7 and 10 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and pressure in each province as presented in the following chart.

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th>Colour Code</th></tr>
<tr><td rowspan="13">Present</td><td rowspan="10">Data available</td><th>Frequency</th><th>Distribution</th><th>Pressure</th><td></td></tr>
<tr><td rowspan="6">**Yearly** - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">**Widespread** - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>**High** - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.</td><td>Red</td></tr>
<tr><td>**Moderate** - If present, potential for spread and crop loss is moderate: pest situation must be monitored and controls may be implemented.</td><td>Orange</td></tr>
<tr><td>**Low** - If present, the pest causes low or negligible crop damage and controls need not be implemented.</td><td>Yellow</td></tr>
<tr><td rowspan="3">**Localized** - The pest is established as localized populations and is found only in scattered or limited areas of the province.</td><td>**High** - see above</td><td>Orange</td></tr>
<tr><td>**Moderate** - see above</td><td>White</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="6">**Sporadic** - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="3">**Widespread** - as above</td><td>**High** - see above</td><td>Orange</td></tr>
<tr><td>**Moderate** - see above</td><td>Yellow</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="3">**Localized** - as above</td><td>**High** - see above</td><td>Yellow</td></tr>
<tr><td>**Moderate** -see above</td><td>White</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="2">Data **not** available</td><td colspan="3">**Not of concern:** The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.</td><td>White</td></tr>
<tr><td colspan="3">**Is of concern:** The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.</td><td>Blue</td></tr>
<tr><td>Not present</td><td colspan="4">The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.</td><td>black</td></tr>
<tr><td>Data not reported</td><td colspan="4">Information on the pest in this province is unknown. No data is being reported for this pest.</td><td>grey</td></tr>
</table>

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http://www.publications.gc.ca/site/eng/9.834174/publication.html

Agriculture and Agri-Food Canada. (2018). *Field Crop and Forage Pests and their Natural Enemies in Western Canada: Identification and Management Field Guides*. Cat. No. A59-23/2018E-PDF. ISBN: 9780660255613.
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Alberta Agriculture and Forestry. *Crops Publications*.
www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3882

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Harker, K.N. and R.E. Blackshaw. (2009). *Integrated Cropping Systems for Weed Management*. Prairie Soils and Crops, 2: 8. http://www.agr.gc.ca/eng/abstract/?id=15723000000272

Leeson, J.Y. and Thomas, A.G. (2009). *Management of Weeds within Tillage Systems: What have we learned from Prairie Weed Surveys?* Prairie Soils and Crops: Vol. 2. https://prairiesoilsandcrops.ca/articles/volume-2-5-print.pdf

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