



Winter Wheat

PRODUCTION MANUAL



Alberta Wheat
COMMISSION

The former Alberta Winter Wheat Producers Commission (AWWPC) is recognized and thanked for coming up with and spear-heading the idea of producing a new Winter Wheat Production Manual for Alberta's wheat producers.



This project was made possible by the kind support, involvement and dedication of many people. The Alberta Wheat Commission would especially like to acknowledge the following;

Alberta Winter Wheat Producers Commission	Dr. Denis Gaudet (AAFC, Lethbridge)
Ducks Unlimited Canada	Dr. Robert Graf (AAFC, Lethbridge)
Dr. Brian Beres (AAFC, Lethbridge)	Dr. Linda Hall (U of Alberta, Edmonton)
Dr. Hector Carcamo (AAFC, Lethbridge)	Dr. Ross McKenzie (AARD, Lethbridge)
Emilio deMilliano (Viterra, Fort Saskatchewan)	Mr. Doon Pauley (AARD, Lethbridge)

The content for this manual was researched and assembled by Dr. Linda Hall's 2011 Cropping System Class (Department of Agricultural, Food and Nutritional Science, University of Alberta). The following students were involved in a class project to develop an up to date winter wheat production manual for Alberta's wheat producers. They are to be congratulated and thanked for all of their hard work.

Ryan Achtymichuk	Aggar Frias Luna	Adele Harding
Brittany Hennig	Jodi Holmstrom	Scott Konieczny
Brent Puchaalski	Ryan Schoorlemmer	Russell Shuttleworth

Copyright 2013 ©Alberta Wheat Commission

Cover Photo Credit: Laura Istead

Disclaimer: The material in this manual is believed to be accurate and up to date at the time of printing, however, the Alberta Wheat Commission accepts no liability for how the information is used and the results obtained from its use.

Table of Contents

Why Grow Winter Wheat?	5
Why Grow Winter Wheat.....	5
Profit Potential.....	5
Cost Determination and Comparison	6
Expected Profits.....	6
Marketing	7
Wheat Price Influencers.....	7
Winter Wheat Markets	9
CWRW (Canadian Western Red Winter)	9
CWGP (Canadian Western General Purpose).....	10
Seeding Management	11
Variety Selection	11
Making a Variety Selection.....	11
2013 Winter Wheat Variety List.....	12
Important factors to consider when choosing your variety	13
The Essence of Timing.....	15
Field Preparation.....	16
Seeding Rate	17
Seeding Depth	17
Soil Fertility and Nutrient Management	19
Rates	19
Guide to Soil Testing.....	21
Fertilizer Product Choice	22
Application Method.....	24
Crop Rotation	25
Crop Rotation	25
Preceding crops to winter wheat and their attributes	26
Examples of a winter wheat crop rotation.....	28
Frost Dates for Various Alberta Locations.....	28
Integrated Weed Management	29
Field Scouting	29
Winter Wheat Life Cycle.....	29
Winter Annual Life Cycle.....	29
Perennial Weed Life Cycle.....	30
Annual Weed Life Cycle.....	30
Advantages of Winter Wheat For Weed Control.....	31



Table of Contents

Rotation	32
Seeding Rate and Fall Weed Control	32
Seed Selection	33
Seeding Date	33
Seeding Depth	33
Fertility	33
Herbicide Selection	33
Herbicide Timing	33
Weed Control Options	34
Weeds Found in Winter Wheat	35
Insects	37
Cereal Leaf Beetle (<i>Oulema melanopus</i>)	38
Wheat Stem Sawfly (<i>Cephus cinctus</i>)	39
Cutworms	41
Grasshoppers	43
Wheat Curl Mite (<i>Eriophyes tulipae</i>)	44
Russian Wheat Aphid (<i>Diuraphis noxia</i>)	45
Wireworms (<i>Ctenicera aeripennis destructor</i>)	46
Diseases	49
General Guideline	49
Quick Reference Table for Diseases Found in Winter Wheat	49
Stripe Rust (<i>Puccinia striiformis</i>)	50
Tan Spot of Wheat (<i>Pyrenophora tritici-repentis</i>)	52
Snowmold (Winter Crown Rot)	53
Wheat Streak Mosaic Virus (<i>Tritimovirus</i>)	54
Fusarium Head Blight (<i>Fusarium graminearum</i>)	55
Common Bunt (<i>Tilletia laevis</i> and <i>T. tritici</i>)	56
Take-All (<i>Gaeumannomyces graminis</i>)	57
Winter Survival	59
Weather/Climate	59
Controllable Factors	61
Assessing Winter Survival	62
References	65
Index	70



Winter Wheat Calendar

Month	*Days	General Guideline for Important Dates	See Section
August	1+	Soil test: Should be done as close to seeding as possible, while allowing time to receive analytic results	Soil Fertility and Nutrient Management
	15-20	Optimum seeding time (Peace Region)	Seeding Management
	15-31	Fall fertilizer application; may be banded or seed placed at seeding	Soil Fertility and Nutrient Management
	15-31	Optimum seeding time (Vermillion)	Seeding Management
September	1+	Scout for Grasshoppers	Insects
	1+	Begin scouting for winter annual and perennial weeds; control with herbicides if necessary	Integrated Weed Management
	1-10	Optimum seeding time (Lacombe)	Seeding Management
	11	Average first frost date for Northern Alberta	Crop Rotations
	12-15	Average first frost date for Central Alberta	Crop Rotations
	1-20	Fall fertilizer application; can be broadcast or banded prior to seeding, or banded or seed-placed at time of seeding	Soil Fertility and Nutrient Management
	10-20	Optimum seeding time (Lethbridge)	Seeding Management
	15-23	Average first frost dates for Southern Alberta	Crop Rotations
	1-30	Begin scouting for Wheat Streak Mosaic Virus	Diseases
October	1-30	Continue scouting for Wheat Streak Mosaic Virus	Diseases
		Continue scouting for winter annual and perennial weeds, control with herbicides if necessary	Integrated Weed Management
November		Evaluate snow cover and note freeze/thaw cycles, and Chinooks, as these factors can impact winter survival	Winter Survival
December		Evaluate snow cover and note freeze/thaw cycles, and Chinooks, as these factors can impact winter survival	Winter Survival
January		Evaluate snow cover and note freeze/thaw cycles, and Chinooks, as these factors can impact winter survival	Winter Survival
February		Evaluate snow cover and note freeze/thaw cycles, and Chinooks, as these factors can greatly impact winter survival	Winter Survival

Winter Wheat Calendar

Month	*Days	General Guideline for Important Dates	See Section
March		Begin scouting for Snowmold at spring melt	Diseases
	1+	Evaluate winter survival, don't be too hasty about plowing down a seemingly bad stand	Winter Survival
	20-30	Spring fertilizer application, as soon as conditions are favorable	Soil Fertility and Nutrient Management
April	1-15	Spring fertilizer application, as soon as conditions are favorable	Soil Fertility and Nutrient Management
	~15	Begin Scouting for Cereal Leaf Beetle	Insects
	1-30	Scout for Wheat Streak Mosaic Virus	Diseases
		Scout for perennial and summer annual weeds; control with herbicides if necessary	Integrated Weed Management
May	1-30	Scout for Tan Spot while plant is tillering and low to the ground	Diseases
	1-30	Begin scouting for Stripe Rust; scouting should be conducted often until 35-45 days prior to harvest	Diseases
	15-30	Begin scouting for Cutworms	Insects
	15-30	Begin scouting for Wireworms	Insects
	14-20	Average date of last spring frost (Southern Alberta)	Crop Rotations
	18	Average date of last spring frost (Northern Alberta)	Crop Rotations
	19-25	Average date of last spring frost (Central Alberta)	Crop Rotations
	1-30	Continue scouting for Wheat Streak Mosaic Virus	Diseases
June	1-15	Continue scouting for Cutworms	Insects
	1-15	Continue scouting for Wireworms	Insects
	20-30	Begin scouting for Wheat Stem Sawfly	Insects
		Conduct herbicide efficacy checks	Integrated Weed Management
July	1-26	Scout for Fusarium Head Blight	Diseases
	1-31	Continue Scouting for Wheat Stem Sawfly	Insects

* Days are approximations only; environmental conditions, previous cropping history and other factors may cause variations. This Calendar should be used as a guideline only.



Why Grow Winter Wheat?

Winter wheat production has moved from 450 thousand acres (182 thousand hectares) in 1978 (University of Saskatchewan, 2002) to 1 654.6 thousand acres (669.5 thousand hectares) in 2011 across Canada (Statistics Canada, 2011), yet many farmers remain hesitant to incorporate it into their rotations.

Improvements to winter hardiness and expanded disease resistance have led to the development of varieties that can be successfully grown across a larger, more environmentally diverse area. See [Seeding Management](#).

Winter wheat's benefits are often overlooked when comparisons are made solely on grain prices. As with any production decision, net returns should be considered not gross revenue alone. Additionally, less measurable benefits such as reduced soil erosion, habitat contributions for waterfowl and rotational benefits are other reasons to grow winter wheat. This publication compares several advantages and disadvantages for winter wheat cropping in Alberta, reflecting the University of Saskatchewan's *Winter Wheat Production Manual* (University of Saskatchewan, 2002).

Advantages to Growing Winter Wheat	Disadvantages to Growing Winter Wheat
Fall, winter and spring moisture can be used more efficiently	Lower protein content than Hard Red Spring Wheat (HRSW)
Crop yields are affected positively by an increase in available soil water	Rotations and harvest must allow for early seeding
Early spring growth by winter wheat reduces annual weed competition and reduces the need for in-crop herbicides	Historically price of winter wheat compared to HRSW
Winter wheat fits well into a reduced or no-till agricultural system	Potential for winter kill
Soil erosion is reduced in conventional tillage systems by the presence of a winter crop	Green bridge can vector pests such as Wheat Streak Mosaic Virus and Barley Yellow Dwarf
Reduced insecticide use	Time and equipment constraints during harvest season
Reduced fungicide use	Viewed as a higher risk crop in some regions
Avoids pests (including wheat midge) due to advanced staging	
Reduced risk of Fusarium Head Blight and Ergot due to early development and maturity	
Reduced selection for herbicide resistance in weeds	
Potential for an earlier harvest than spring wheat	
Enhanced diversity of the cropping system	
Enhanced nesting area for upland birds	
High yield potential (15-40% more than spring seeded wheats)	

Profit Potential

The high yield potential of winter wheat can result in higher profits. Further, decreased herbicide, insecticide and fungicide use can result in decreased overall costs. By expanding the seeding and harvest window, fewer machines (combines, truck, etc.) and operators are needed, allowing producers to farm more acres with lower overall costs.



Why Grow Winter Wheat?

Cost Determination and Comparison

As a result of the constantly changing economic environment that agriculture operates in, costs can vary between regions and in time. Alberta Agriculture and Rural Development (AARD) has several online calculators to determine a specific operation's costs, year-to-year.

There is no additional cost (or discount) associated with seeding winter wheat. Regardless of seeding method, the same number of passes over the field would have to be made as with spring wheat. There are varietal differences in seed cost, yield, winter survival, and selling price. For more information on this, see [Marketing](#) and [Seeding Management](#).

Cost of Production - Crop Enterprise

Available at:

<http://www.agric.gov.ab.ca/app21/ldcalc>

Note:

Depending upon the soil zone selected, winter wheat may not be available to select as a crop type. However, all variables can be manually edited in subsequent windows. Canadian Prairie Strong or Spring Wheat can be selected and then manually edited to reflect Winter Wheat.

Expected Profits

In the past, winter wheat market prices were considerably lower than spring wheat classes, such that producers were not interested. This situation is changing, as premiums paid for the recently developed, high protein Canadian Western Red Winter (CWRW) Select varieties have made winter wheat more similarly priced to some Canadian Western Red Spring (CWRS) wheats (Figure 1).

Evidently, crop returns fluctuate between years, depending on many factors such as oil prices, world produc-

tion levels, and global demand. Producers must not guide themselves solely on what the highest-quality and protein varieties are, but also by what is the most convenient variety for their operation. Additional factors such as, winter wheat's "marketing flexibility,... potential for early movement,... and more efficient storage" (Ducks Unlimited Canada, 2011b) should then be considered when thinking of incorporating winter wheat into a cropping rotation. See [Marketing](#).

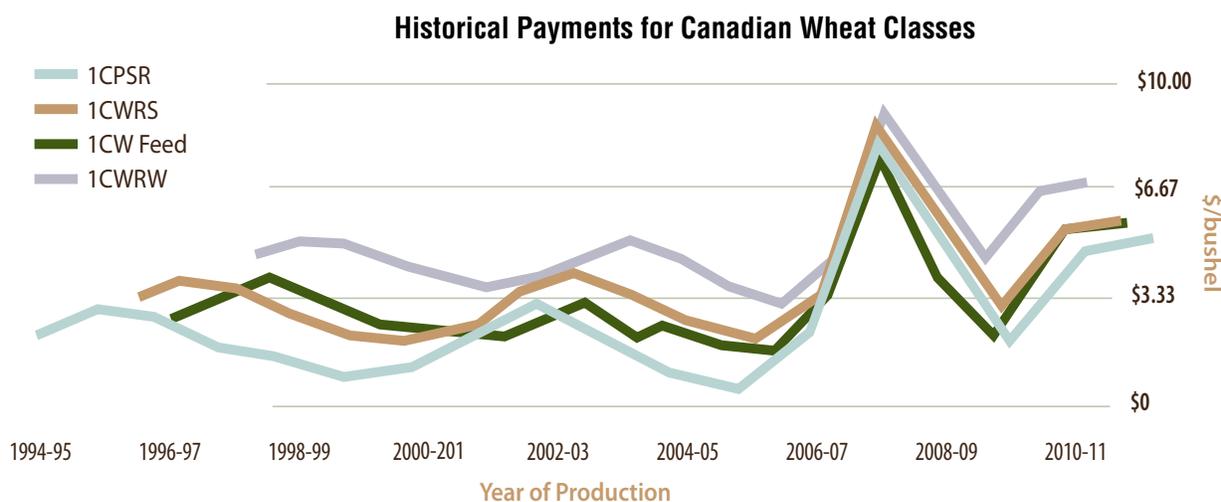


Figure 1. Payments, by class, from 1994 to 2011.

(Composed from Canadian Wheat Board data on final historical payments and the Price Return Outlook for 2011-12, as of Oct 27, 2011.)



Wheat Price Influencers

Global prices for grains, including wheat, have reached historic highs in the past 5 years. Whether prices are increasing or decreasing, multiple factors and their interactions impact the price of wheat (Table 1).

Wheat Price Influencers	Supply	World's supply. Decrease in supply = increase in price.
	Demand	Canada exports wheat all over the world for food and feed. World's population is increasing. Ethanol production is increasing.
	Currency	Global commodity markets are determined in US dollars. Countries' relative currency value compared to the US dollar is important.
	Speculators	The increase in non-traditional investors in the commodity market has created increased volatility.
	Big Shocks	Violent weather can result in a loss of crops. Wars can result in a stoppage of trade.

Table 1. Factors Influencing Wheat Price (McCalla, 2009)

Supply

The price of wheat is influenced by the world's supply of wheat. If the supply is lower than normal, the price tends to be higher. Globally, the main exporters of wheat and, as a result, influencers of supply, are Canada, Argentina, Australia, the United States, and The European Union (Figure 1) (Canadian Wheat Board, 2011).

Trade barriers imposed by countries, which influence the amount of wheat another country can export, influence the supply of wheat. Wheat yields also have an effect on the supply. The decrease in land available for production, due to climate change and urban sprawl, for example, also impact the supply. Additionally, the price of other crops will influence a producer's decision to grow wheat, depending on how profitable wheat is relative to other crops (McCalla, 2009).

Competition in Global Markets (5 year average)
% of Global Trade - WHEAT

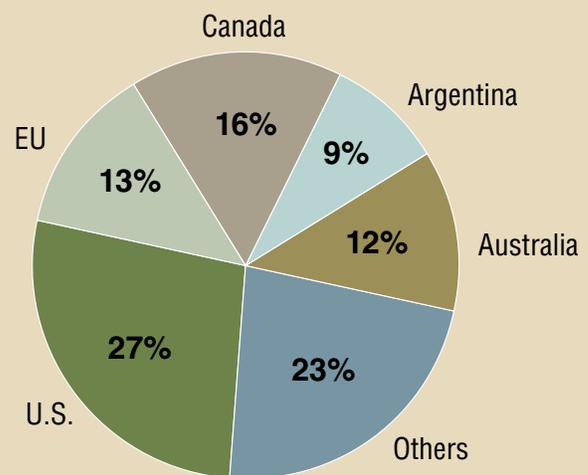


Figure 1. The percentage of total wheat sales in the world. This chart is not limited to CWRW wheat. Canada makes up about 16% of wheat sales in the world. (Canadian Wheat Board, 2011)

Demand

Global demand for wheat will have an influence on the price. As demand increases, the price usually increases as well. Canadian wheat is exported all over the world. The majority of Canadian wheat is sold to Iraq, Bangladesh, the United States, and Japan (Canadian Wheat Board, 2011). The map in Figure 2 shows the approximate percentage of total Canadian wheat sales globally.

As the world's population continues to increase, so too will the demand for wheat. The populations of developing countries are increasing at a much faster rate than those of developed countries. These developing countries will require more food to feed their mounting populations. Figure 3 illustrates the predicted growth rate of the world's population up to the year 2030 (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2010).

The demand for Canadian Western General Purpose (CWGP) wheat is influenced by the amount of animal feed required and the amount of ethanol being produced. Since ethanol is considered a green fuel, which reduces greenhouse gas emissions, production is expected to increase (Figure 4). Further, the Canadian government has mandated minimum levels of biofuels be blended into fuel currently sold in Canada (Mukhopadhyay and Thomassin, 2011).

Canadian Global Wheat Sales

Approximate percentage of sales

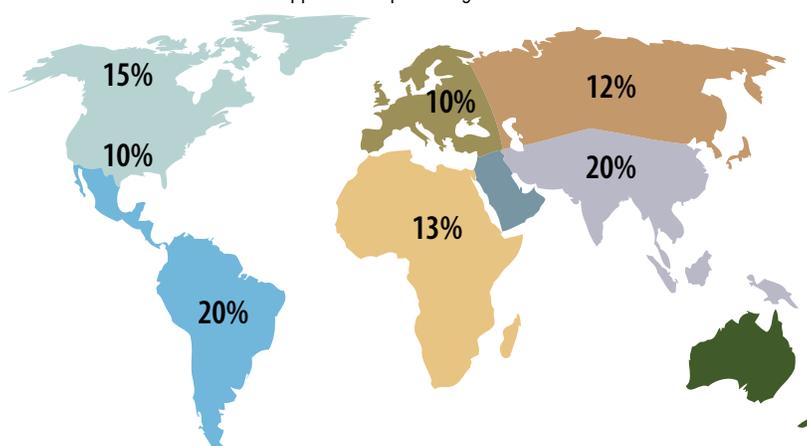


Figure 2. Distribution of Canadian wheat sales globally. This map is not limited to sales of CWRW wheat and includes all sales of Canadian wheat. (Canadian Wheat Board, 2011)

World Population

Source FAO Global Food Trends

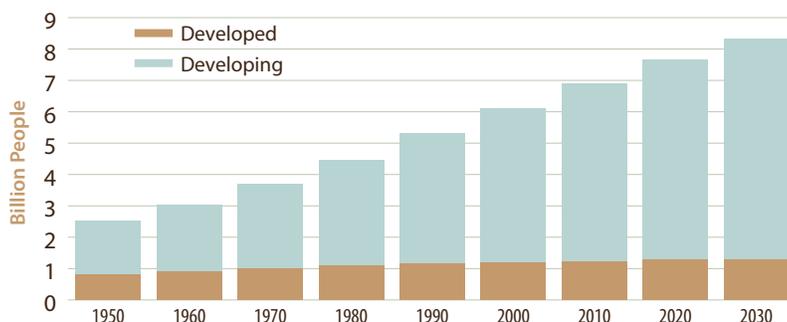
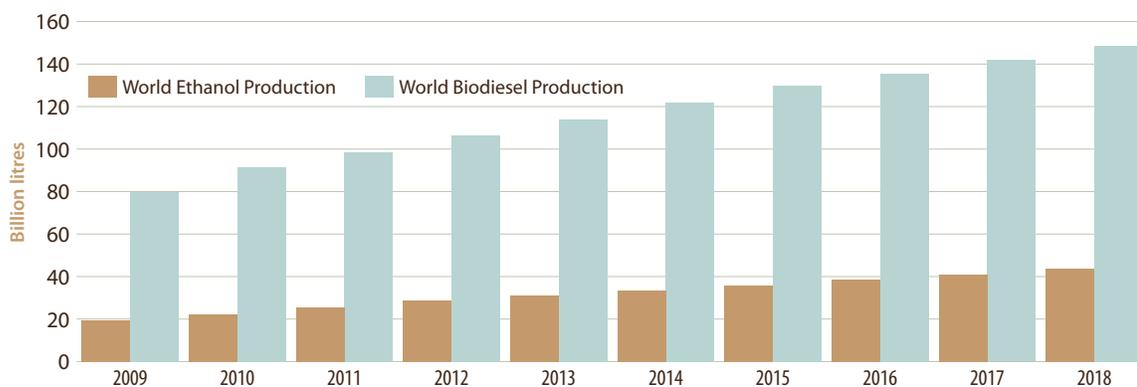


Figure 3. Predicted increase in the world's population up to the year 2030. The blue represents the population of developed countries while the yellow represents the population of developing countries. The population of developing countries is expected to increase at a much greater rate. As the world's population increases, the demand for wheat will likely increase. (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2010)

Figure 4. Estimated levels of biodiesel and ethanol production in the world until 2018. (Food and Agriculture Organization of the United Nations, 2009)



Currency, Speculators and Big Shocks

The value of a country's currency in relation to the US dollar is important for importing and exporting. Since all global commodity markets are determined in US dollars, this will influence how much of a particular commodity a country can buy. If a country's currency is worth more than the US dollar, commodities such as wheat will be less expensive for that country to buy.

Speculation in the market also influences commodity prices. Speculators are people who buy and sell commodities in large quantities for the sole purpose of making money. They do not physically take possession of the commodity being traded, but rather trade contracts in an attempt to make a profit. The increase of nontraditional investors in the commodity market has amplified the volatility of the market. However, these speculators are unlikely to drive a sustained increase in price.

Finally, big shocks are a reference to any unexpected event that can cause a large change in supply. Problems such as violent weather, which can destroy large portions of a crop in a country, and wars, which can result in the stoppage of trade, will influence the price of wheat. Also, countries in Europe and North America, as well as Australia, have all decreased their stockpile of grain. This means that a big shock can have a large influence on the price due to the fact that there are no longer substantial stockpiles of grain to counteract the supply shocks. It is difficult to predict when and how severe big shocks will be until after they have occurred (McCalla, 2009).

Winter Wheat Markets

Winter wheat has been grown on the Canadian Prairies since the early days of wheat production. In the mid-1980s, a large increase in the acres of winter wheat seeded occurred, followed by a return to average levels. Again in the last few years winter wheat acres saw a considerable spike, as the amount nearly doubled. Winter wheat typically yields higher than spring wheat due to its ability to take advantage of the spring moisture and the longer growing season. However, the protein levels of winter wheat are typically

Western Canadian Wheat Production 2005 – 2009

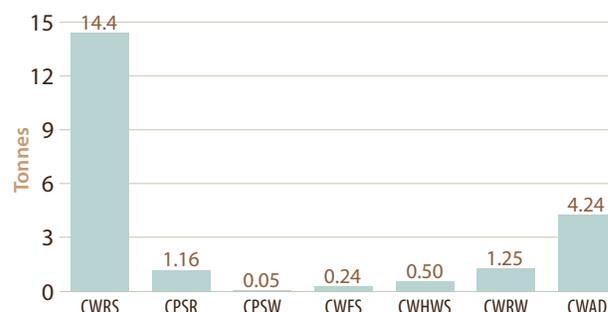


Figure 5. Classes of wheat grown in Western Canada and their respective production (million tonnes), 2005-2009. (Canadian Wheat Board, 2011)

lower than that of spring wheat (Graf, 2011; McCallum and DePauw, 2008). Even though winter wheat has some advantages over spring wheat, the acres of winter wheat grown in comparison to CWRS are low (Figure 5).

Winter wheat is segregated into two classes for marketing purposes:

- Canadian Western Red Winter (CWRW)
- Canadian Western General Purpose (CWGP)

Traditionally winter wheat was grouped into the classes CWRW Select and CWRW Generic, where "select" varieties were meant for milling and the "generic" varieties were of lower quality and bred for feed or industrial purposes. With the creation of the Canadian Western General Purpose (CWGP) class in 2008, any new varieties that would have been placed in the "generic" class have been registered as CWGP. In addition, by August 1, 2013, the existing CWRW Generic varieties will be re-classified as CWGP (Graf, 2011), with the exception of CDC Falcon which will take effect one year later (August 1, 2014).

CWRW

CWRW wheat is primarily sold as milling wheat. It can be used in the production of bread and other baked goods, as well as for the making of pasta (Graf, 2011). Previously, this class of wheat had to be sold

Marketing

through the Canadian Wheat Board (CWB). Producers may now market their CWRW wheat through a private company or the CWB. Profitability is determined by the price a producer receives and the total yield. The price of wheat is, in turn, dependent on the market value and the quality of the grain. CWRW wheat grading standards are outlined in Figure 6.

CWGP

CWGP wheat is a relatively new class of wheat. It was created in 2008 and is made up of varieties of wheat that are high yielding but do not have the desirable high protein, milling and baking qualities of other wheats. CWGP wheat is mainly used for ethanol production, animal feed and other industrial purposes.

Canadian Western Red Winter (CWRW) Wheat

Export grade specifications*

	No 1 CWRW	No. 2 CWRW	No. 3 CWRW
Minimum test weight, kg/hL	79.0	76.5	74.0
Minimum protein, % (13.5% moisture basis)	11.0	11.0	No minimum
Total foreign material including other cereal grains	(Max.) 0.4% including 0.2% other seeds	(Max.) 0.7% including 0.2% other seeds	(Max.) 1.3% including 0.2% other seeds
Wheats of other classes or varieties	(Max.) 3% including 1% contrasting classes	(Max.) 5% including 2% contrasting classes	(Max.) 10% including 3% contrasting classes
Damage			
Fusarium damage, %	0.8	1.0	1.5
Heated, %	0.05	0.1	0.5
Smudge, %	0.30	3	b
Sprouted (total), %	0.5	1.0	2.5
Total damage, %	2	5	
Shrunken and broken			
Shrunken, %	3	3	3
Broken, %	3	b	8
Total, %	3	5	8

Figure 6. Grading specifications for CWRW wheat. (Canadian Wheat Board, 2011)

Seeding Management

3

Variety Selection

Winter wheat varieties are available for all production areas of the Prairies. Selecting an appropriate variety with the right mix of characteristics for your region is a critical decision that will influence your success.

Winter wheat varieties in western Canada are designated into two classes:

- Canada Western Red Winter (CWRW) is a hard wheat exhibiting excellent milling quality available in three milling grades. Both No. 1 and No. 2 CWRW have a minimum protein requirement of 11%, while No. 3 CWRW does not have a minimum protein requirement. For more information please see the Canadian Grain Commission website at www.grainscanada.gc.ca. Flour produced from high grade CWRW wheat performs well in the production of hearth bread (such as French-style bread) and certain types of noodles, and is also suitable for the production of various types of flat bread, steamed bread and related products.
- Canada Western General Purpose (CWGP) are typically higher yielding varieties that are most suitable for ethanol product or animal feed. Varieties of this class do not meet the strict quality requirements of the CWRW class but may have a similar appearance. General Purpose winter wheat varieties may have hard or soft kernels and are red or white.

Making a Variety Choice

(Source: Graf, Briggs & Sieusahai, 2011)

1. **Collect information** such as Provincial Variety Guides, seed sources, and consider other producer's experiences with growing various varieties. Two examples are below.

Alberta Seed Guide:

<http://www.seed.ab.ca/index.html>

Variety Selection Tool:

http://www.usask.ca/agriculture/plantsci/winter_cereals/index.php

2. **Identify critical needs and wants.** For this step **do not** initially look at yield, but instead at non-yield characteristics. Prioritize what traits are critical and decide on target ratings, unacceptable and acceptable ratings. Examples of non-yield characteristics include: winter survival, maturity, lodging resistance, protein content, and various types of disease resistance.
3. **Eliminate varieties that do not meet your critical needs.** For example, if you feel that a variety **must** have a "Good" rating for winter survival, then all varieties with ratings in lesser categories should no longer be considered.
4. **Compare yield potential** among the remaining candidates.



Seeding Management

Table 1. 2013 Winter Wheat Performance in Alberta. Yield, maturity and protein content are all given relative to CDC OSPREY, which is the common check variety. (R. Graf, AAFC, Lethbridge). Original source: Table prepared, reviewed and approved by: Alberta/British Columbia Grain Advisory Committee

Source: seed.ab.ca

2013 WINTER WHEAT VARIETY LIST • ALBERTA WINTER WHEAT PERFORMANCE • 2013 PUBLICATION

Variety	Overall Yield (% CDC Osprey)	Yield Test Category ¹ (% CDC Osprey)				Agronomic Characteristics							Disease Tolerance ³					
		Overall Station Years of Testing	Low (<45 bu/ac)	Medium (45-75 bu/ac)	High (75-105 bu/ac)	Very High (>105 bu/ac)	Winter Survival ³	Maturity Rating ⁴	Protein (%)	Height (cm)	Lodging Resistance ³	Shattering Resistance ³	Test Weight (lb/bu)	TSW Hardness & Color ⁵	Bunt	Stripe Rust	Leaf Rust	Fusarium Head Blight
CANADA WESTERN RED WINTER (Yield and agronomic data only directly comparable to CDC Osprey)																		
CDC Osprey (bu/ac)	76	35	62	86	118													
CDC Osprey²	100	(236)	100	100	100	VG	M	12.2	90	G	G	63	32	HR	VP	VP	P	P
AAC Gateway ▲	102	(23)	XX	105	100	XX	F	M	+0.7	75	VG	G	63	34	HR	VP	G	F
AC Bellatrix	102+	(201)	110+	101	100	F	L	+0.3	88	G	G	64	36	HR	F	VP	VP	F
AC Readymade †	96-	(83)	99	96-	95	97	P	VL	+1.7	90	VG	F	63	36	HR	P	XX	VP
AC Tempest	98	(137)	100	97-	100	98	P	VL	+1.4	89	VG	G	63	37	HR	P	G	VP
CDC Buteo	99	(117)	102	100	97	101	VG	M	+0.2	88	F	G	65	34	HR	VP	G	G
Emerson ▲	98	(41)	XX	100	97	XX	G	M	+0.4	83	VG	G	64	30	HR	VP	G	VG
Flourish *	100	(56)	XX	102	98	XX	F	E	+0.5	78	VG	G	63	35	HR	F	F	VP
McClintock *†	96-	(78)	89	97	95	100	F	L	0.0	91	VG	G	64	32	HR	VP	G	VG
Moats ▲	104	(21)	XX	107	104	XX	G	M	+0.4	89	G	G	65	33	HR	P	G	VG
Norstar †	95-	(131)	103	96-	92-	88-	VG	L	-0.1	108	VP	G	64	33	HR	VP	XX	VP
Radiant	103+	(171)	105	102	103+	100	VG	L	-0.1	87	VG	G	63	36	HR	VP	P	VP
CANADA WESTERN GENERAL PURPOSE (Yield and agronomic data only directly comparable to CDC Osprey)																		
Accipiter *	108+	(42)	XX	108	108+	105	G	M	-0.2	81	VG	G	64	30	HR	VP	XX	G
Broadview *	104+	(56)	XX	106	103	XX	G	E	-0.7	78	G	G	63	32	HR	VP	VP	VG
ODC CLAIR †	103+	(125)	103	103+	104	105+	VG	M	-0.4	88	F	G	63	34	HR	VP	XX	P
ODC Falcon	102+	(177)	94	104+	102	103	F	E	-0.4	73	VG	G	63	31	HR	VP	VP	G
ODC Harrier †	105+	(141)	108	104+	105+	104	G	M	-1.0	93	G	G	62	31	HR	VP	VP	P
ODC Kestrel †	104+	(108)	106	104	105+	102	VG	M	-1.4	93	G	G	62	32	HR	VP	XX	P
ODC Ptarmigan	110+	(84)	XX	110+	109+	111+	G	M	-2.0	90	F	G	61	34	SW	VP	P	P
ODC Raptor †	101	(95)	99	102	102	98	G	M	-0.4	81	VG	G	63	30	HR	VP	XX	G
Peregrine *	108+	(43)	XX	107+	109+	105	VG	M	-0.5	94	F	G	64	33	HR	VP	G	VG
Pintail ▲	109+	(41)	XX	109	109+	XX	VG	M	-1.5	85	G	G	61	30	HR	VP	G	P
Sunrise	110+	(35)	XX	116	108+	XX	G	M	-0.8	87	G	G	61	33	SR	VP	G	G

* - Protected by Plant Breeders' Rights (PBR). ▲ - Applied for PBR protection. XX - insufficient data to describe. † - Flagged for removal.
¹Yield Test Categories are based on the site means for small plot trials. The defined range for each Yield Test Category is provided in bu/ac. The actual yields (bu/ac) for CDC OSPREY are reported in the Overall and Low, Medium, High, and Very High Yield Test Categories.
²All yields are reported relative to CDC OSPREY. Varieties that are statistically higher (+) or lower (-) yielding than CDC OSPREY are indicated. No symbol after the yield figure indicates that there is no statistical difference.
³Resistance / Tolerance Ratings: VP = Very Poor, P = Poor, F = Fair, G = Good, VG = Very Good.
⁴Maturity Ratings: VE = Very Early, E = Early, M = Medium, L = Late, VL = Very Late.
⁵Kernel Hardness and Colour: HR = Hard Red, SW = Soft White, SR = Soft Red.
REMARKS: Winter wheat can be grown successfully in all areas of Alberta if seeded into standing stubble within the optimal seeding date period (generally before September 15) and if there is adequate snowfall. Varieties with Poor winter survival are generally not suitable outside of southern Alberta. The provincial average maturity date for CDC OSPREY is August 7 (219 days after January 1). Radiant has resistance to the wheat curl mite, the vector that carries Wheat Streak Mosaic Virus. AC Bellatrix and Flourish are the only varieties with resistance to common bunt; other varieties should be treated with a systemic seed treatment to reduce the potential for plant infection. Winter wheat may escape Fusarium head blight infection if seeded before September 15. Fields in southern Alberta should be inspected in the fall for infestation by Russian wheat aphid, as it may reduce winter survival. Note that the varieties formerly designated as CWRW "Generic" will be moved to the Canada Western General Purpose class. For more information, please refer to the Variety Designation Lists at the CGC website (www.grainscanada.gc.ca). Limited quantities of Flourish, Emerson and Moats will be available in fall 2013. AAC Gateway will not be available in fall 2013.

Important factors to consider when choosing your variety

Marketing Opportunities

Variety selection may be influenced by marketing options. CWRW varieties may be sold as a milling or industrial wheat. While CWGP varieties are for fuel or feed end uses. See **Marketing** for more information.

Producers are reminded that as of August 1, 2013, the Canadian Grain Commission will remove CDC Clair, CDC Harrier, CDC Kestrel and CDC Raptor from the CWRW class and place them into the CWGP class. The same will occur for CDC Falcon on August 1, 2014. These changes have been incorporated into Table 1.

Winter Hardiness

Adequate winter hardiness is particularly important when growing winter wheat outside the Chinook belt of southern Alberta and when seeding conditions are sub-optimal. Long term evidence has shown that a winter hardiness rating of “Fair” is usually adequate in most areas of the prairies in most years.

Ideally, plants entering freeze-up should be at the three leaf stage with healthy crowns. Seeding beyond the recommended seeding date range, and/or into inadequate standing stubble will often influence both winter survival and yield. See **Winter Survival**. Therefore, seeding should normally be completed by the end of the first week of September for most areas in western Canada. In Parkland areas of Saskatchewan and Alberta,

seeding by the end of August is recommended. Agronomic practices that enhance crop health and vigour, particularly under suboptimal conditions, will often help to ensure an adequate plant stand in the spring.

Disease and Pest Resistance

When selecting a variety, consider disease and pest concerns that are common in your region. See Table 1 and the **Diseases** section for ratings and more specific information.

Producers in all areas should be concerned with the potential for common bunt infection, as most varieties are highly susceptible. In Alberta and western Saskatchewan, stripe rust tends to be more of a threat than in the eastern prairies, where resistance to stem and leaf rust and Fusarium Head Blight are of particular concern.

Producers should keep in mind that a two week break to avoid a “green bridge” of plant material between harvest and planting is important in controlling Wheat Streak Mosaic Virus. While Radiant has resistance to the wheat curl mite vector of this disease, there is compelling evidence that the mite can evolve to overcome this type of resistance. Therefore, good agronomic practices are important and will help to prolong the effectiveness of the resistance incorporated into Radiant.

While it has not been a problem for several years, farmers in southern Saskatchewan and Alberta should also scout their fields for evidence of Russian wheat aphid feeding. While the aphid will not over-winter, feeding on young seedlings in the fall will weaken the plants, making them more prone to winter injury. At the current time, all winter wheat varieties in western Canada are susceptible to the Russian wheat aphid.

The most common diseases and pests that breeders are working towards resistance are:

- Stem Rust
- Leaf Rust
- Stripe Rust
- Fusarium Head Blight
- Leaf Spots
- Wheat Streak Mosaic Virus
- Common Bunt
- Wheat Stem Sawfly (emerging threat)

Canada Western Red Winter (CWRW)	
VG:	CDC Osprey, CDC Buteo, Norstar, Radiant
G:	Emerson, Moats
F:	AAC Gateway, AC Bellatrix, Flourish, McClintock
P:	AC Readymade, AC Tempest
Canada Western General Purpose (CWGP)	
VG:	CDC Clair, CDC Kestrel, Peregrine, Pintail
G:	Accipiter, Broadview, CDC Harrier, CDC Ptarmigan, CDC Raptor, Sunrise
F:	CDC Falcon

Table 2. Winter Survival Ratings for Winter Wheat Varieties by Class. VG= Very Good. G=Good. F=Fair. P=Poor. (R. Graf, AAFC, Lethbridge).

Seeding Management

Straw Height and Lodging Resistance

Height and lodging resistance are especially important considerations in higher moisture regions, or in irrigated production systems, where straw management and lodging are more likely concerns. In general, varieties with a “Fair” rating for lodging resistance will have adequate straw strength under rain-fed production but will suffer some lodging under high rainfall or irrigated production. For high rainfall, high fertility conditions, varieties with a “Good” or “Very Good” rating are recommended.

Producers are also reminded that under drought conditions, short varieties tend suffer greater yield loss due to less extensive root systems.

Maturity

Maturity is not normally a concern with winter wheat because it is usually harvested in mid-August. However, there are some substantial differences in maturity that become particularly evident when there are cool, moist conditions during the ripening phase. Under cool, moist conditions, the difference between an “Early” variety (CDC Falcon, Flourish) and a “Late” variety (AC Bellatrix, Radiant) can be as much as 10 days.

Yield

Provincial Seed Variety Guides are available and provide information on yield, productivity traits and seed availability. It is important to note that yield potential is greatly influenced by management practices, climatic zones, disease pressure, and the particular growing season.

When examining yield figures in a provincial publication, first note the standard check variety. In Alberta, the check is CDC Osprey; in Saskatchewan the check is CDC Buteo, in Manitoba it is CDC Falcon. These varieties have different characteristics and thus, the relative ratings for some of the traits may differ. It is important to be somewhat familiar with the standard check.

It is very important to recognize that not all of the varieties are tested in trials every year. This means that the yield figures between varieties are not necessarily di-

rectly comparable. To some extent, this is indicated by the number of station years of testing – note that most are different. The only direct, head-to-head comparison in the table is with the standard check variety. This is also the case for protein content.

When comparing yield figures in the tables published in Alberta and Saskatchewan, note that the relative yields are provided for various productivities. Varieties will differ in their yield response under various production regimes. For example, under low productivity, most likely the result of drought, AC Bellatrix yield significantly more than CDC Osprey, and is the only variety to do so. Conversely, Norstar yields significantly less than CDC Osprey at the higher yield categories, probably because of greater susceptibility to lodging.

Yield performance of new varieties is based on the best data available over at least two years of testing at multiple locations. However, because the data is limited, the values are likely to change until a larger database across several years of testing becomes available. In Alberta, varieties that are statistically higher yielding than CDC Osprey are indicated with a “+”; those varieties that are statistically lower yielding are indicated with a “-”. In cases where yield appears to be higher or lower than the standard check (CDC Osprey) but there is no significance indicated, it means that there was not enough statistical confidence to indicate significance due to too much variability in performance among the trial locations.

Other Traits

Depending upon the province, other traits for the varieties are provided and may be relevant under various production scenarios. Examples are: protein content, shattering resistance, test weight, thousand kernel weight, and kernel hardness and colour.

Up and Coming Winter Wheat Varieties

The 2013 Winter Wheat Variety List (Table 1) summarizes the current and future winter wheat varieties for which data is available.



Winter wheat breeding is an on-going effort and research continues to bring improved varieties to market. Future varieties will have enhancements to the any of the following traits:

- Disease resistance
- Winter hardiness
- Increased yield
- Improved lodging resistance
- Earlier maturity
- Higher protein concentration for CWRW varieties

While herbicide resistance would provide more flexibility for producers' crop rotations, this is not a possibility at the current time in Canada.

UPCOMING CWRW VARIETIES

- Flourish (available fall 2013)
- Moats (available fall 2013)
- Emerson (available fall 2013)
- AAC Gateway

UPCOMING GENERAL PURPOSE VARIETIES

- Accipiter (now available)
- Broadview (now available)
- Peregrine (now available)
- Pintail
- Sunrise
- Swainson (registration pending)

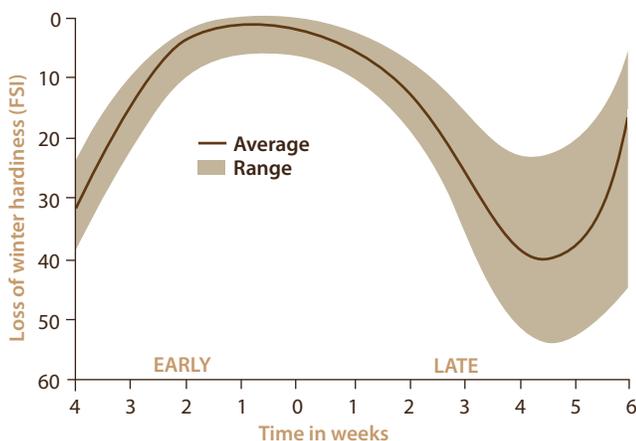


Figure 1. Influence of seeding date on winter hardiness of winter wheat. (University of Saskatchewan, 2002)

The Essence of Timing

The window of time that seeding occurs is critical to survival in the winter months and seeding past the optimal dates for your region may result in a **5-10 percent yield penalty** for every week delayed (Lafond, May and Irvine, 2005; Ducks Unlimited Canada: Agronomics, 2011). According to Campbell *et al.* (1991), **seeding date** was the **most dominant** management factor in spring plant counts. Winter hardiness may be compromised as the seeding date is delayed (Figure 1).

Generally, winter survival depends on the seedlings' ability to establish a **well-developed crown** prior to freeze up, which occurs at approximately the three leaf stage (University of Saskatchewan, 2002) (Figure 2). This allows the plant to build up enough carbohydrate reserves to mobilize during the winter for respiration and in the spring for initial regrowth (Top Crop Manager, 2001). Also extremely important is the process of cold acclimation, which relies on seedling dry matter accumulation (Lafond, May & Irvine 2005). See **Winter Survival**.

Seeding too early can also be a problem, although this is not as common a concern due to the harvest window of the previous crop. Seeding too early can allow the seedlings to grow to an advanced stage, which increases the likelihood of frost damage (Alberta Agriculture and Rural Development, 2002). Early seeding can also present an issue of disease transmission from spring wheat to the winter wheat, as spring wheat material is still green, creating a "green bridge" (McKenzie, 2011). See **Diseases**.

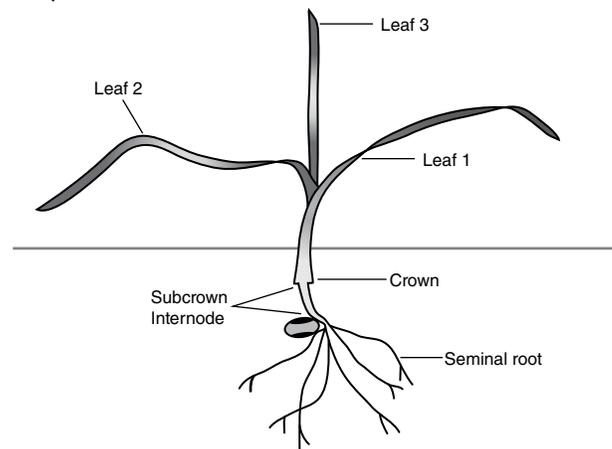


Figure 2. Winter wheat at the three leaf stage. Note the crown development. (University of Saskatchewan, 2002)

Seeding Management

Generally, seeding dates should be earlier across the prairies as you go from south to north, and to a lesser extent, east (Ducks Unlimited Canada: Agronomics, 2011). Table 3 provides approximate optimal seeding dates for Alberta.

Area	Range of Dates
Lethbridge	September 10 to 20
Lacombe	September 1 to 10
Vermillion	August 25 to September 5
Peace Region	August 15 to 20

Table 3. Optimal Seeding Dates for Winter Wheat (Alberta Agriculture, Food and Rural Development; Ducks Unlimited Canada: Agronomics, 2011)

Field Preparation

Planning to seed winter wheat should begin with harvest of the previous crop to ensure a good seedbed and adequate stubble. The most successful and recommended method of seeding for winter wheat is direct seeding, or “stubble-in”, as it provides the best snow management system (Loeppky, Lafond and Fowler, 1989). Minimizing the amount of soil disturbance during seeding is also essential when considering drill types (McKenzie *et al.*, 2007) or drill types used in conjunction with residue management (Beres *et al.*, 2011). McKenzie *et al.* (2007) reported that disc drills produced the highest winter wheat grain yield over knife-style openers. Similar results were observed by Beres *et al.* (2011) although it was noted that the results with the disc drill were more variable compared to a knife opener configured with 30cm row spacing. The variability could be related to residue management as trash clearance is generally less of an issue with knife openers compared to traditional disc drill configurations.

Important to factors to consider:

(1) Stubble Type and Height: Stubble Trapping Potential (STP) is a measure of how effective stubble will be as a snow trap. The target STP for winter wheat is 20 or higher, after seeding. Prior to seeding, an appropriate target is a STP of 40, as some stubble will be knocked down during the seeding process. (Ducks Unlimited Canada: Successful Winter Wheat Seeding, 2011). Canola, oats, flax and forage crop stubble

generally provide adequate tall, dense stubble, without potential disease risks. However, the yield potential of winter wheat may differ between crop stubble types even if the stubbles have high STP values. For example, Irvine *et al.* (2013) reported that canola, barley silage, and pea stubble types provided the greatest grain yield of winter wheat compared to barley grain and oat stubble. Barley silage stubble provided the most consistent results whereas canola and pea stubble were more variable, which may be a reflection of differences in STP values for these optimal stubble types. Even though oat stubble would have a high STP value, lower grain yield was observed (Irvine *et al.*, 2013).

$$STP = \frac{\text{stubble height(cm)} \times \text{stems per m}^2}{100}$$

Harvested Crop Stubble	STP
Cereals	>80
Oilseeds	30 to 50
Chemfallow	>40
Pulse Crops	above 20 not attainable

Table 4. Optimal STP Targets for Different Crop Types (Ducks Unlimited Canada: Successful Winter Wheat Seeding, 2011)

The height of the stubble will influence seedling survival during the winter, as well as moisture reserves for spring growth (Loeppky *et al.*, 1989). More snow provides insulation, which decreases fluctuations in temperature and decreases the risk of an anaerobic environment being created, which can be a risk factor for disease. Such conditions can cause respiration issues throughout the winter (Loeppky *et al.*, 1989; Barker, 2001).

(2) Residue Management: Chaff and straw should be spread the width of the cut during harvest to decrease issues with chaff/straw rows. The rows can result in lower germination and immobilization of nutrients (Ducks Unlimited Canada: Successful Winter Wheat Seeding, 2011). Heavy-harrowing to manage residue is very effective but the operation would reduce standing stubble and STP; therefore it should be avoided or only used in conjunction with drills configured with wider-row spacings (30 cm) to minimize stubble disturbance (Beres *et al.*, 2011).

Seeding Rate

The ideal fall plant density for winter wheat should be at least **30 plants per square foot**, which translates to an approximate seeding rate 450 seeds m² (roughly 2.0 - 2.25 bushels per acre)(Beres *et al.* 2010). Seeding rates may be fine-tuned using the formula below.

Seeding Rate Calculation

$$\begin{aligned} \text{Seeding Rate (lbs/ac)} = \\ (\text{desired plant population/ft}^2) \times (\text{1000 kernel wt. (g)}) \\ \div \text{seedling survival rate (0.70)} \\ \div 10 \end{aligned}$$

- A target plant population in spring of approximately 20-25 plants/ft² is suggested for winter wheat.
- 1000 Kernel Weight is a measure of seed size, representing the weight, in grams of 1000 kernels. This measure can vary considerably by crop, variety, year and even field-to-field within the same year. Calculating seeding rate based on 1000 kernel weight will ensure there are adequate seeds per square foot to achieve target plant populations.
- A seedling survival rate of 70% is estimated for winter wheat, and takes into account germination, seedling mortality and winter survival. The percent survival should be expressed in decimal form for calculation purposes (i.e. 70% = 0.70).

AARD Seed Rate Calculator

Available at:
<http://www.agric.gov.ab.ca/app21/ldcalc>

Higher seeding rates, above current recommendations, may not increase grain yield (McKenzie *et al.*, 2007; Beres *et al.* 2010) but are associated with greater spring plant density, which improves weed competitive ability and reduces weed biomass (Beres *et al.* 2010).

Seeding Depth

The recommended seeding depth for winter wheat is **less than 1 inch (25 mm)** deep into a firm seedbed.

Winter wheat differs somewhat from spring wheat in its ability to emerge from deeper planting (Loeppky, Lafond and Fowler, 1989). This is because the subcrown internode length, which is genetically controlled, is shorter in winter wheat. The subcrown internode is responsible for seedling emergence. This is an important consideration for seeding shallow.

After the growing season of the previous crop, dry surface soil conditions are likely, so seeding into moisture, as with a spring crop, is not usually possible (Lafond *et al.*, 2005). As seeding date has a larger effect on the emergence of the seedling, due to temperature, it is best to not wait for rain (Lafond *et al.*, 2005). It is essential to seed winter wheat **shallow (less than 1 inch)** to encourage quick emergence and to allow the kernel access to fall rains, as this is the main source of moisture for germination.

For winter wheat to achieve germination and adequate establishment, only 9 mm of rain is needed when the wheat is seeded less than 1 inch deep (Lafond and Fowler, 1989). The likelihood of receiving at least 9 mm of rain is good, across the Prairies. According to Lafond *et al.* (2005), there was only one year between 1897 and 2004 when less than 9 mm of moisture was received in August and September in the Eastern Prairies.



Figure 3. Winter wheat emergence in a dryland cropping system. (Photo: Newground Magazine, Arysta LifeScience)



Soil Fertility and Nutrient Management

Proper fertilization is essential to achieving maximum yield and quality of winter wheat. There are many general guidelines for proper fertility establishment; however, these guidelines are most effective when paired with soil test results. This will allow for the highest yield potential and the best quality possible. Soil nutrient levels will change from year to year, even in fields that seem uniform, and incorporating soil sampling can help maintain a sound fertility management program (McKenzie *et al.*, 2000).

Nitrogen fertilizer recommendations are provided in Table 1, and are in lb/ac for winter wheat in the Brown, Dark Brown and Thin Black soil areas at three soil moisture levels. (See **Crop Rotation**, Figure 1. for soil zones in Alberta.) These recommended levels are to achieve the “sufficient” levels as seen in Figure 2. Additional phosphorus fertilizer requirements, based on Phosphorus available in the soil, are outlined in Table 2. Sulphur and Potassium fertilizer recommendations are found in Tables 3 and 4.

Rate Guidelines

- Fertilizer rates should be largely based on soil test results.
- It is generally **not** recommended to apply fertilizers other than nitrogen (N) and phosphorus (P) unless a deficiency has been identified.
- N fertilizer is used by the crop to meet its growing requirements, and also in the reproductive stages of development. It is important to have sufficient N available in these final stages, as well, because it will affect the protein levels of the grain (McKenzie *et al.*, 2006).
- Proper fertilization is also essential to optimize winter survival. See **Winter Survival** for more information.



Figure 1. Comparison of a 210 kg/ha urea treatment on winter wheat (left) and a 30 kg/ha urea treatment (right) at Bow Island, Alberta, June 5, 2007. (Photo: Ross McKenzie)

Soil Nitrogen (lb/ac)	Brown + Dark Brown Soil Zone			Thin Black Soil Zone		
	Soil Moisture Level			Soil Moisture Level		
(0-24 inches)	Low	Medium	High	Low	Medium	High
0-10	40	60	90	50	70	100
10-20	30	50	80	40	60	90
20-30	20	40	70	30	50	80
30-40	10	30	60	20	40	70
40-50	0	20	50	10	30	60
50-60	0	10	40	0	20	50
60-70	0	0	30	0	10	40
70-80	0	0	20	0	0	30
80-90	0	0	10	0	0	20
90-100	0	0	0	0	0	10
>100	0	0	0	0	0	0

Table 1. Nitrogen fertilizer recommendations by soil type (McKenzie *et al.*, 2000)

Soil Fertility and Nutrient Management

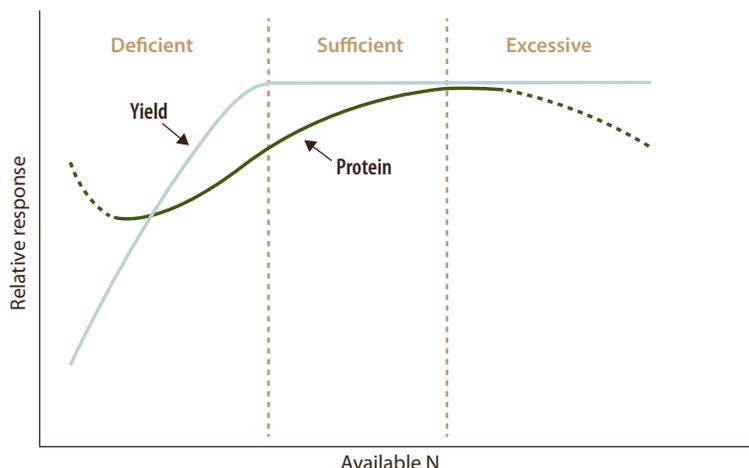


Figure 2. Relative response of available N to yield and protein. (McKenzie *et al.*, 2006).

Soil Test Phosphorus (0-6") P (lb/ac)	Soil Zone		
	Recommended P ₂ O ₅ (lb/ac)		
	Brown	Dark Brown	Thin Black
0-10	30	35	40
10-20	25	30	35
20-30	20	25	30
30-40	20	20	25
40-50	15	20	20
50-60	15	15	20
60-70	15	15	15
70-80	0	15	15
80-90	0	0	15
>90	0	0	0

Table 2. Phosphorous fertilizer recommendations at various soil test levels using Kelowna or modified Kelowna soil test P method (McKenzie *et al.*, 2000)

Guide to Soil Testing

Soil testing is an important tool in assessing soil fertility and deciding on proper fertilizer applications. The following information is a brief guide to soil sampling. Further information and guidance can be obtained by contacting a local fertilizer dealer, private laboratory or crop advisor (Alberta Agriculture and Rural Development, 2002).

When to Sample

- As close to seeding as possible to allowing sufficient time to receive analytical results (R. McKenzie, personal communication, 2011).

Where to Sample

- **Random Sampling:** Traditional approach used in fields with little variation
 - › Samples taken from 15-20 random locations throughout the field (Alberta Agriculture and Rural Development, 2002).
- **Benchmark Sampling:** Better approach for fields with greater variability
 - › Soil samples are taken from the same representative area every year.
 - › Select a representative area in the field that is fairly uniform, flat and

Soil Test SO ₄ -S (lb/ac)	Soil Zone								
	Brown & Dark Brown			Thin Black & Black			Gray Wooded		
	Recommended SO ₄ -S (lb/ac)								
	Soil Moisture Level								
	Low	Medium	High	Low	Medium	High	Low	Medium	High
0	10	15	20	10	15	20	10	14	20
5	5	10	15	5	10	15	5	10	15
10	0	5	10	0	5	10	0	5	10
15	0	0	5	0	0	5	0	0	5
>20	0	0	0	0	0	0	0	0	0

Table 3. Sulphur fertilizer recommendations for wheat (McKenzie, 2001)

Soil Fertility and Nutrient Management

productive, usually between .5 to 1 acre, and mark it using GPS co-ordinates.

- › Multiple representative areas may be selected to assess different nutrient concerns in the field (Alberta Agriculture and Rural Development, 2002).
- › Use Random Sampling technique (above) within benchmark areas.

Taking samples

- Representative soil samples can be obtained by using a core sampling tool, and should be taken from the top 0-15 cm and 15-30 cm at each of the 15 to 20 sampling sites (Alberta Agriculture and Rural Development, 2002).
- For more accurate evaluation, or if deficiencies are expected, separate samples should be taken from the 0-15 cm, 15-30 cm, and 30-60 cm depths at the same 15 to 20 sites (Alberta Agriculture and Rural Development, 2002).
- Cores should be placed in clean pails or bags, and then cores from the same depth from the field or benchmark areas should be mixed (Alberta Agriculture and Rural Development, 2002).

Submitting Samples

- Air-dry approximately half a kilogram of soil in a clean shallow container at room temperature. Do not dry with artificial heat (Alberta Agriculture and Rural Development, 2002).
- Place air dried sample in appropriate soil containers and label each with:
 - › Producer/Farm Name
 - › Address, including Postal Code
 - › Depth from which the sample was taken
 - › Legal land location of field
 - › Cropping history (i.e. was a pulse crop grown on the field last year?)
 - › Indicate if manure has been applied in the past three years (R. McKenzie, personal communication, 2011).
- Contact your laboratory for necessary forms and packing and shipping instructions.

Soil Test K (lb/ac)	Soil Zone											
	Brown			Dark Brown			Thin black			Black & Grey Wooded		
	Recommended K ₂ O (lb/ac)											
	Soil Moisture Level											
	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
0	100	105	110	105	110	115	105	110	115	110	115	120
25	90	95	100	95	100	115	95	100	105	100	105	110
50	80	85	90	85	90	105	85	90	95	90	95	100
75	70	70	80	75	75	95	75	75	85	80	80	90
100	60	60	70	65	65	85	65	65	75	70	70	80
125	50	50	55	55	55	75	55	55	60	60	60	65
150	35	40	45	40	45	50	40	45	50	45	50	55
175	25	30	35	30	35	40	30	35	40	35	40	45
200	15	20	25	20	25	30	20	25	30	25	30	35
225	15	15	15	15	15	20	15	15	20	15	20	25
250	15	15	15	15	15	15	15	15	15	15	15	15
>250	0	0	0	0	0	0	0	0	0	0	0	0

Table 4. Potassium fertilizer recommendations for wheat (McKenzie, 2001)

Soil Fertility and Nutrient Management

Fertilizer Product Choice

Fertilizer product choice and application timing will depend on nutrient requirements, fertilizer prices, equipment type and conditions. Care should be taken to minimize losses.

NITROGEN

Nitrogen is the most limiting nutrient for winter wheat production. Rates should reflect target yield, less credits for residual soil N, organic matter and preceding N-fixing crops, based on soil test results.

Environmentally Smart Nitrogen (ESN) (44-0-0)

ESN is a slow releasing fertilizer, which has been shown to have a small yield benefit compared to regular urea. This is possibly due to a delay in N supply, which can result in a greater assimilation of ammonium (NH_4^+) than nitrate (NO_3^-). The main benefit of using ESN is the opportunity to apply the entire amount of N at time of seeding because of its increased seed safety from its slow releasing nature (McKenzie *et al.*, 2010). Generally 80 lbs/ac (90kg/ha) of ESN can be placed with the seed using a 10% seedbed utilization without causing injury (R. McKenzie, personal communication, 2011).

Urea (46-0-0)

Urea is the most common form of nitrogen fertilizer applied. Depending on soil and weather conditions, applying urea on the soil surface can increase risk of loss via ammonia (NH_3) volatilization. However, this risk may be low in regions of cool, dry soil conditions at the time of application due to a reduced rate of urea hydrolysis. This increases the probability that a sufficient amount of precipitation may be received to transport urea into the soil (McKenzie *et al.*, 2010). Ideally, the window between broadcasting urea and a precipitation event should be as short as possible. Urea can be effectively banded at the time of seeding. This will reduce potential volatilization losses because the fertilizer is not exposed to air. Urea can also be seed-placed, although care must be taken not to exceed safe rates. Excessive urea placed with the seed can have a negative effect and reduce yield. Safe seed-placed rates can be seen in Table 5.

Anhydrous Ammonia (82-0-0)

The use of anhydrous ammonia can be a good option if you have access to a suitable ground opener that ensures separation of the anhydrous ammonia (NH_3) from the seed row, while sealing the soil surface to prevent escape of NH_3 . The high concentration of N (82%) also allows for 1.78 times more acres to be fertilized per tonne of fertilizer than regular urea (46-0-0). This type of fertilizer often has a price advantage over other types of urea fertilizers. Anhydrous ammonia requires careful handling to ensure personal safety (Green, 1998).

OTHER NUTRIENTS

Phosphorous (11-51-0, 12-51-0 and 11-55-0)

Phosphorous is the second most limiting fertilizer next to nitrogen. Adequate P levels will result in rapid growth and earlier maturity, which is especially beneficial in areas where frost is a greater concern (McKenzie and Middleton, 1997). Phosphorous does not move readily in the soil; therefore, placing phosphorous with the seed is the most effective method to achieve maximum availability of the fertilizer to the plant. Side banding P near the seed is also an effective option. Broadcast applications are generally less effective, and should be applied at two to four times the recommended rates. A greater response may occur in the year following application than in the year of application (Alberta Agriculture and Rural Development, 2002).

Sulphur(21-0-0-24S, 20-0-0-24S and 19-3-0-22S) and Potassium (0-0-62)

Soil testing and field test strips are the best way to determine if these two nutrients are deficient. Sulphur (S) and potassium (K) deficiencies are not nearly as widespread as nitrogen and phosphorus deficiencies. However, they can be common in some areas and soil types, so it is important to determine if deficiencies may be present in a field, using a soil test (Alberta Agriculture and Rural Development, 2002).

Micronutrients

Deficiencies in micronutrients are uncommon, but when they do occur the impact on crop yield can be just as detrimental as with macronutrients. Typically in Alberta,

Soil Fertility and Nutrient Management

most micronutrients are rarely deficient. Deficiencies of some, such as copper on organic and mineral soils, in central and northern Alberta, are more common. Generally the use of micronutrient fertilizers should only be used on the advice of a professional agrolgist (Alberta Agriculture and Rural Development, 2002).

Effect of Fertilizer Type on Grain Yield

Different types of fertilizer may have an impact on yield and protein content, but typically the results are not significant. Below (Figure 3, Figure 4) are graphs comparing the effect two different types of N fertilizer had on yield and protein in winter wheat.

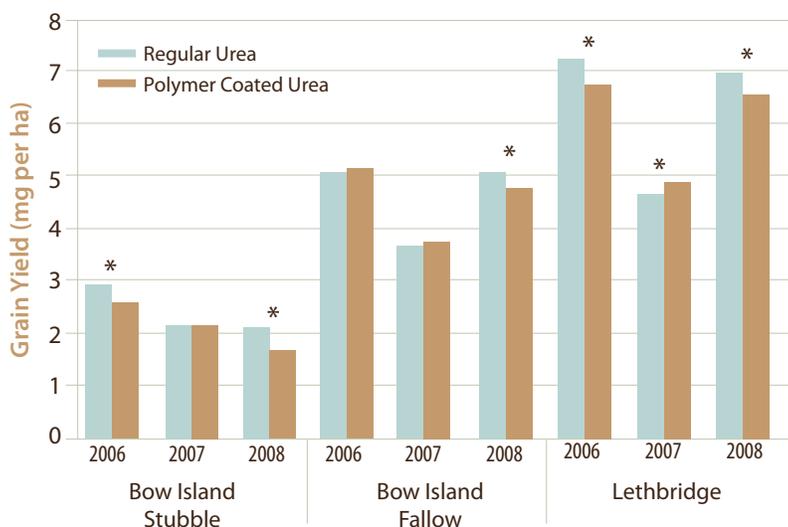


Figure 3. Effect of fertilizer type on winter wheat grain yield each year at Bow Island. Fertilizers were broadcasted on the soil surface in early spring. Values are means over three N rates (30, 60, and 90 kg N ha⁻¹). Years without stars are not significantly different from each other. (McKenzie *et al.*, 2010)

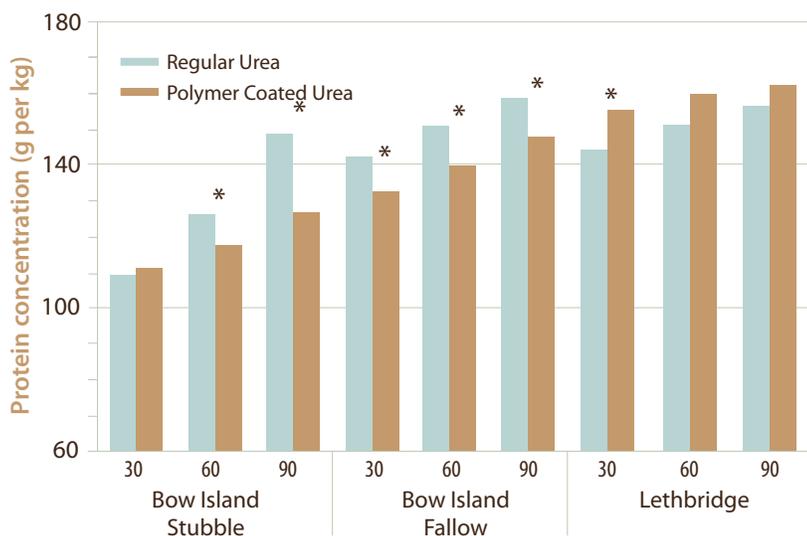


Figure 4. Effect of fertilizer rate (30, 60, and 90 kg N ha⁻¹) and type on winter wheat protein concentration in three environments in southern Alberta. Fertilizers were broadcast on the soil surface in early spring. Values are means over 3 years (2006–2008). Within the same N rate and environment, values without stars are not significantly different. (McKenzie *et al.*, 2010)

Soil Fertility and Nutrient Management

Application Method

Fall Band

Applying N at time of seeding is beneficial as it can overcome the difficulty of fertilizing early in the spring when it may be difficult to get into the field. Banding at time of seeding in a direct seeding operation is a second effective option, and it saves the expense of an additional operation. However, banding followed by tillage prior to seeding has been shown to create a drier, rougher, lumpy seedbed. This can result in greater variability in seeding depth and poorer seed-soil contact, which ultimately will lead to a reduction of seedling emergence, particularly at drier sites (McKenzie *et al.*, 2001).

Seed Place

Available soil moisture and percent seedbed utilization can affect the amount of N that can safely be seed-placed. Seedbed utilization (SBU) refers to the percent of seedbed over which the fertilizer and seed has been spread. With a reduced SBU, high N rates and poor soil moisture conditions can lead to greatly reduced emergence. Table 5 offers some general guidelines on safe rates for seed-placed nitrogen for two different SBU's and soil moisture conditions.

$$\text{SBU} = [\text{spread (inches)} \div \text{row spacing (inches)}] \times 100$$

- Seed Bed Utilization is the percentage of seedbed over which seed and nitrogen have been spread, relative to row spacing.
- The spread refers to opener width. For example, a knife opener will have a narrower spread and lower SBU than a sweep opener.
- The potential for damage to the seed from fertilizer is higher with a lower SBU.

Seed-placed treatments can be effectively used at time of planting, but care must be taken to ensure that the safe application rates are not exceeded. With the use of ESN, the safe application rates increase to 80 lbs/ac (90 kg/ha)

at a 10% SBU (R. McKenzie, personal communication, 2011). Seed-placed treatments can be used effectively in conjunction with banding at the time of seeding, mixed rates of Polymer coated urea, or as a split application.

Spring Broadcast

The traditional practice has been to top-dress N on winter wheat crops in early spring. The efficiency of this method, however, is reduced by various mechanisms. When using spring applications it is important to apply N as early as possible to ensure the plants are able to meet their maximum potential. Applications in the late spring have been shown to delay N uptake until after the maximum grain yield potential has been established. Also, if the soil conditions are too dry the N may not move down through the soil to where roots can access it. There is also an increased risk of volatilization losses when using spring applications (McKenzie *et al.*, 2001).

Split Application

Another option is to apply part of the N requirements at time of seeding, and the rest the following spring. It is most effective if fall moisture conditions are low at the time of seeding, but by spring are very good. In such a situation, split applications can be very effective. The split application approach has been shown to improve N use efficiency and grain protein. The fall application of N will accommodate the early season growth requirements of the winter wheat. Applying the remaining N fertilizer in either early spring or later in the growing season will contribute to increasing grain protein (McKenzie *et al.*, 2006).

Nitrogen Fertilizer ¹	% Available Moisture	10% SBU	50% SBU
		lb N/acre	
Urea (46-0-0)	>75%	55	70
	50%-75%	40	50
	<50%	30	40

Table 5. Safe rates of seed-placed nitrogen fertilizer using urea (46-0-0) at two seedbed utilization levels and three moisture levels. (McKenzie *et al.*, 2000)¹ Available soil moisture is stated in percent of field capacity for medium (loam) to fine textured (clay loam) soils. Assumes soil moisture will not change significantly during germination and emergence of winter wheat. If soil moisture decreases after seeding, then some fertilizer injury may occur.

Crop Rotation

For winter wheat production, planning a crop rotation that suits a farm’s management style and location is critical for success growing winter wheat. Furthermore, selecting an appropriate crop to precede winter wheat is essential for optimizing winter survival. Across Alberta’s vast geography, there are hugely varied climatic conditions, farming practices and soil zones. Therefore, it is important to recognize that what works on one farm, or in one region, may not work in another.

Soil Group Map of Alberta

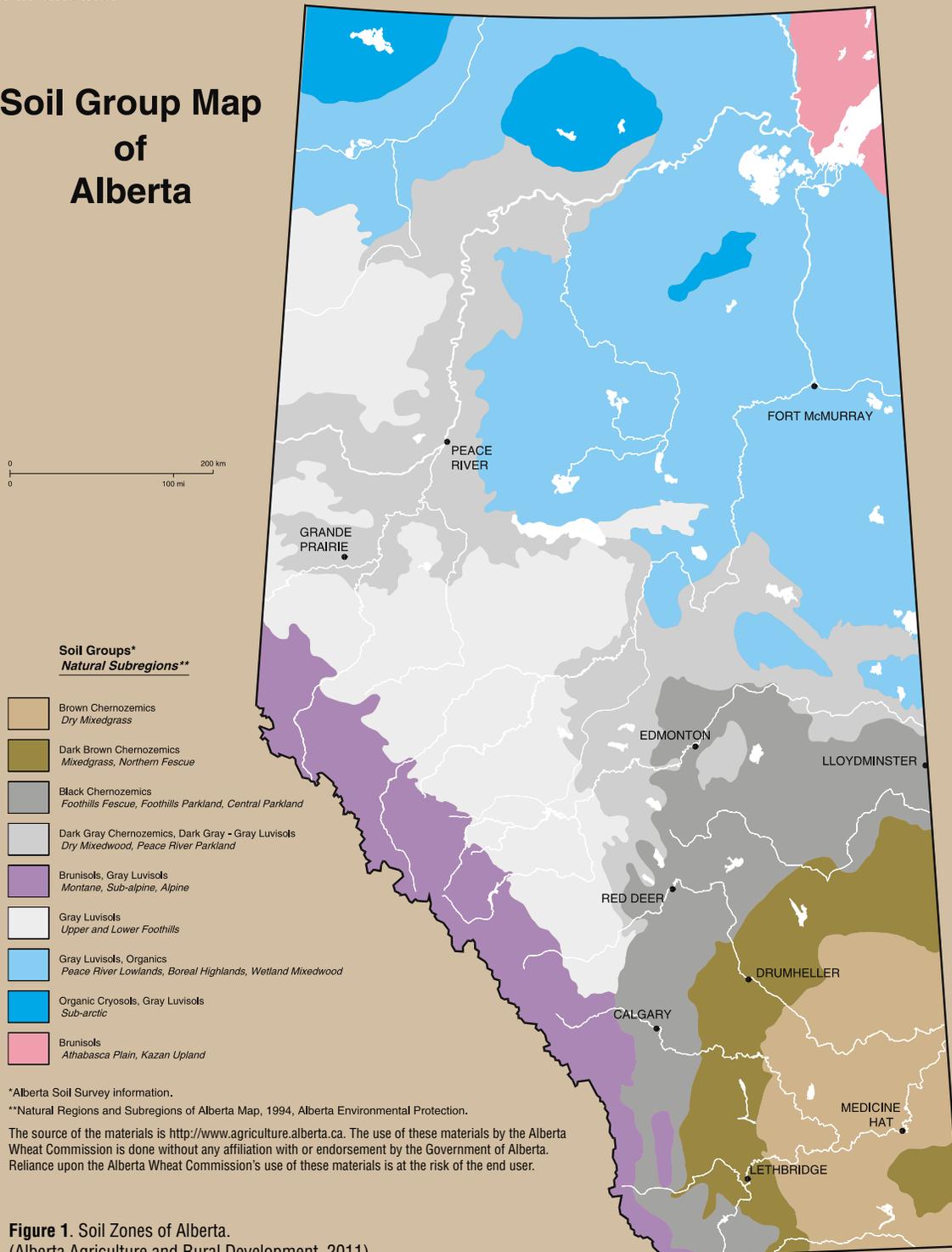


Figure 1. Soil Zones of Alberta.
(Alberta Agriculture and Rural Development, 2011)

Crop Rotation

Zone 'A'	Southern Alberta	Brown Chernozemic and Dark Brown Chernozemic soils
Zone 'B'	Central Alberta	Black Chernozemic soils
Zone 'C'	Northern Alberta	Dark Grey Chernozemic and Dark Grey-Grey Luvisol soils

Table 1. Production Zones for Winter Wheat in Alberta.

Preceding Crops to Winter Wheat and their Attributes

Previous Crop	Advantages	Disadvantages	Fertility	Pests / Issues	Comments
Field Peas <i>Pisum sativum</i>	Improves soil quality, fixes nitrogen. Early harvest allows for timely winter wheat seeding.	Little to no stubble residue. Higher risk of snow cover being wind swept, resulting in lack of crop insulation.	Increases soil nitrogen fixation and soil quality.	Increases potential for snow mold. (See Diseases.) Winter survival of winter wheat can be a concern.	Winter survival can be a concern when wheat is seeded into pea stubble; particularly applicable to Zones B&C.
Argentine Canola <i>Brassica napus</i>	Stubble captures and traps snow creating insulation for wheat crop.	Later harvest may delay winter wheat seeding.	Canola has high N and S requirements. Consider sulfate sulphur application if soils tests are low AFTER canola	Good rotational crop	Following canola with wheat maintains many farm operations' general rotation
Polish Canola <i>Brassica rapa</i>	Same as Argentine	Approximately 2 weeks earlier harvest than Argentine and can be straight cut	Same as Argentine	Good rotational crop	Excellent option for stubble and timing. No herbicide tolerance available.
Barley <i>Hordeum vulgare</i>	Barley can be harvested early, allowing sufficient time to plant winter wheat.	Many pathogens, insects, weeds and soil nutrient zones are similar to those of winter wheat.	Barley and winter wheat require similar nutrients.	Green Bridge: Wheat Streak Mosaic Virus; Stripe Rust; Tan Spot	Rotation not ideal.
Winter Wheat <i>Triticum aestivum</i>	Following winter wheat crop can be planted immediately after previous crop is harvested.	Pathogens, insects, weeds and soil experience no diversity and can reduce potential crop yield.	Same as winter wheat grown in previous year.	Green Bridge: Wheat Streak Mosaic Virus; Stripe Rust; Tan Spot; Wheat Stem Saw Fly; Grassy Weeds	Not a recommended practice.

Previous Crop	Advantages	Disadvantages	Fertility	Pests / Issues	Comments
Spring Wheat <i>Triticum aestivum</i>	Provides appropriate stubble for winter wheat to capture snow during winter.	Provides a susceptible host to the same pests as winter wheat.	Similar to winter wheat fertility needs.	Green Bridge: Wheat Streak Mosaic Virus; Stripe Rust; Tan Spot; Wheat Stem Saw Fly; Grasshoppers; Wild oats	Not a recommended practice.
Chemical Fallow	Moisture management is increased, as no crop is using moisture, and more is available for the subsequent winter wheat crop. Weed, pathogen and insect cycles can be altered by providing no host and controlling pests properly.	Fallow stubble is brittle and may not adequately trap snow. A post-seeding STP of ≥ 20 is required. See Seeding Management: Field Preparation.		Spring and winter annual, perennial and biennial weeds can be expensive to kill over the summer when no crop competition is provided.	Used in areas for moisture management and crop rotation planning.
Summer Fallow	Weed, disease and insect control can be effective. Traditional tillage approach.	Moisture management is not optimal. Soil quality can be decreased as soil is more subject to erosion.	Can speed up the break down of plant residue, making nutrients more readily available to next crop.	Soil can become over worked, which reduces quality. Soil erosion and wind effects can dramatically reduce the amount of topsoil.	Not a recommended practice.
Oats <i>Avena sativa</i>	Short growing season allows adequate time for winter wheat planting.	High biomass residue. Volunteer oats need to be controlled in the winter wheat crop.	Oats are a relatively low input crop. Low levels of nitrogen required.	Green Bridge: Wheat Streak Mosaic Virus; Stripe Rust; Tan Spot; Grasshoppers; Wild oats	Volunteer oats need to be controlled in winter wheat crop. Control of wild oats in wheat can be costly.
Fall Rye <i>Secale cereale</i>	Grows well on light, sandy soil. Good drought tolerance. Early harvest. Allelopathic control of weed.	Weedy nature. Susceptible to ergot.	Low input crop.	Green Bridge: Wheat Streak Mosaic Virus; Stripe Rust; Tan Spot; Volunteer Rye	Weedy nature can be a large problem in succeeding crops.

Table 2. Preceding crops to winter wheat and their attributes.

Crop Rotation

Sample Crop Rotations

Year 1	Year 2	Year 3	Year 4
Field Peas	Winter Wheat	Canola	-
Chem-Fallow	Winter Wheat	Canola	-
Oats	Winter Wheat	Canola	-
Summer Fallow	Winter Wheat	Canola	-
Field Peas	Winter Wheat	Field Peas	Winter Wheat

Table 3. Crop rotations including winter wheat in Northern and Central Alberta (Zones B & C).

Year 1	Year 2	Year 3
Canola	Winter Wheat	Canola
Chem-Fallow	Winter Wheat	Canola
Summer Fallow	Winter Wheat	Canola
Fall Rye	Winter Wheat	Canola

Table 4. Crop rotations including winter wheat in Southern Alberta (Zone A)

Examples of a Winter Wheat Crop Rotation

In **Northern Alberta; Zone C**, including the Peace Country and the Highway 16-North region, the producer may face challenges around harvesting the preceding crop and planting winter wheat in a timely manner. As such, the producer may want to look at a crop with a shorter growing season (i.e. Polish canola, peas, oats, summer-fallow, chem-fallow). In these areas, snow cover is typically higher during the winter months, creating more insulation for the winter wheat crop, compared to Southern Alberta, Zone A, where stubble is needed to capture the snow because snow is less permanent.

Given the more abundant and consistent snow cover in Zone C, field peas, in spite of their limited remaining stubble, can be an excellent crop to grow prior to winter wheat.

For a producer in **Southern Alberta, Zone A**, snow capture during the winter months is a concern; therefore, the crop grown prior to winter wheat must have adequate stubble height (see **Seeding Management**) during the winter months. This limits potential crops that could be grown prior to winter wheat to those with taller stubble. For example, field peas has very short stubble residue in comparison to canola stubble residue.

The growing season in Southern Alberta is longer than Northern and Central Alberta, which allows producers to plant winter wheat at a later date than in locations further north. In Edmonton, the frost-free period is 115 days, while Lethbridge has 124 such days and Medicine Hat has 132 frost-free days (Table 5). This allows for a wider window to both grow and harvest crops prior to winter wheat, as well as to plant a winter wheat crop.

Frost Dates for Selected Alberta Locations

Zone	Station Location	Average Date of First Fall Frost	Average Date of Last Spring Frost	Frost-Free Period (Days)
A	Medicine Hat	September 23	May 14	132
A	Lethbridge	September 18	May 17	124
A	Calgary	September 14	May 20	117
B	Red Deer	September 12	May 20	115
B	Tofield North	September 14	May 25	112
B	Lloydminster	September 15	May 19	119
B	Edmonton	September 13	May 21	115
C	Grande Prairie	September 11	May 18	116

Table 5. Frost dates for selected Alberta locations.

(Alberta Agriculture and Rural Development, [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/sag6301](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag6301), Viewed November, 2011)

Integrated Weed Management

Weed control is an integral part of sustainable cropping systems. Recent innovations to agronomic practices have simplified control. Diverse rotations for both herbicide groups and crops reduces the risk of resistance and creates maximum yield conditions for the crop. Winter wheat has many advantages over spring wheat with respect to weed competitive ability, mostly due to early canopy closure in the spring.

Field Scouting

The first step toward a good management strategy is proper weed scouting. Scouting requires a thorough pattern be travelled in a field, accessing high and low areas and getting a good average of the field's weed density and weed types, as seen in Figure 1. Accurate weed identification is important in making appropriate weed management decisions. When in doubt, photograph the weed, dig it up and seek reference.

Winter wheat needs to be scouted similar to the staging of other cereals. Crop maturity is critical for many herbicide treatments. It is particularly important to scout in

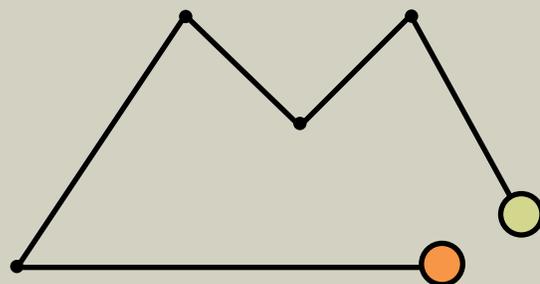


Figure 1. A suggested pattern of travel for field scouting.

the late fall for **winter annuals** and **perennials** because they tend to be the most competitive weeds in a winter wheat crop. Table 2 highlights common weeds of cereals. Figures 2-5 outline life cycles of various weed types, as well as winter wheat's growth habit.

During scouting, check the entrance of fields for weed infestations as this area may contain high weed propagates from equipment, traffic, etc.

Winter Wheat Life Cycle

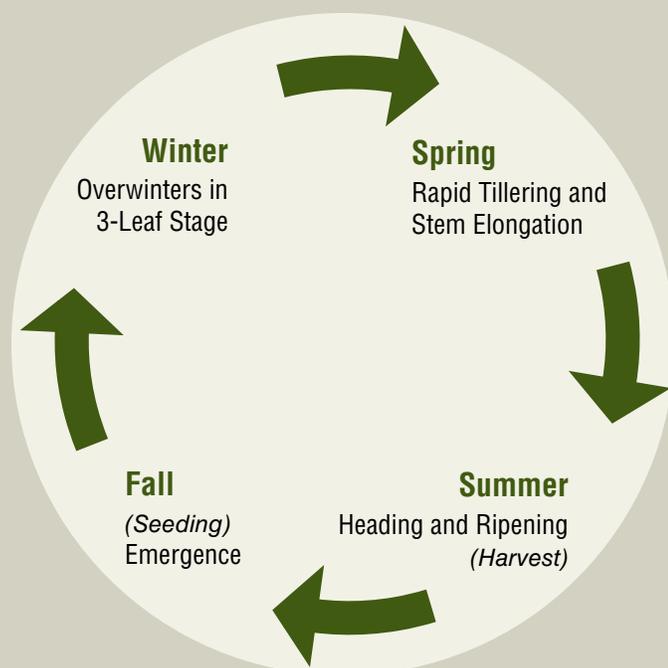


Figure 2. Growth Habit of Winter Wheat

Winter Annual Weeds Life Cycle

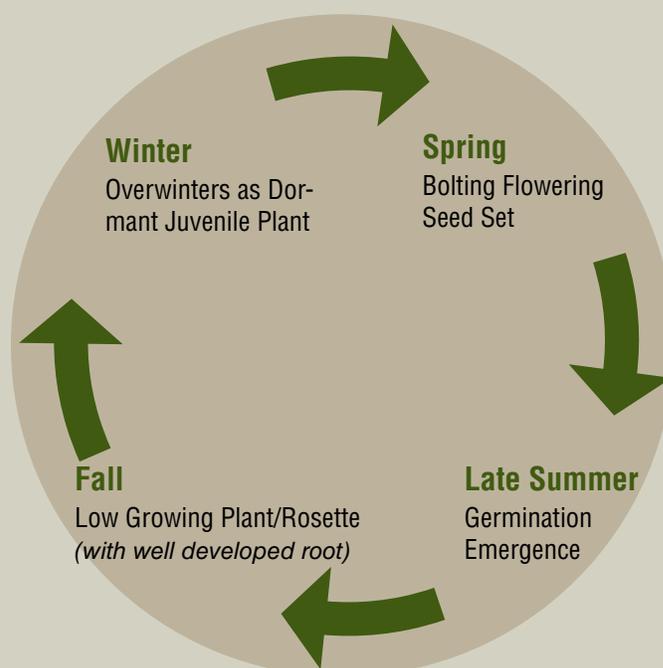


Figure 3. Growth habit of winter annual weeds.

Integrated Weed Management

Winter annuals can be the most significant weed concern because their life cycle is synchronized with winter wheat. They are a species that germinates in the fall and overwinters as a dormant rosette. The weed resumes growth in the spring, sets seed and then dies in the summer. Thorough scouting in the fall is essential for effective weed management. Some winter annuals include: flixweed, shepherd's purse, stinkweed and cleavers. (See Table 2 for a comprehensive list.)



Figure 4. Cleavers, a winter annual. (Photo: MAFRI, 2013)

Perennial weeds has a life cycle of at least two years. Many species can reproduce by seed production or through the spread of root material, which may be difficult to control. Post-harvest and pre-seeding windows provide an opportunity for control for perennial weeds, provided there is enough re-growth. A pre-harvest herbicide application in the crop preceding winter wheat may also provide control.



Figure 6. Quackgrass, a rhizotomously spreading perennial. (Photo: MAFRI, 2013)

Perennial Weed Life Cycle

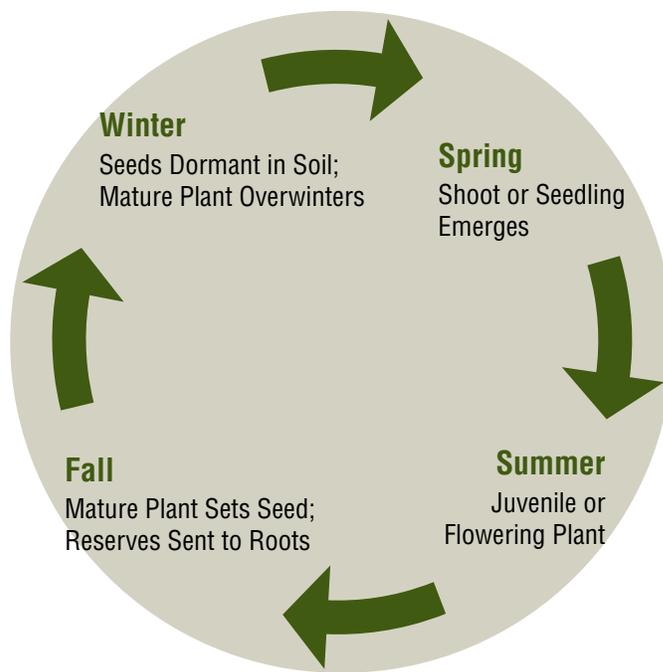


Figure 5. Perennial weed life cycle. Perennials can grow and reproduce by seed or structures such as stolons or rhizomes.

Annual Weed Life Cycle

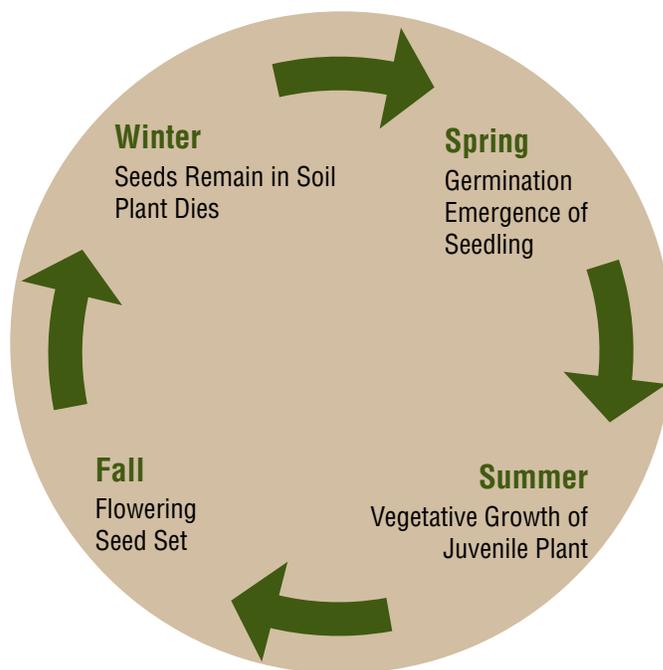


Figure 7. Growth habit of annual weeds.

Annuals germinate in the spring, set seed in the same year and then die in the late fall. They are less likely to be a concern in winter wheat because of the competitiveness of the crop when the weed seeds are germinating.

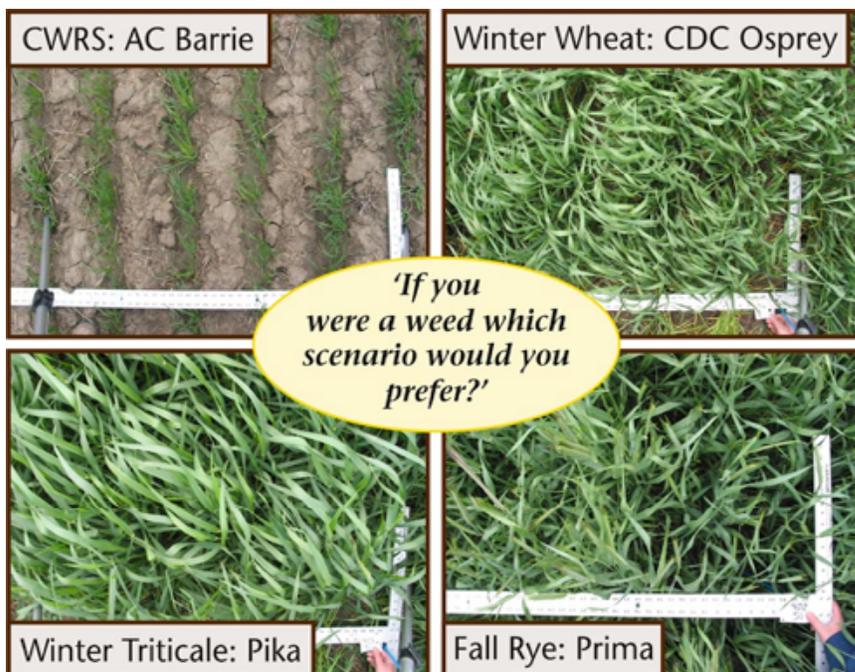
Advantages of Winter Wheat For Weed Control

Many winter wheat cultivars develop early and larger canopies than spring wheat, which leads to earlier canopy closure during the germination and early growth stages of annual weeds (Figure 9a). Furthermore, earlier canopy closure and biomass development improves the use of nutrients and water (Beres *et al.* 2010b).



Figure 8. Wild oats, an annual weed. (Photo: MAFRI, 2013)

Figure 9a. Stand of Canadian Western Red Spring Wheat (AC Barrie) (TOP LEFT), compared to Canadian Western Red Winter (CDC Osprey) (TOP RIGHT). The early and dense canopy of winter wheat (and other fall seeded cereals) contributes to lower weed biomass, compared to a spring seeded wheat. (Photo: Brian Beres, AAFC, Lethbridge)



Annual vs. Winter Crop Competition

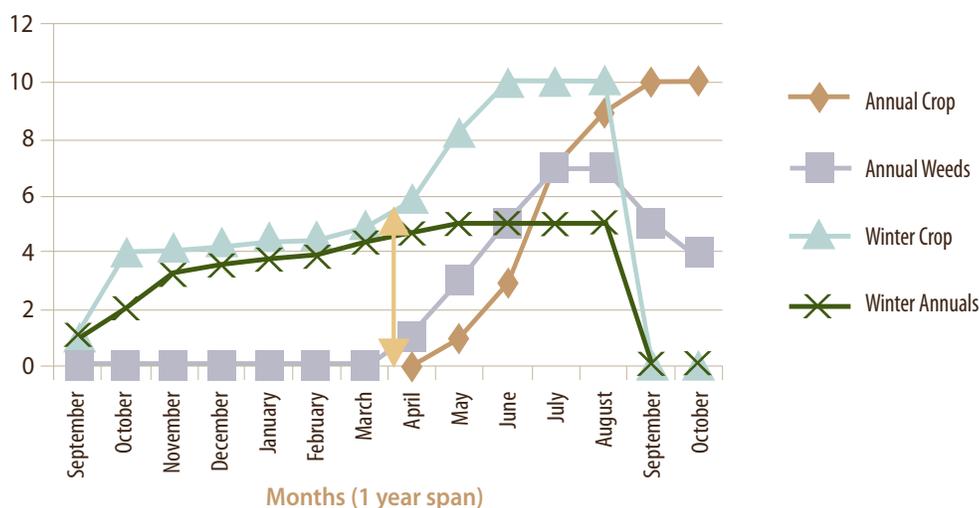


Figure 9b. Conceptual image illustrating the relationship between weed biomass production and crop phenology. The arrow represents the head start in biomass that winter wheat has over annual weeds, such as wild oats. This graph shows that annual crops are quickly overcome with weeds in the early months of the growing season.

Integrated Weed Management

Rotation

Winter wheat is a sound agronomic crop phase in the rotation because it can reduce the annual weed seed bank, much like spring-annual crop phases can reduce the winter annual seed bank. Wild oats often do not pose a significant threat to a winter wheat crop to warrant spraying, thereby reducing herbicide costs. Winter wheat's early and vigorous spring growth helps edge out wild oats and other spring annual weeds.

Seeding Rate and Fall Weed Control

Winter wheat seeding rate is important as it can increase yields when at a competitive rate and a good seeding rate will give the crop a better advantage over annual weeds in the spring.

A study conducted by Agriculture and Agri-Food Canada experimented with seeding rates of 300, 450, and 600 seeds m^{-2} . They reported that all yield-related variables, except crop biomass and kernel weight, respond-

ed to seeding rate. Grain yield was 0.24Mg/ha (metric tons/hectare) optimized at the 300 and 450 seeds/ m^2 rates but the greatest weed biomass reductions were observed for the 600 seeds m^{-2} rate. The study, conducted in Lacombe and Lethbridge, used a pre-seed burn off of glyphosate and fall application of 2,4-D, or fall application of 2,4-D with spring application of thifensulfuron/tribenuronclodinafop (Refine Extra) mixed with clodinafop (Horizon) (Beres *et al.*, 2010).

Crop disease levels may increase at the highest seeding rate as the dense canopy provides micro-conditions conducive to leaf spot and powdery mildew, which may have caused the lower grain yield at the highest sowing density. Figure 11 shows the density and biomass for weeds at different seeding rates. A seeding rate of 450 seeds m^{-2} will produce optimal grain yield and high weed competitive ability.

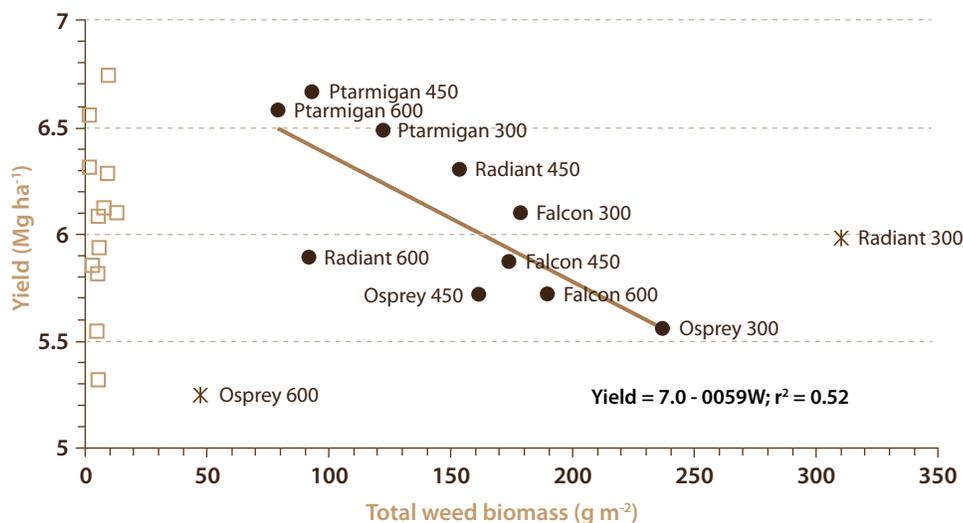


Figure 10. Linear regression for the effect of total (dicot plus monocot) weed biomass on winter wheat yield trends for fall-applied 2,4-D in Alberta, Canada, 2002–2004. The labels indicate variety and seeding rate (seeds m^{-2}). The open square points are for fall 2,4-D plus spring herbicide treatment. Combinations and closed circle points are for only fall 2,4-D treatments. The regression model coefficients are inset in the chart; W = total weed biomass and is preceded by the linear slope coefficient. 'Osprey 600' and 'Radiant 300' were considered outliers and excluded from the analysis. (Beres *et al.*, 2010).



Figure 11. Radiant at 450 seeds/ m^2 (LEFT) and 600 seeds/ m^2 (RIGHT). Visually similar, few weeds are present in Due to early canopy closure, though the photo on the left had a higher grain yield on average. (Photo: B. Beres, AAFC, Lethbridge).

Seed Selection

Plant breeding has created winter wheat varieties with higher yield potential that are better able to withstand disease, insects and weed competition. Starting out with weed and disease free seed will lessen the chances of disease spread and the introduction of weeds. Buying certified seed is recommended, as this ensures the seed has been grown, inspected and cleaned according to stringent guidelines. See **Seeding Management: Variety Selection**.

Seeding Date

Later seeding dates can weaken the crop's weed competitive ability causing a greater reliance on herbicide control, which is not always effective; therefore, the increased weed pressure from delayed seeding dates can have adverse effects on crop yield. Late seeding can also affect plant survival, which can reduce the stand density and increase weed abundance and distribution, often increasing herbicide inputs in the spring. Figure 9b shows a conceptual image of the difference between biomass production of weeds vs. winter/annual crop phenology. When delayed seeding occurs there are limited chances for a fall in-crop application, leaving weed control to occur at a later date, when the weeds are more established. See **Seeding Management: The Essence of Timing**.

Seeding Depth

A well-established crop will be the most competitive against weeds. Seeding shallow (less than 1") is necessary with winter wheat because of its short coleoptile and also allows the seed to germinate quickly with fall moisture. Deep-seeding winter wheat causes reduced seedling vigor, delayed emergence and, ultimately, higher winter-kill. Increased winter-kill means the crop will lose its competitive advantage, and stronger herbicide use may ensue. See **Seeding Management: Seeding Depth**.

Fertility

Soil test results will provide appropriate guidelines for application rates of N, P, K, and S for the field. Nitrogen is used more efficiently when put down with the

crop, and the wheat canopy will close, out competing annuals in the spring. Banding and point injection will generally limit weed access to the fertilizer, which can reduce weed density and biomass. Beres *et al.* (2010c) reported that fall-banded N applications reduced monocot weed biomass by 29% relative to spring broadcast N application (Table 2). Controlled release urea products such as polymer-coated urea may cause high weed biomass in some situations where release is delayed and plant growth is slowed, creating opportunity for weeds (Beres *et al.*, 2010c). See **Soil Fertility and Nutrient Management**.

Herbicide Selection

Identifying weeds is the first step to effective chemical control. Incorrect identification (such as scentless chamomile vs. flixweed) can add up to an expensive chemical bill. Selecting a herbicide can be less complex in winter wheat when compared to other crops, as there are only about 20 herbicide chemistries registered for in-crop applications on winter wheat.

Not only should early emerging weeds be targeted, but also volunteer seedlings. Control of volunteer cereals will help control disease vectors. See **Insects and Diseases**.

Refer to the provincial *Crop Protection* guide for herbicide selection, weed spectrums and rates. Always follow herbicide labels.

Herbicide Timing

In order to optimize herbicide effectiveness, weeds need to be correctly identified, including their growth stage. Weed densities should also be noted in a field.

Winter wheat should be scouted similar to any other wheat crop, but scouting for weeds will be segmented into: pre-seeding, 3 leaf stage, and prior to flag leaf emergence. A pre-seed glyphosate application is a popular choice to control winter annuals and perennials. This application can be coupled with the pre-harvest application in an annual crop to lower cost.

Weeds will continue to emerge throughout the fall, particularly winter annuals, so a fall herbicide applica-

Integrated Weed Management

tion may be effective prior to freeze-up. An application 2,4-D at label rates is effective for control of winter annuals (Beres *et al.*, 2010a, 2010b). Regular scouting is imperative to ensure registered growth stages for the herbicide are not exceeded. Care must also be taken to not apply the product too early. The herbicide should be applied under favourable conditions. When weeds and wheat plants are stressed by environment, or not actively growing, neither will metabolize chemical very well, leading to plant injury.

Producers need to be alert in the spring, as winter wheat is often at the ideal stage to spray when pre-seed burnoff is happening for spring seeded crops. The appropriate window to spray can be inadvertently overlooked. Spraying at the wrong stage (especially 2,4-D) can cause sterile heads and a significant yield loss.

Weed Control Options

Weed Control in the Previous Crop

Good weed sanitation in the crop before winter wheat helps to establish a competitive crop. Biennial and perennial weeds should be addressed to limit weed pressure in the fall.

Pre-Seed Burnoff

A pre-seed burn off of glyphosate can be economical and provide a clean field for planting winter wheat. Sometimes glyphosate requires an additive, especially when trying to broaden the weed spectrum, act faster or get residual effects. There are six registered combinations of additives and glyphosate registered for winter wheat. See Table 1.

1. **Express SG/Express Pro + Glyphosate (Group 2,9)**
 - Express products are Group 2 systemic herbicides that inhibit cell elongation of weeds. Express Pro contains Methsulfuronmethyl, which provides residual control of broadleaf weeds for up to 15 days.
 - Express products provide control of tough to kill weeds such as dandelion, flixweed, narrow leaved hawks beard, stinkweed, volunteer canola (including Roundup Ready) and wild buckwheat.
2. **2,4-D + Glyphosate (Group 4,9)**
 - 2, 4-D is a non-selective systemic herbicide. Weeds should be in the 2-4 leaf stage for best control. Accumulation of the chemical occurs in the actively growing areas of the roots or shoots causing ab-

Glyphosate Additive	Active Ingredient	Residual Control	Benefits Beyond Straight Glyphosate
Express SG	Tribenuron-methyl 50%	No	Additional control of hard to kill weeds plus RR volunteer canola
Express Pro	Tribenuron-methyl 42.9%/ Methsulfuronmethyl 8.6%	Yes, up to 15 days	Above plus residual control of flushing broadleaf weeds
2,4-D	2,4-D Amine or Ester	No	Broad spectrum weed control; control of RR volunteer canola
PrePass	Florasulam and Glyphosate	Yes, up to 21 days	Long residual saves fall spraying; control of RR volunteer canola
Heat	Saflufenacil and Glyphosate	No	Fast control of tough to kill weeds; different chemical group (14)
CleanStart	Carfentrazone and Glyphosate	No	Winter annual, volunteer canola and dandelion control

Table 1. Registered Pre-Seed Burnoff Applications for Winter Wheat



normal growth. Adding 2,4-D to glyphosate will broaden the spectrum of controlled weeds and control Roundup Ready volunteer canola.

3. Pre-Pass (Group 2,9)

- Florasulam is taken into the leaves where it inhibits acetolactate synthase causing an inhibition in protein synthesis, thereby starving the plant. Broadleaf weeds are best controlled at the 2-4 leaf stage. Rosettes can be up to 15 cm across.

4. Heat (Group 14,9)

- Heat is a fast-acting Group 14 herbicide that moves quickly through the plant and inhibits protoporphyrinogen oxidase, causing cell membrane damage. Symptoms can appear within hours of application. Heat can control broadleaf weeds up to 8 leaf, and rosettes less than 8 cm across.

5. CleanStart (Group 14,9)

- Carfentrazone-ethyl is a contact herbicide that is useful in controlling volunteer Roundup Ready canola, kochia and other smaller broadleaf weeds. There is no residual in Clean Start, and it should be applied to broadleaf weeds between the 3 leaf and 10 cm rosette stages.

Fall Application of 2,4-D (Group 4)

Since winter annuals will be growing in the fall, an application of 2,4-D may suppress and control these weeds. 2,4-D, like all phenoxy herbicides, can cause injury to plants if not applied at the correct time. Spraying at the wrong time can cause sterile heads and a significant yield loss. Generally 2,4-D applications in spring when the crop is in a late vegetative stage

is when injury may occur. Consequently, earlier and when the crop and weeds are actively growing is better for efficacy and a strong winter wheat stand.

Although **not registered** for use in the fall on winter wheat, label rates of 2,4-D for broadleaf winter annual control can be applied safely if the crop and weed are actively growing and the application occurs in frost-free conditions (Beres *et al.*, 2010a, 2010b). 2,4-D is registered for spring applications when wheat is tillering and weeds are at the 2-4 leaf stage. However, spring applications can be difficult to apply under appropriate conditions, before wheat plants are too mature.

In two Agriculture and Agri-Food studies, fall-applied 2,4-D applications performed in mid-October have been successful. Winter-kill and crop injury was low and weed populations were suppressed, so it can be speculated that a fall treatment of 2,4-D may be the only chemical required to control winter annuals and perennials in the fall (Beres *et al.*, 2010a, 2010b).

Spring Control

Early scouting and timely applications can prevent losses due to herbicide injury. Not all herbicide chemistries registered for in-crop application on spring cereals are registered for winter wheat. Taking into account the weed spectrum, population and stage of the crop and weeds, a selection may be made from the *Crop Protection* guide or online.

AARD Herbicide Selector

Available at:

<http://www.agric.gov.ab.ca/app23/herbssel>

Weeds Found in Winter Wheat

Weeds	Growth Habit	Emergence	When to Control
Annual Smartweed/Lady's Thumb	Annual	Spring/Summer	Spring/Summer
Annual Sow Thistle	Annual/Winter Annual	Fall/Spring	Fall/Spring
Canada Thistle	Creeping Perennial	Spring/Fall	Spring/Fall
Cleavers	Annual/Winter Annual	Spring/Fall	Spring/Fall
Common Chickweed	Annual/Winter Annual	Spring/Fall	Spring/Fall

Table 2. Weeds Found in Winter Wheat

Integrated Weed Management

Weeds	Growth Habit	Emergence	When to Control
Cow Cockle	Annual	Spring/Summer	Spring/Summer
Dandelion	Perennial	Spring/Fall	Fall
Downy Brome	Annual/Winter Annual	Spring/Fall	Spring/Fall
Field Horsetail	Perennial	Spring/Fall	Spring/Fall
Flixweed	Annual/Winter Annual	Spring/Fall	Spring/Fall
Foxtail Barley	Perennial		
Green Foxtail	Annual	Spring/Summer	Spring/Summer
Hemp Nettle	Annual	Spring/Summer	Spring/Summer
Japanese Brome	Annual/Winter Annual	Spring/Fall	Spring/Fall
Kochia	Annual	Spring/Summer	Spring/Summer
Lamb's Quarters	Annual	Spring/Summer	Spring/Summer
Narrow Leaved Hawks Beard	Annual/Winter Annual	Spring/Fall	Spring/Fall
Perennial Sow Thistle	Perennial	Spring/Fall	Spring/Fall
Prostrate Pigweed	Annual	Spring/Summer	Spring/Summer
Pygmy Flower	Annual/Winter Annual	Spring/Fall	Spring/Fall
Quackgrass	Perennial	Spring/Fall	Spring/Fall
Redroot Pigweed	Annual	Spring/Summer	Spring/Summer
Round Leaved Mallow	Annual	Spring/Summer	Spring/Summer
Scentsless Chamomile	Annual/Biennial/Winter Annual	Fall/Spring/Summer	Fall/Spring/Summer
Shepherd's Purse	Annual/Winter Annual	Spring/Fall	Spring/Fall
Stinkweed	Annual/Winter Annual	Spring/Fall	Spring/Fall
Stork's Bill	Annual/Biennial/Winter Annual	Fall/Spring/Summer	Fall/Spring/Summer
Toadflax	Perennial	Fall/Spring	Fall
Volunteer Barley	Annual	Spring/Summer	Spring/Summer
Volunteer Canola & Other Mustards	Annual	Spring/Summer	Spring/Summer
Volunteer Oats	Annual	Spring/Summer	Spring/Summer
Volunteer Wheat	Annual	Fall/Spring/Summer	Fall/Spring/Summer
Wild Buckwheat	Annual	Spring/Summer	Spring/Summer
Wild Oats	Annual	Spring/Summer	Spring/Summer

Insects

Insect control is an essential component of managing a cropping system. Although they can easily be overlooked, once insect pests reach economic thresholds, prompt action is necessary to prevent significant crop loss. Chemical, biological and cultural control are all tools that can help manage the pest. While the priority is maintaining a healthy and productive crop, it is also important to be environmentally friendly, by not over applying insecticides and considering biological control options. An integrated use of practices can be used to ensure efficient and superior management of insects.

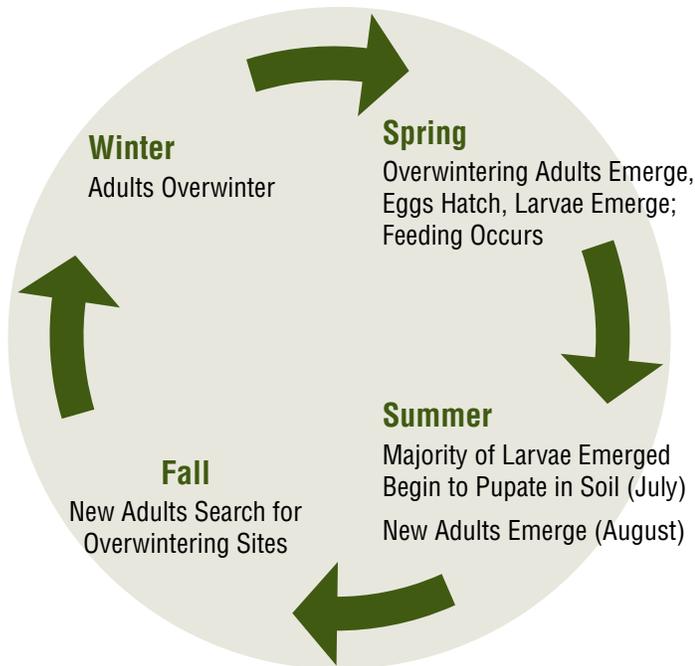
Insect		Damage	Damaging Stage	Crop Stage	When to Scout
MAJOR INSECTS					
Beetle	Cereal Leaf Beetle	Feeds on the leaves, causing elongated slits on leaves	Larva	Fresh Tissue	May -June
Sawfly	Wheat Stem Sawfly	Bores inside stem and cuts stem to exit	Larva	Maturing Wheat Stem	Late-June to Mid-August
MINOR INSECTS					
Cutworms	Army Cutworm	Grazes on leaves, fresh matter	Larva	Early Spring Wheat Growth	Mid-May to Mid-June
	Pale Western Cutworm	Cuts the plant below soil surface			
Grasshoppers	Clear Winged	Feeds on emerging wheat tissues	Adult	Fresh Tissue: 1 Leaf Stage to Killing Frost	Before and After Seeding (prior to winter)
	Striped Winged				
Mite	Wheat Curl Mite	Feeds on leaf, which prevents the leaf from unrolling	Larva	Fresh Tissue	Not Applicable
Aphids	Russian Wheat Aphid	Infest new leaves as they emerge, causing flag leaf to trap head and curl; leads to poor pollination	Nymphs and Adults	Foliage and Grain Spikes of Actively Growing Parts	Early to Mid- May
Wireworms		Feed on roots	Larva	When plant is trying to receive nutrients through roots	Mid-May to Mid-June

Table 1. List of Major and Minor Insects that pose a threat to Winter Wheat

Insects

Cereal Leaf Beetle (*Oulema melanopus*)

Identification and Life Cycle (Carcamo, 2011; Glogza, 2002)



What kind of damage should I be looking for?

The first apparent damage from Cereal Leaf Beetle (CLB) is from adult feeding in the spring. Damage is characterized by long, narrow slits in the upper leaf surface. The larvae of the CLB emerge in June, and begin to aggressively feed on the surface of the leaves. They feed between veins, removing all green material and leaving a windowpane effect on the lower leaf surface (Kher *et al.*, 2011; Purdue University: Cereal Leaf Beetle, 2009). Cumulatively, a severely damaged crop will have a frosted appearance. The most damage is caused by the larval feeding. The larvae and adults both prefer new plants or young tissue on older plants.



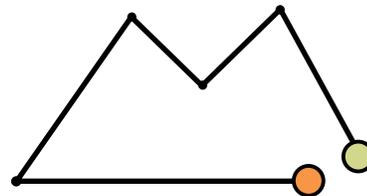
Figure 1. Adult CLB, characterized by an orange-red thorax, yellow legs and metallic blue-black heads and wing covers. Adults are approximately ¼ inch long. (Photo: K. Boltze, AAFC, Ottawa)

When should I scout?

Since the larvae emerge in the spring, scouting should commence in early June. Controlling them early is more effective when the larvae are small. However, up to now the pest has been controlled by a parasitoid wasp (*Tetrastichus julis*) which has followed the pest or can be relocated to areas where the beetle pest is expanding. Spraying insecticides is not recommended to protect this effective biocontrol agent.

What kind of pattern should I use to scout the field for CLB?

- Be sure to cover a representative area of the field.
- Walk along field edges (~50 ft off edge), as well as the inner portion of the field.
- Pay particular attention to areas that appear “frost bitten”, as this may be an indication of CLB damage.



How do I know if I need to take action?

Damage to young plants tends to impact plant vigour. Injury to the upper leaves limits the plant’s ability to photosynthesize and reduces reproductive growth. To determine whether control measures are warranted, calculate the economic threshold for CLB, while scouting. The CLB larvae are the target of control.

Calculating the Economic Threshold

1. Sample 10 tillers at 10 random locations in the field
2. Control is recommended if there is an average of 3 eggs and/or larvae per tiller that are found **before** boot stage
3. Control is recommended if there is an average of one larvae per flag leaf **at or after** boot stage

(Government of Saskatchewan, 2011)

What control options are available?

Chemical: Determine CLB abundance before making a decision to spray. Calculate the Economic Threshold. If spraying is warranted, consult the *Crop Protection* guide for registered insecticides.

Biological: *Tetrastichus julis* is a parasitoid wasp for the CLB and it helps control it by parasitizing the beetle. The wasp lays multiple eggs inside the larvae eventually killing it. Once the larvae have finished developing, they burst out of the body as larvae and continue their life cycle (Kher *et al.*, 2011). Lady beetles serve as natural controls of CLB, by feeding on CLB larvae. Predators of CLB can significantly suppress populations, once well established.



Figure 2. Larva of CLB. Typically larvae are slightly larger than the adult beetle, and have a slug-like appearance. The bodies are yellowish-orange and covered with a mucus secretion, which gives a wet, black appearance. Larvae have 3 pairs of brown-black legs. (Photo: BC Ministry of Agriculture)



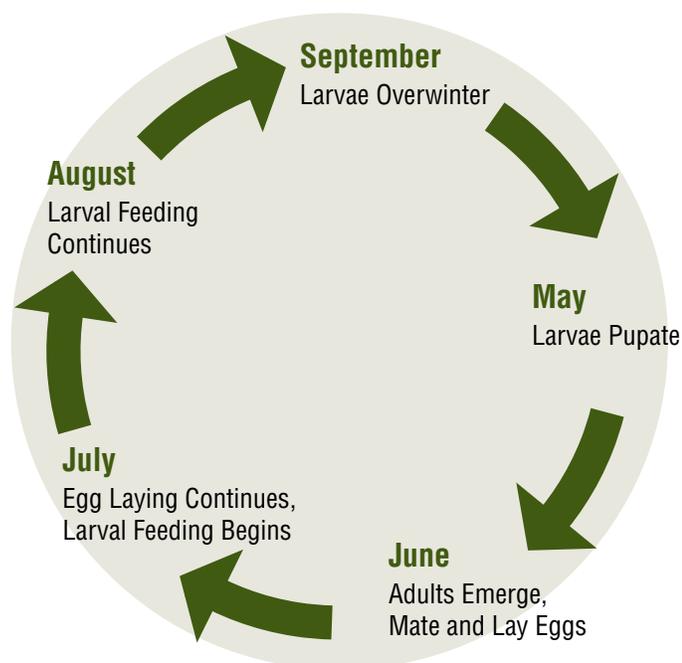
Figure 3a. *T. julis*, the parasitic wasp of CLB, in the larval stage, developing in CLB larva. (Photo: T. Larson, AAFC, Lethbridge)



Figure 3b. CLB Eggs. The eggs are cylindrical and bright yellow-orange in colour. They darken to brown and eventually black, just prior to hatching. Eggs are laid in chains of 2-3 on the upper leaf surface, along the middle vein. They hatch in about 5 days, but hatching depends on temperature. (Photo: North Dakota State University)

Wheat Stem Sawfly (*Cephus cinctus*)

Identification and Life Cycle
(Government of Saskatchewan, 2011)



What kind of damage should I be looking for?

Adult Wheat Stem Sawfly emerge in June and females deposit eggs in wheat stems, or the elongating stems of other host plants. If multiple eggs are laid in the same stem, only one survives to become a mature larva. The larvae are born in the stem and remain there for most of the lifecycle (Beres *et al.*, 2011). The larvae feed upwards in the plant and then begin to move down at ripening, or as the plant dries down. The larvae chew a groove around the inside of the stem about 2 cm from the ground. Larvae create a cocoon and overwinter low in the stem. Adults emerge from the cocoon in the following spring.

Damage occurs from boring and cutting the wheat stem. There is reduction in yield, seed set and grade quality, from larval feeding in the stem. The cut made around the base of the stem, weakens the plant, causing it to readily lodge with rain and wind. Further yield losses occur from the heads falling and not being harvested.

Insects

Winter wheat is not generally the preferred host of Wheat Stem Sawfly in Canada; however, winter wheat crops can be infested if planted too late or growth is delayed in the spring. Montana experiences sizeable crop losses from sawfly damage in winter wheat because of a strain with an earlier life cycle better synchronized with winter wheat. See Figure 7.

When should I scout?

Adult sawfly can be captured in late June and early July with a sweep net. Fields should be monitored again in later July. Infested wheat stems may be present and visible as a mottled discolouration. Stems should be split and inspected for the S-shaped larvae.

What kind of pattern should I use to scout the field for the Wheat Stem Sawfly?

- Ensure a good representation of the field is covered.
- Walk along edges (~50 ft off edge) as well as the inner portion of the field.
- Around harvest time, pay particular attention to areas that appear lodged as this may be caused by the presence of the Wheat Stem Sawfly.
- Infestations may be more severe at field margins, but are not limited to edges.

How do I know if I need to take action?

The percentage of plants infested by Wheat Stem Sawfly should be assessed before harvest. To confirm the presence of Wheat Stem Sawfly, the stems of wheat plants should be cut open and checked for typical sawdust-like “frass”, evidence of sawfly feeding. Subsequent solid stem spring wheat varieties are recommended if 10-15% of the winter wheat crop (or more),



Figure 4. Lodged wheat from Wheat Stem Sawfly infestation near Claresholm, AB. Approximately 90% of stems have been cut. (Photo: H. Carcamo, AAFC, Lethbridge)



Figure 5. Adult Male Wheat Stem Sawfly. They can be distinguished by their 2 pairs of wings, shiny black abdomen, with 3 yellow bands, and yellow legs. Adults range in size from 10-15 mm and are characteristically inactive, often found with their heads downward. Females have an ovipositor at the end of their abdomen, used to “saw” into stems and lay eggs. (Photo: H. Goulet, AAFC, Ottawa)

was damaged by Wheat Stem Sawfly. Swathing winter wheat crops is recommended if more than 15% of stems are infested by sawfly (Alberta Agriculture and Rural Development, 2012). Information about sawfly infestation levels is most useful for making decisions relative to future cropping plans.

What control options are available?

Chemical: There is no insecticide registered to control Wheat Stem Sawfly. And research trials have not shown any insecticides to be cost effective (Government of Saskatchewan, 2012).

Cultural: Damage from sawfly can be reduced by incorporating crops resistant to infestation, such as oats and non-cereals, into rotation (Beres *et al.*, 2011). See **Crop Rotation**. Solid stem cultivars decrease the ability for larvae to bore through wheat stems, thus reducing damages. Currently only spring wheat cultivars with solid stem traits are available; such winter wheat cultivars are still being developed in Canada but some cultivars with various degrees of solid pith are available in Montana. It should be noted that solid stem wheat are not resistant to, but rather tolerant to, sawfly damage. See **Seeding Management** for variety information. Swathing infested wheat is recommended to prevent infested stems from lodging. Tillage has been shown to reduce sawfly populations, but also increases soil erosion and negatively impacts populations of insects that parasitize sawfly. Tillage also represents an additional cost.

Biological: Naturally occurring enemies help to suppress sawfly populations. One such parasitoid is *Bracopneptis cephi*, a wasp that parasitizes sawfly in wheat fields (Figure 8). The wasp feeds on sawfly larvae.

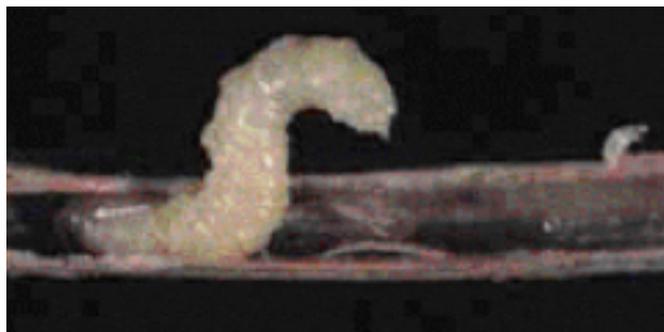


Figure 6. Sawfly larvae. Larvae have a distinct S-shape, when removed from the stem, and are about 13 mm at maturity. They are cream coloured with a brown head at maturity but colourless when newly hatched. (Photo: G. Evjen, AAFC, Swift Current)



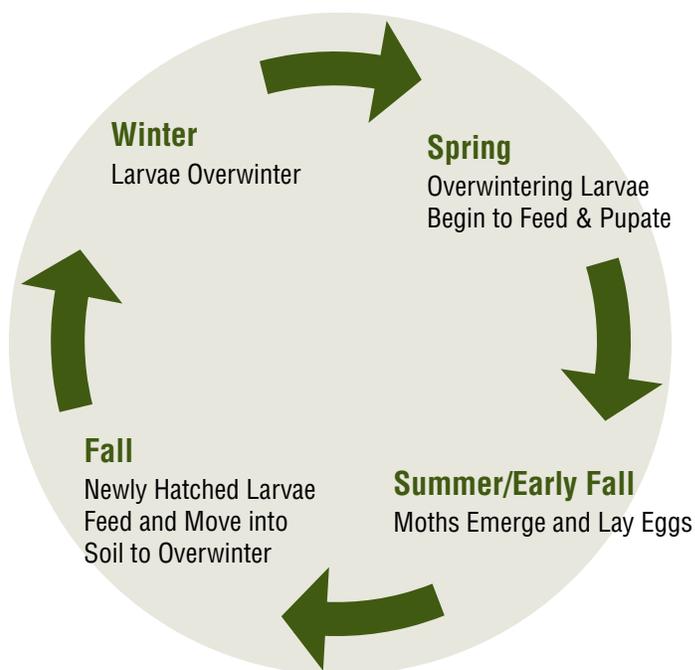
Figure 7. Region *historically* most impacted by Wheat Stem Sawfly (yellow). Sawfly is becoming an emerging issue further south in the US, beyond what shown in the above image. (Image: S. Torgonrud, AAFC, Lethbridge)



Figure 8. *Bracon cephi*, a key parasitoid of Wheat Stem Sawfly (Photo: H. Goulet, AAFC, Ottawa)

Cutworms – Army & Pale Western (*Euxoa auxiliaris* & *Agrotis orthogonia*)

Identification and Life Cycle (Hein *et al.*, 2006)



From late August to October, moths lay eggs in the soil, which hatch within a few days or up to 2 weeks. The newly hatched larvae, or cutworms, feed on plants and then become inactive over the winter, at which point they are about half way to maturity. In the spring, they resume activity and feeding and in May the mature larvae begin to burrow deeper into the soil to pupate. Moths emerge in June through the larval tunnels.

What kind of damage should I be looking for?

The Army Cutworm grazes above ground on plant leaves. The damage is visible as holes in leaves and notches at leaf edges. Plants can recover from Army Cutworm feeding, provided the damage is not severe. The Pale Western Cutworm feeds just below the soil on the stem (Hein *et al.*, 2006; International Maize and Wheat Improvement Center, 2010). Such damage appears as dead or wilted plants. If the growing point of the plant is damaged, it will not recover. Plants should be examined for evidence of feeding, as to not confuse damage with what might be winter kill.

Insects

The Army Cutworm is greenish-brown to greenish-grey, with a darker top side than under side. It features a narrow stripe, pale in colour, along the mid-back. Its head is pale brown with brown freckles (Figure 9). The Pale Western Cutworm forms a C-shape when disturbed and is pale yellow-grey, with a white mid-dorsal line. Its head is yellowish brown with 2 apparent dashes, which form a black inverted V (Figure 9).

When should I scout?

Scouting should begin mid-May, when the larvae emerge and begin feeding (Hein *et al.*, 2006). Fields should be scouted on a weekly basis until mid-June. Cutworms are nocturnal and feed at night. Therefore, it may be difficult to find them active and above ground on bright, sunny days.

What kind of pattern should I use to scout the field for Cutworms?

- Ensure a representative area of the field is covered.
- Pay particular attention to circular, bare areas, as well as 'wilted' volunteer canola plants (Hein *et al.*, 2006). Cutworms may also feed along rows.
- Dig in the dirt, particularly around damaged plants. They are often found in close proximity to wilted or dead plants.

How do I know if I need to take action?

To determine whether control measures are warranted, consider the nominal economic threshold for Army cut-

worms, of 5-6/m² (Manitoba Agriculture, Food and Rural Initiatives, 2012). Economic thresholds have not been extensively researched, so other factors to consider when considering control options include:

- Health of the crop: Healthy and vigorous winter wheat crops can withstand higher cutworm populations.
- Moisture conditions: Under good moisture conditions damage is likely to be less significant than if the crop is drought stressed.
- Larvae size: If larvae are too mature, most of the feeding has already occurred and an insecticide treatment may not be worthwhile.
- Wheat growth stage: Healthy, actively growing wheat can withstand more damage than a winter wheat crop just coming out of dormancy.

What control options are available?

Chemical: There are very effective insecticides for cutworm control. Product choice may depend on the type of cutworm present. Reference the *Crop Protection* guide for product options.

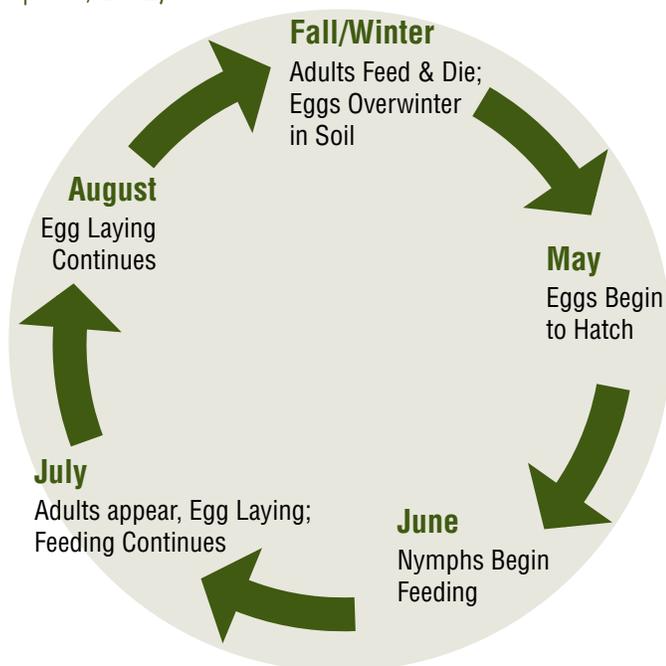
Biological: The most successful predators of cutworms are insectivorous birds. (Montiguide, 2000; International Maize and Wheat Improvement Center, 2010). Parasitic wasps also contribute to the reduction cutworm populations.



Figure 9. Pale Western Cutworm (top). Army Cutworm (bottom).
(Photo: University of Nebraska Lincoln)

Grasshoppers

Identification and Life Cycle
(Purdue University, 2009; Alberta Agriculture and Rural Development, 2012)



Grasshopper is the name given to a large and diverse group of insects. Grasshoppers are characterized by chewing mouth parts, slender bodies, wings that fold lengthwise, big, strong hind legs for jumping, as well as a gradual change in form and size as they develop. In North America, there are in excess of 600 species of grasshoppers, of which there are 85 in Alberta. Only four species are considered pests of economic importance.

What kind of damage should I be looking for?

Grasshoppers are grass feeders and cause damage at the older nymph and adult stage (Alberta Agriculture and Rural Development, 2003b). Damage can be severe, especially when attacking winter wheat vegetation in its early stages. In the most severe cases, only the mid-vein of the leaf remains.

When should I scout?

Take record of the current growing season. If the year is dry, there is a greater possibility for grasshopper infes-

tation on cultivated fields. Scout in the fall, when winter wheat is trying to emerge and set stand.

What kind of pattern should I use to scout the field for Grasshoppers?

- Ensure a representative area of the field is covered.
- Begin at one corner of the field and walk diagonally across the field. At the corner, turn and walk along the field edge.
- Pay particular attention to bare areas, as well as 'leafless' plants as this may indicate an infestation of Grasshoppers.

How do I know if I need to take action?

To determine whether control measures are warranted, calculate the economic threshold for Grasshoppers, while scouting. Also consider factors such as crop stage, insect maturity and growing conditions.

Calculating the Economic Threshold

1. Sample 20 random locations across the field. Count the number of grasshopper nymphs that jump up from a one square foot area, as it is approached.
2. Control is required if there is an average of 8-12 grasshoppers per square metre.

(Alberta Agriculture and Rural Development, 2012)

What control options are available?

Chemical: There are effective insecticides for Grasshopper control. Reference *Crop Protection* guide for the most up to date insecticides. Spray the outside borders of the field first, as this may help prevent spread of the infestation further into the field (Bradshaw and Wright, 2011). Insecticides are most effective when applied after eggs have hatched and Grasshoppers are in the nymph stage.

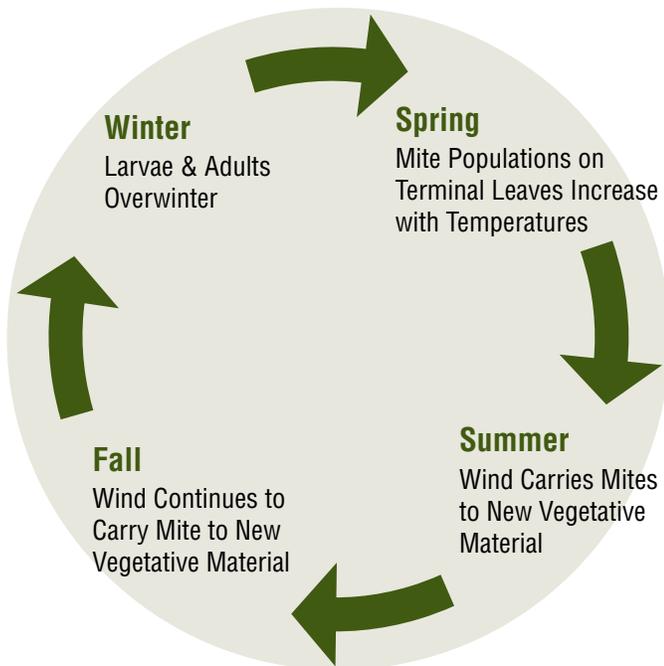
Cultural: Avoid planting winter wheat if the season has had extreme drought and a warm winter is foreseen. Increasing the seeding rate can help compensate for partial stand loss (Bradshaw and Wright, 2011). Crops such as peas and oats can be planted as a "barrier crop", surrounding a crop more preferred by Grasshoppers.

Insects

Wheat Curl Mite (*Aceria tulipae*)

Identification and Life Cycle

(Grains Research and Development Corporation, 2009)



The Wheat Curl Mite is nearly impossible to see without magnification, measuring about 1/100 of an inch. The mites are white, cigar-shaped organisms with 4 forward-directed legs near the head. Under optimal conditions (temperatures of around 25°C), the mite has a life cycle of 7-10 days, and populations increase dramatically. Population growth slows under hot (above 30°C), dry conditions.

What kind of damage should I be looking for?

The Wheat Curl Mite affects the leaves by curling the edges, as well as occasionally trapping the flag leaf (Grains Research and Development Corporation, 2009). The main concern of this insect is that it vectors the disease, Wheat Streak Mosaic Virus. See **Diseases: Wheat Streak Mosaic Virus**.

When should I scout?

Scouting is not economical or effective as only preventative measures help in the control of the Wheat Curl Mite (Grain Research and Development Center, 2009).

What kind of pattern should I use to scout the field for the Wheat Curl Mite?

- Detection of the mite is difficult without magnification; therefore, scout for the deformities in the crop.
- Mites usually appear first at field edges. Large infestations will cause leaf blades to curl upward and inward.

How do I know if I need to take action?

There is currently no economic threshold for the Wheat Curl Mite (Grain Research and Development Center, 2009).

Need to take action? What action is best?

Chemical: There are no pesticides registered for control of the Wheat Curl Mite.

Cultural: Do not seed winter wheat near newly emerged volunteer cereals. By controlling volunteer host plants early, at least 2 weeks prior to planting winter wheat, the Wheat Curl Mite population is diminished. The mites cannot survive in the absence of living host plants for more than 10 days. Spring wheat, barley, corn and some grasses can act as hosts to the mite.

Varietal: AC Radiant winter wheat is resistant to the Wheat Curl Mite. See **Seeding Management: Variety Selection**.

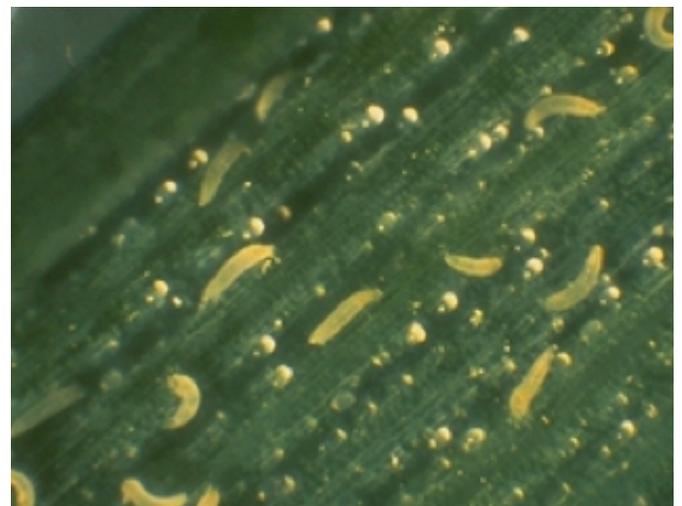
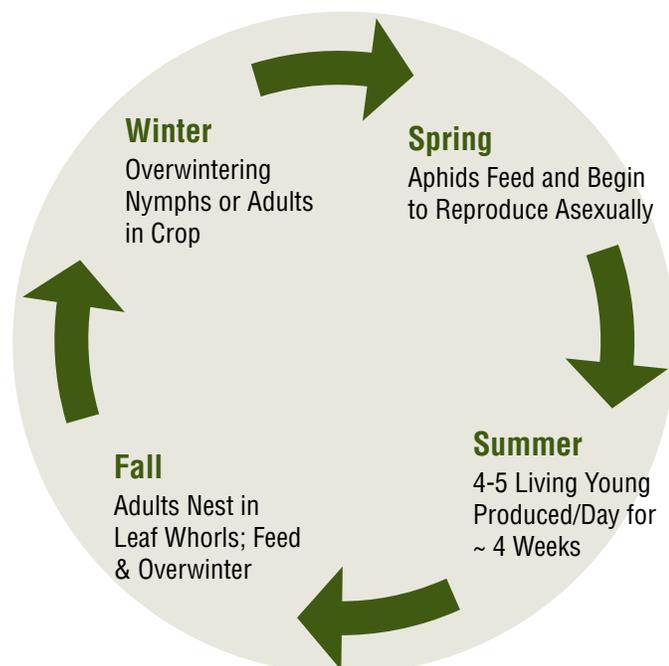


Figure 10. Wheat Curl Mites.
(Photo: Montana State University)

Russian Wheat Aphid (*Diuraphis noxia*)

Identification and Life Cycle (Karren *et al.*, 1989)



Adult Russian Wheat Aphids are bright green in colour and football-shaped. They measure 1.6mm – 2.1mm. Distinguishing features include shortened antennae and reduced cornicles at the end of the abdomen. Viewed from the side, the Russian Wheat Aphid has a supracaudal structure that looks like a double tail.

What kind of damage should I be looking for?

The Russian Wheat Aphid injects a toxin into the leaves as it feeds on the plant phloem. This toxin produces white streaking on the leaves, eventually turning purple. The transmitted toxin may cause the plant to be discoloured and deformed. The flag leaf begins to curl, preventing the wheat head from fully emerging and causing poor grain filling (Hodgson *et al.*, 2008; Shea *et al.*, 2006). Often it is easier to spot damage first, and then look for the aphid.

When should I scout?

Russian Wheat Aphid can be found on winter wheat from emergence in the fall until grain ripening the following year. Generally they are located on the newer leaves.

What kind of pattern should I use to scout the field for the Russian Wheat Aphid?

- Ensure a representative area of the field is covered.
- Travelling a zigzag pattern across the field may be appropriate when scouting for aphids, which can be uniformly distributed across a field.
- Pay particular attention to distorted areas, as well as white/purple plants, as this may be an infestation of the Russian Wheat Aphid.

How do I know if I need to take action?

To determine whether control measures are warranted, calculate the economic threshold for Russian Wheat Aphid, while scouting on a weekly basis.

Calculating the Economic Threshold

1. Sample 10 plants at 10 random locations across the field.
2. Control is required if $\geq 10\%$ of plants are infested with at least one aphid, when the first node is visible or when 10% or more of tillers are infested with one aphid, when the tip of the flag leaf is just visible.

(Government of Saskatchewan, 2011)



Figure 11a. Russian Wheat Aphid. (Photo: University of Idaho)

Insects



Figure 11b. White streaking on cereal leaves, caused by Russian Wheat Aphid feeding. Streaking eventually turns purple.
(Photo: Kansas State University)

Need to take action? What action is best?

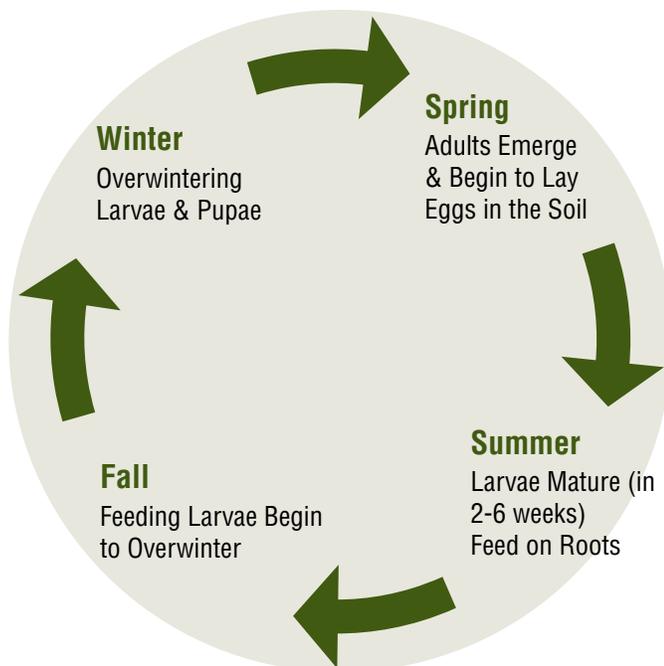
Chemical: There are very effective insecticides available for Russian Wheat Aphid control. Reference the *Crop Protection* guide for the most up to date insecticides. Attempt spraying the outside borders first as this may help prevent their infestation into the field (Shea *et al.*, 2006). Control depends on complete coverage.

Cultural: Control weeds and other volunteer crops to prevent an alternative source of food within the field between seasons. Volunteer wheat and barley host aphids between the harvest of spring crops and the emergence of winter wheat. A variety of wild grasses also can act as hosts to the Russian Wheat Aphid throughout the year (Shea *et al.*, 2006). Maintaining a vigorous crop can also help, as Russian Wheat Aphid tends to thrive in stressed crops.

Wireworms

(Ctenicera aeripennis destructor)

Identification and Life Cycle



Wireworms are the larvae of Click Beetles. They are slender with a hard, jointed body and three sets of legs behind the head. The last body segment is notched. Wireworms range in colour from shiny tan to copper and are 1-4 cm at maturity (Figure 12).

What kind of damage should I be looking for?

- Signs of wireworm feeding include:
- Hollowed out seeds and dead seedlings
- Damaged, but uncut, stems; wilted plants
- Patches of poor plant growth and vigor
- Missing rows (wireworms tend to feed along crop rows)
- Plants with dead centre leaves, but outer leaves are still green

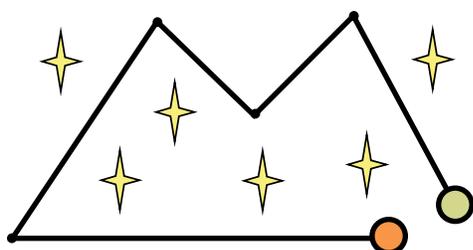
(Syngenta, Wireworm Field Guide)

When should I scout?

Begin scouting for larvae around June, in the crop to precede winter wheat. Continue for the month of June as the maturation of larvae takes 2-6 weeks, and in extreme cases, 2-5 years (Alberta Agriculture and Rural Development, 2012). The wireworms survive for extended periods in the soil, feeding on roots and seeds.

What kind of pattern should I use to scout the field for wireworms?

- Ensure a representative area of the field is covered.
- Dig in areas of crop damage to confirm insect presence.
- Bait balls can be planted randomly throughout the field to attract wireworms underground.
- Bait balls are a good indication of insect presence, but not density (Syngenta, 2011).
- Whole potatoes may also be used as wireworm bait.



How do I know if I need to take action?

If in scouting of the crop preceding winter wheat, wireworms were found, consider use of a seed treatment targeting wireworms. Thresholds for wireworms have not been extensively tested. There is a nominal threshold of 32/m² for cereals (Government of Saskatchewan, 2011). Several 1 m² areas of the field should be examined to a depth of 6" (15 cm) for the presence of wireworms, and an average calculated.



Figure 12. Wireworm. Note three pairs of legs immediately behind the head. (Photo: Ontario Ministry of Agriculture, Food and Rural Affairs)

Need to take action? What action is best?

Chemical: There are no post-emergent insecticide options for wireworm, but pre-emergent insecticides are available in the form of seed treatments. Refer to the *Crop Protection* guide.

Cultural: Avoid planting canola and flax in known infected fields as these are the preferred hosts for the wireworms (Maine Potato IPM Program, 2001). Optimize emergence by aiming for good seed-to-soil contact, seeding at an appropriate time for the production area and seeding 1" deep or less, at the recommended seeding rate. Good agronomics support quicker emergence and healthier stands, which are better able to recover from wireworm damage. See **Seeding Management**.



Figure 13. Click Beetle (Adult Wireworm). (Photo: Ontario Ministry of Agriculture, Food and Rural Affairs)



Disease occurs in crops when there is an interaction between a susceptible host, a virulent pathogen and favourable environmental conditions. The plant (host) must be at a susceptible stage of development and the pathogen must be virulent and be in a stage where it is able to affect the plant. Third, the environment must be suitable for the pathogen to infect the host and the disease to spread. If any one of the three aspects of the “disease triangle” (Figure 1) does not exist, disease will not occur. Control of a disease relies on breaking any one element of the disease triangle.

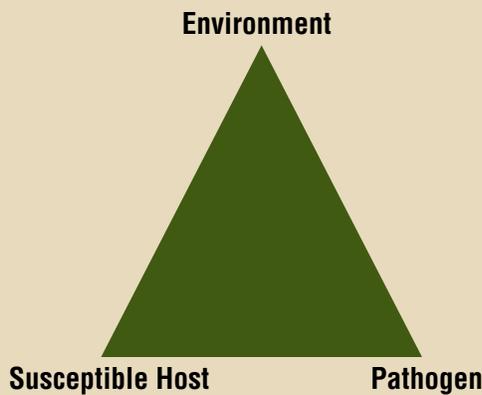


Figure 1. The Disease Triangle.

General Guidelines

- Stressed plants generally perform better under disease pressure than unstressed crops due to the activation of **defense mechanisms**. Crops with lush canopies, having been fertilized well and facing optimal conditions, will be at greater risk to disease losses (D.A. Gaudet, personal communication, 2011).
- **Crop rotations** are a critical component of disease control and a balanced rotation is able to keep disease pressure low.
- **Cleaning and disinfecting** your machinery and bins will reduce spore loads for seed borne diseases.
- Farm saved seed has a higher risk of disease problems than **certified seed**.
- Be wary of a phenomenon called the “**Green Bridge**”. Many pests require a living plant to survive. Ideally, the previous crop will be dead before winter wheat emerges. If green material is still present when the next crop emerges, harbored pests can transfer from the mature areas to the new crop. Ensure that there are definite breaks (10-14 days) in the presence of living materials between crops.

Quick Reference Table for Diseases Found in Winter Wheat

Disease	Potential Damage	Crop Stage Impacted	When to Scout	Resistance	Cultural Control	Chemical Control*
Stripe Rust	Significant yield loss in susceptible varieties, 5-10% if resistant	Juvenile and adult leaves, Kernels	From emergence to 35-45 days before harvest	Pintail Flourish Moats	Control volunteers and hosts in headlands	Spray susceptible varieties at 5% incidence
Snow Mold	Minimal to 100% mortality	2-10 tillers, when the plant overwinters	Check damage at spring melt	None Available	Seed early, fertilize with phosphorous and potassium	None Available
Tan Spot	Possible yield loss	Juvenile and adult leaves	Oval or irregular tan coloured lesions with halos	None Available	Crop rotation	Use an approved foliar fungicide

Diseases

Disease	Potential Damage	Crop Stage Impacted	When to Scout	Resistance	Cultural Control	Chemical Control*
Fusarium Head Blight	10% of kernels infected results in grain rejection	Adult, headed out with filling kernels	Around anthesis of the heads	Emerson	Do not plant on corn stover. Crop rotation	Foliar fungicides can provide suppression
Wheat Streak Mosaic Virus	Minimal to total crop failure	Juvenile leaves	Late fall to early spring	AC Radiant**	Eliminate the "green bridge"	None Available
Common Bunt	Yield loss under high inoculum. Seed quality issue.	Kernels	Heading	Bellatrix	Seed early, sanitize bins and equipment. Crop rotation.	Use an approved systemic seed treatment
Take-All of Wheat	20-30% yield losses under severe disease pressure	Most visible before heading	Before plants head out	None Available	Crop rotation	None Available

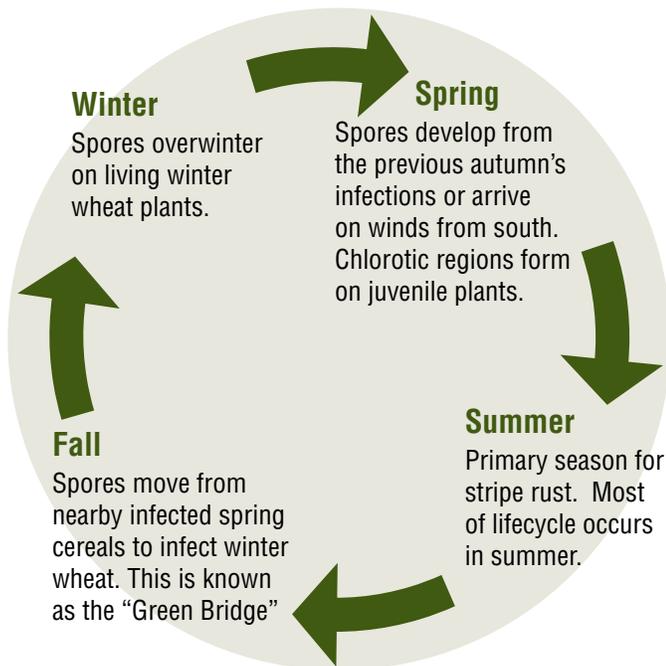
Table 1. Diseases found in Winter Wheat.

*Consult *Crop Protection* guide for approved fungicides.

**AC Radiant is resistant to the Wheat Curl Mite, the vector of Wheat Streak Mosaic Virus.

Stripe Rust (Yellow Rust, Glume Rust) - *Puccinia striiformis*

Identification and Life Cycle



What should I be looking for?

Look for long streaks of rust to orange coloured pustules that erupt from chlorotic regions on the leaves following stem elongation (See Figure 2). The streaks are oriented vertically on the leaves (Bockus *et al.*, 2010). They can also occur in masses of orange flecks. If plants are infected before the winter, the leaves will have flecks of pustules on the lower leaves. Pay close attention when conditions are wet, especially when the soil is saturated and dew is present on crops.

Monitor agricultural websites, such as the USDA, from and for the Pacific Northwest region of the United States for the development of rust in these regions, as rust can travel great distances by air.

Damage can be confused with cereal leaf beetle if the pustules have not emerged yet. [See Insects.](#)



Figure 2. Plants heavily infected with Stripe Rust. (Photo: B. J. Puchalski)

When should I scout?

Scout frequently from emergence to 35-45 days prior to harvest.

Economic thresholds and losses

Losses range depending on cultivar choice and environmental conditions. Resistant varieties have a slow progression of the disease, which will result in a lesser 5-10% yield loss. Resistance in many varieties becomes fully expressed if daytime low temperatures rise above 25°C. Susceptible varieties may lose up to 90% of their leaf surface. Grain yield decreases as greater amounts of leaf area are lost. Less photosynthesis can occur and the plant loses water due to damages to the leaf's epidermal layer.

Apply a foliar fungicide to susceptible varieties at 5% incidence within the field and 5% severity on the leaves

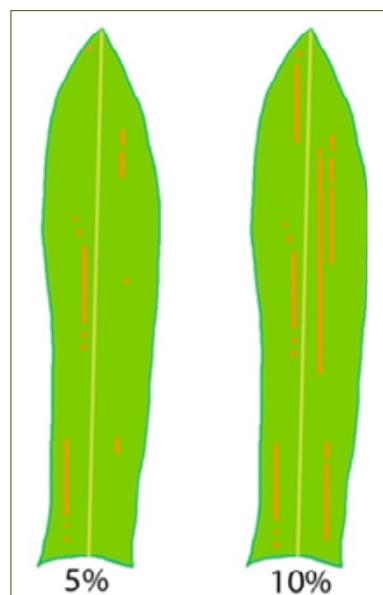


Figure 3. Generalized diagram of what 5% and 10% severity looks like on the wheat leaves.

(Figure 3). Treatment should be applied prior to 5% incidence on the flag leaf.

Need to take action? What action is best?

Resistance: Resistance is available in the winter wheat varieties: Pintail, Flourish and Moats. The resistance of AC Radiant has largely been defeated and the races of rust are shifting rapidly. Check provincial recommendation list to determine if selected variety is resistant.

Cultural: Remove volunteer wheat in the headlands and within the field which can harbor rust. Rust can only persist on live plant tissue and develops only on wheat, not on oats, barley or canola.

Chemical: Foliar fungicides provide good control. Seed treatment can delay the onset of disease in seedlings. Consult the *Crop Protection* guide.

Tan Spot of Wheat (Yellow Leaf Spot) - *Pyrenophora Tritici-Repentis*

Identification and Life Cycle

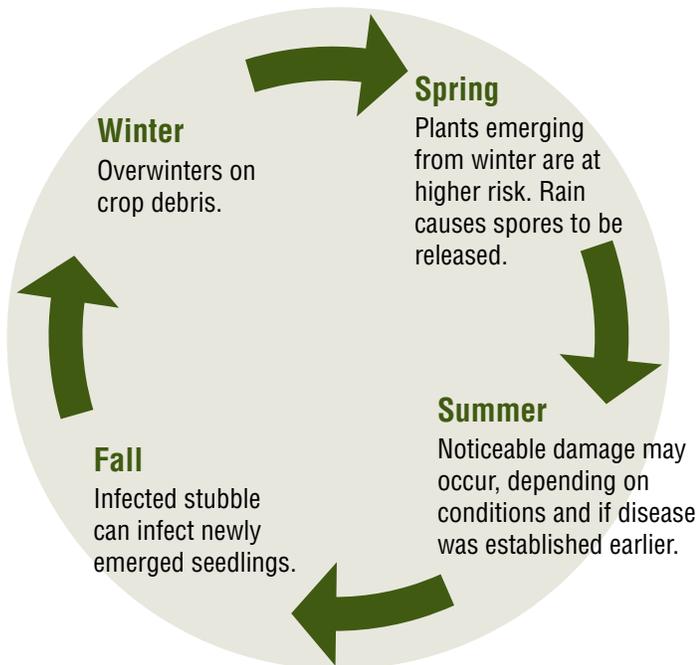


Figure 4. Tan Spot chlorotic regions at 5-10% incidence. (Photo: Western Committee on Plant Diseases)

What should I be looking for?

Tan Spot of wheat first appears as dark brown/black spots on lower leaves. This is followed by the development of irregular tan colored lesions with chlorotic or necrotic halos along the veins (See Figure 4). Lesions can grow up to 12 mm long and, under favorable conditions, these lesions can coalesce to cover the entire leaf (Bockus *et al.*, 2010; S. Strelkov, personal communication, 2011).

When should I scout?

Scout while the plants are still tillering and low to the ground. The disease has difficulty moving vertically and infections will not be as damaging after stem elongation (Strelkov, 2011).

Economic thresholds and losses

Susceptible varieties can lose most of their photosynthetic area (Bailey *et al.*, 2003). The result is reduced yield, poor grain filling and low bushel weight. If the heads are infected, mature kernels may develop red smudge or black point (Bailey *et al.*, 2003).

Need to take action? What action is best?

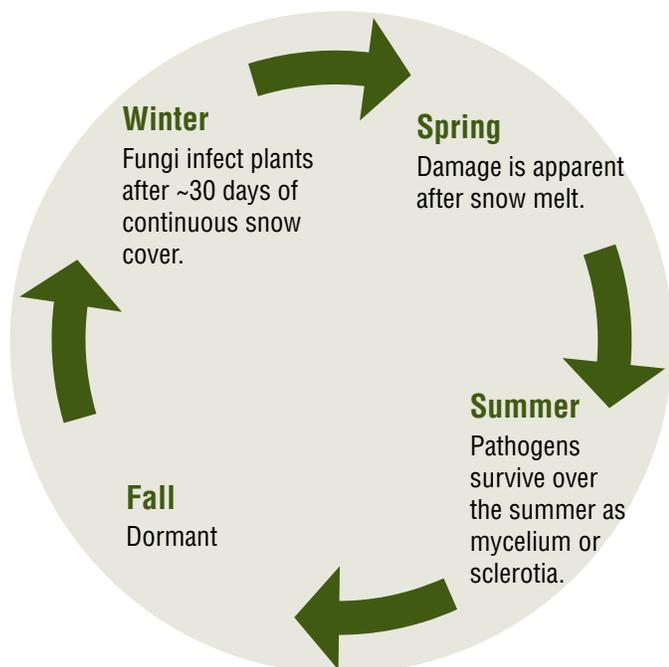
Resistance: As of now, there are no resistant winter wheat varieties available.

Cultural: Crop rotation out of cereals for 2-3 years, reduces disease incidence (Strelkov, 2011). Non-host crops include canola, flax, corn, alfalfa and potatoes. Tan Spot prefers conditions inherent to reduced tillage. Spores can spread from mature fields to new crops via the "green bridge". Infected crop residues may be buried to reduce spread.

Chemical: Foliar fungicides provide good control. As with any chemical treatment, the decision to spray should be based on expected yield gains and the cost of application. Consult the *Crop Protection* guide.

Snow Mold (Winter Crown Rot)

Identification and Life Cycle



What should I be looking for?

Several species of fungi cause snow molds (See Figure 5). Depending on the species, infection can occur by spores that are released by fruiting structures in the autumn or under the snow in winter. In the spring after snow melt, look for irregular, white or brown patches, with white mycelium around the plants (Smith, 1981). A mycelia plaque might also be visible when the outer leaf sheath is removed. Brown or black sclerotia may be present on the leaf surface. Damage can range from thinned rows, to a few isolated spots to the general



Figure 5. Cottony snow mold visible on the field surface (Photo: D.A. Gaudet)

field. Damages are most severe where snow accumulated in drifts and remained for prolonged periods.

When should I scout?

Scout for damages when the snow melts. Scouting through snow is too difficult to attempt. However, signs of snow mold disappear rapidly as temperatures rise and spring rains occur.

Economic thresholds and losses

Snow mold inflicts greater losses the longer a winter wheat crop is under continuous snow cover. The map below indicates continuous snow cover by region. Areas with more days of continuous snow face greater risk in growing winter crops. Snow molds can attack most overwintering crop species including grasses, alfalfa and clover.

Need to take action? What action is best?

Resistance: As of now, there is no resistance available in Canadian winter wheat varieties. There is a correlation between more winter hardy varieties and snow mold resistance, though. So choosing more winter hardy varieties could help against cottony snow mold.

Cultural: Plant winter wheat early. The longer the plants have to establish and cold-harden, the better they will do against both winterkill and cottony snow mold (Smith, 1981) See [Winter Survival](#) for more information. Tight winter wheat rotations should be avoided. A rotation with 3-4 years of spring sown annual crop will lessen inoculum build up.

Chemical: No chemical options are available.

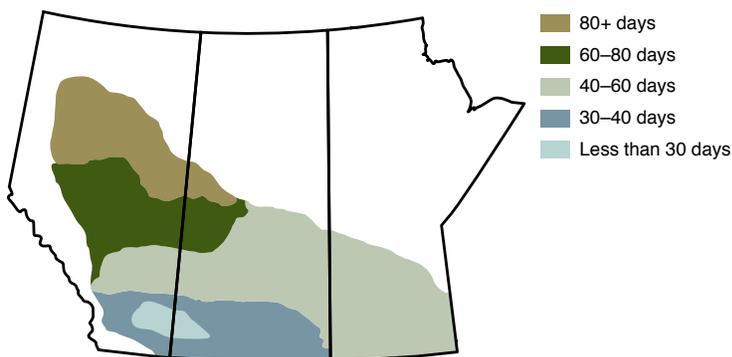
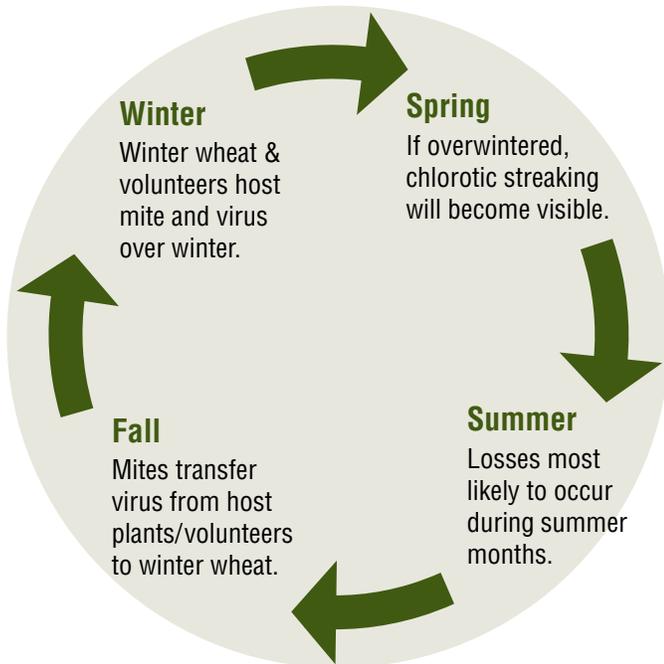


Figure 6. Days of continuous snow cover on the Canadian Prairies.

Diseases

Wheat Streak Mosaic Virus (*Tritimovirus*)

Identification and Life Cycle



What should I be looking for?

The vector for Wheat Streak Mosaic Virus is the wheat curl mite. The virus cannot spread without the mite. See *Insects*. WSMV occurs as chlorotic patches in the field, originating from plants closest to the headlands. Often field margins are most severely affected. Plants are usually stunted, with mottled streaking on the leaves, which eventually yellow completely and die off (Bockus *et al.*, 2010; Peel *et al.*, 1997). The heads will be completely or partially sterile and the grain is typically shriveled.

When should I scout?

Scouting should begin in late fall to early spring (Bailey *et al.*, 2003). Damages become visible soon after growth resumes in the spring.

Economic thresholds and losses

Losses can be from less than 1% to complete crop failure. Damages depend on when infection occurred. Fall infections are the most severe. Economic thresholds are based on controlling the vector, the wheat curl mite. **See *Insects*.**

Need to take action? What action is best?

Resistance: AC Radiant is moderately resistant to the wheat curl mite and, therefore, WSMV.

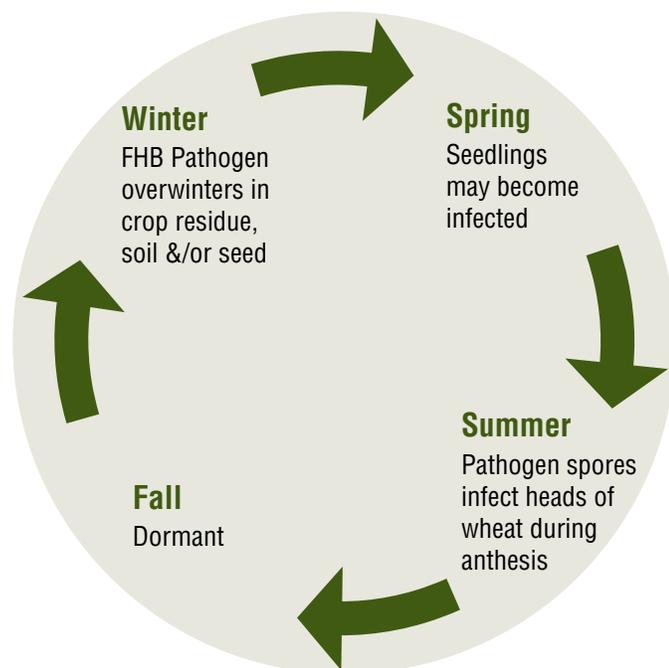
Cultural & Chemical: Control all volunteer host plants. Eliminate the “green bridge”. **See *Insects*.**



Figure 7. Close up of the chlorotic streaking on young leaves. (Photo: B.J. Puchalski)

Fusarium Head Blight (Scab) - *Fusarium Graminearum*

Identification and Life Cycle



What should I be looking for?

The heads of the wheat appear partially bleached and Fusarium Head Blight (FHB) gives the kernels a slight pink or orange colouration (Bockus *et al.*, 2010, Esker 2010). The kernels themselves are shriveled and if severely infected, are chalky in appearance. Blighted heads may be referred to as Fusarium Damaged Kernels or “tombstone” kernels (Figure 8). FHB may look like Take-All but heads are not completely sterile and not completely bleached (Bailey *et al.*, 2003). White, fungal growth on the heads may be present if conditions are moist.

When should I scout?

Infection occurs at head emergence and throughout flowering. The disease is promoted by high rainfall and warm temperatures at flowering. Fungicide should be applied at early flowering to suppress the disease, if fungicide is warranted. Winter wheat often escapes FHB damage, given its early maturity.

Economic thresholds and losses

Yield losses arise from floret sterility and poor grain filling. Grade is also reduced and the grain may contain mycotoxins, making it unsuitable even for feed. Having 10% of your kernels, by weight, damaged by FHB will result in your grain being graded sample. No. 2 Canadian Western Red Winter allows for only 1% and No. 1 only 0.8% FHB damaged kernels (Canadian Grain Commission, 2011).

Need to take action? What action is best?

Resistance: Emerson winter wheat has very good resistance to FHB.

Cultural: Do not plant winter wheat on corn stover. Also avoid planting adjacent to fields with infested cereal or corn residues. Test seed at an accredited laboratory to ensure it is free of detectable levels of *Fusarium graminearum*. In irrigated production situations, manage irrigation as to avoid irrigating during flowering. This minimizes the humid conditions that promote infection. Seeding rates may be increased for a more uniform and shorter flowering period.

Chemical: Foliar fungicides are available for FHB suppression. Refer to the *Crop Protection* guide for product selection and application timing. A foliar fungicide application may be warranted if conditions remain warm and wet after head emergence, the pathogen is established in the area and the projected yield return exceeds the cost of application.

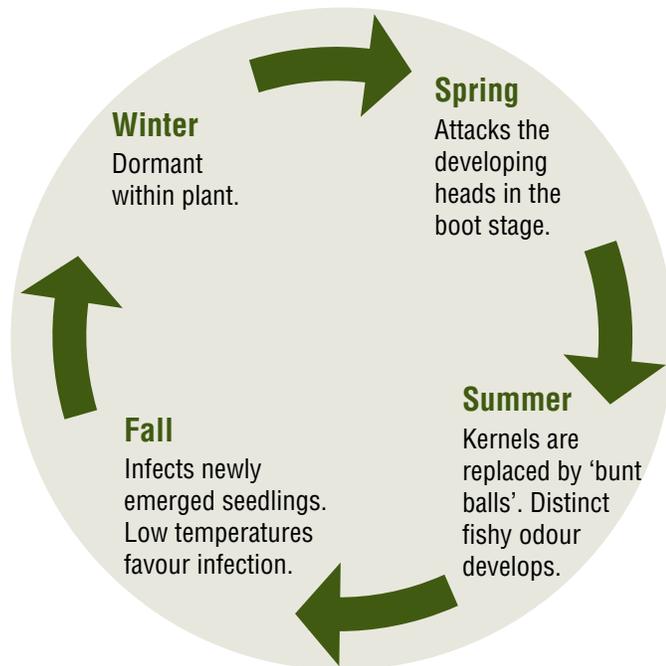


Figure 8. “Tombstone” kernels, characteristic of FHB. (Photo: B.J. Puchalski)

Diseases

Common Bunt (Stinking Smut) - *Tilletia Laevis* and *T. Tritici*

Identification and Life Cycle



What should I be looking for?

Common bunt is characterized by the kernels of wheat being replaced with sooty black teliospore masses, known as bunt balls (Agrios, 2005; Miles *et al.*, 2009). These bunt balls can be broken easily with pressure and smell distinctly of fish (Bailey *et al.*, 2003). Infected tillers are shorter than healthy ones. Look for slightly stunted plants. Bunted heads will swell after precipitation, resulting in black heads becoming visible (Figure 9).

When should I scout?

This disease is seed borne and infects plants right at germination. The fungus remains inactive until heads begin to form on infected plants. Bunt balls replace kernels.

Economic thresholds and losses

Common bunt can cause significant yield losses, provided there is a large inoculum load present. Yield loss is equivalent to the percentage of infected tillers (Bailey *et al.*, 2003). Losses due to downgrading can be significant. Even low levels of bunt infection (1% or less by weight) can be problematic. Bunted grain is primarily rejected due to odour (Bailey *et al.*, 2003). Further, bunted grain may contaminate clean grain and handling facilities, so delivery may be refused all together.

Need to take action? What action is best?

Resistance: The winter wheat variety Bellatrix is moderately resistant.

Cultural: Sanitation of equipment and bins that come in contact with common bunt helps to limit disease spread. Contaminants can be present in combines and augers and can be decreased by harvesting and processing non-host crops (Bailey *et al.*, 2003). The chances of disease development are increased if seeds are planted deep and the soil is cool (Agrios, 2005). Use certified seed. Never plant bunted seed, as seed cleaning and seed treatments will not be able to sufficiently overcome the disease. Soil borne bunt will persist for one year, so crop rotation will reduce inoculum loads. Contaminated grain can be composted. Burning and spreading it is not advisable.

Chemical: Common bunt can be adequately controlled through seed treatment fungicides. Systemic fungicides will perform better than protectants, since control will carry into winter. Refer to the *Crop Protection* guide.



Figure 9. A bunt ball compared to healthy grain kernel. (Photo: CPS Collection)

Take-All (*Gaeumannomyces Graminis*)

Identification and Life Cycle

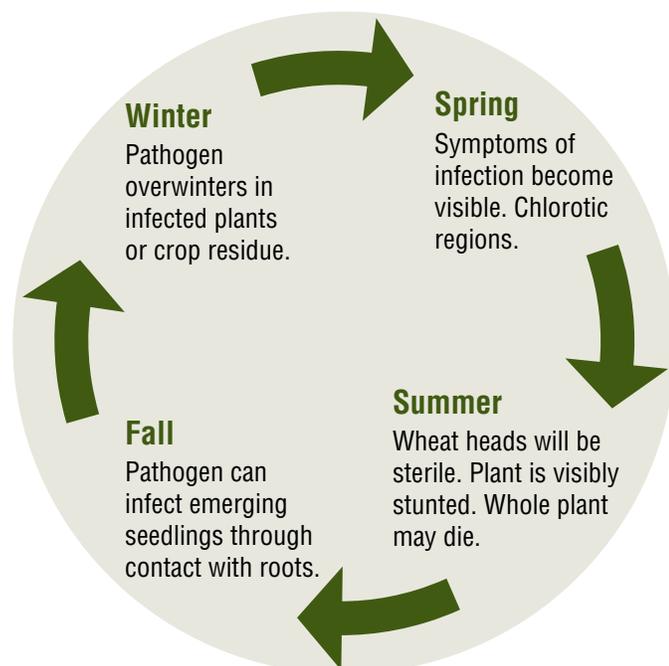


Figure 10. Roots characteristic of Take-All. (Photo: M. McMullen, NDSU)

What should I be looking for?

Uproot the plant and check for shoe polish black roots and crowns (Figure 10). Infected plants are easy to pull up as roots may have entirely rotted. Diseased plants are stunted with visibly white heads, occurring in evident patches. The whiteheads are also sterile with shriveled kernels (Agrios, 2005). Thick, brown runner hyphae may also be present and a thick, dark mat of mycelium will be found between the lowest outer sheath and the culm (Bockus *et al.*, 2010).

When should I scout?

Scout for disease presence at stem elongation. Control measures must be enacted in the next season. Infection is favoured by soil temperatures from 12-20°C and high soil moisture.

Economic thresholds and losses

Low levels of infection may go undetected and have little impact on yield. However, yield losses of 20-30% can occur under significant disease pressure. The intensity of losses increases under continuous cropping.

Need to take action? What action is best?

Resistance: No cultivars are resistant.

Cultural: A crop rotation of two years out of wheat is the most effective control option, with a rotation into legumes or other dicots preferable (Lipps, 2011). Nitrogen fertilizer regime also matters, with nitrates favouring Take-All development and ammonium and slow release forms inhibiting it (Bockus *et al.*, 2010). If a crop is suffering from any nutrient deficiency, it will be more prone to Take-All infection. Sufficient levels of phosphorous will favour strong root development and decrease disease severity. Slightly acidic soils also hinder disease development. It is important to control grassy weeds, such as quackgrass, which can be infected and increase the inoculum load (Lipps, 2011).



Winter wheat's ability to survive a winter comes from its ability to cold acclimate or "harden off" before a cold event. This ability is a reflection of the many factors that are at work both inside and outside the plant. Some factors producers are able to control, but others cannot be managed, such as the amount of snowfall in a particular winter. Knowing what these factors are allows a producer to properly react and adjust, mitigating potential damages.

While all tissues in the plant must acclimate to the cold individually (roots, leaves and meristematic crown tissue (Fowler, 1982)), it is the survival of the crown tissue that is most critical to the survival of the plant as a whole (Skinner *et al.*, 2008). Management practice recommendations are based on increasing winter survival of the meristematic crown tissue.

Weather/Climate/Uncontrollable Factors

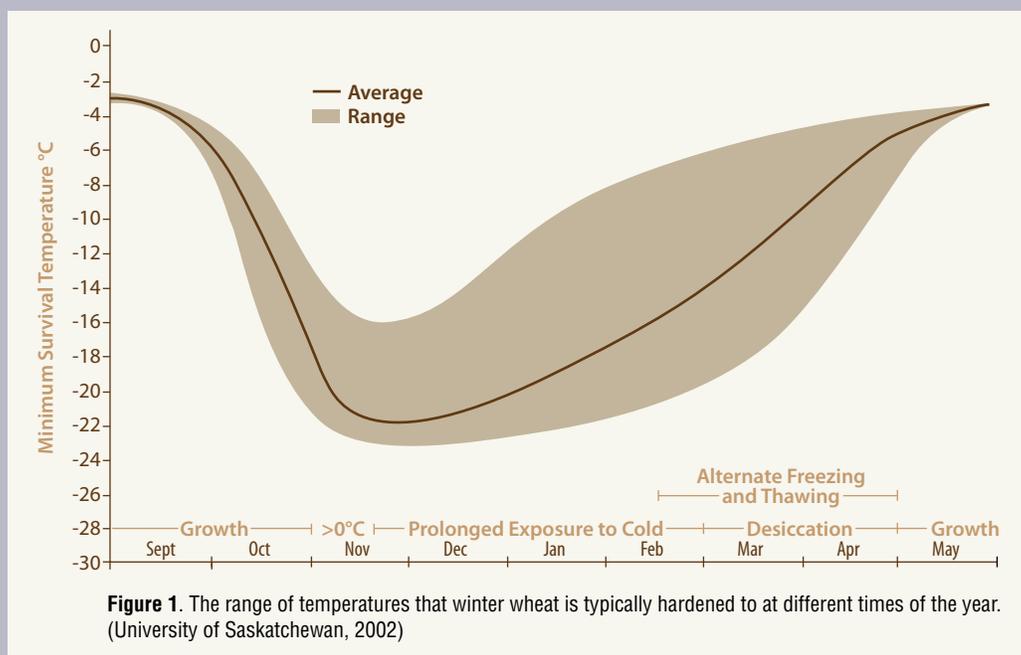
Winter wheat needs to be able to gradually harden off before a major cold event. For example, the crop is unlikely to survive the soil temperature dropping below -6°C before the end of September (Figure 1). The hardening off process begins when the temperature drops below 9°C (Fowler, 1982), and continues as the temperature decreases.

The speed of this acclimation is dependent upon the crown temperature; the colder the crown of the plant, the faster it hardens off (Fowler, 1982).

Winter wheat is best adapted to surviving the winter if it is between the three leaf to first tiller stage (Stage 2 – Stage 4 on the staging diagram). Any more or less developed than this will result in a decrease in winter survival capacity.

Cold tolerance is dynamic, however, and it can be lost if temperatures increase above the previous minimum temperature that the plants had hardened to. If the crowns of the plant are exposed to warmer temperatures for as little as 50 hours, the cold hardiness of the plant can be decreased substantially (Fowler, 1982). The loss of hardiness has two major implications:

- If the temperature of the crown drops again below the current level of winter hardiness, injury will occur.
- Once a crop loses winter hardiness, not only will it never reach the original level of winter hardiness, but it will become more prone to dehardening and will deharder faster the next time an increase in temperature over the minimum survival temperature occurs. See Example 1.



Winter Survival

Example 1:

Crop originally hardened to -19°C . Temperatures rise to -15°C for a prolonged period. This results in the crops new minimum survival temperature becoming -15°C , a loss of 4°C of winter hardiness. If it took 80 hrs for the loss of winter hardiness to occur, should the temperature increase again, this time past the new minimum of -15°C , crop dehardening will occur at a faster rate, (i.e. the crops will lose more degrees of hardiness in a shorter time, perhaps 60 or 70 hours to lose 4°C of hardiness, instead of the 80 hours that it took the first time). (Fowler, 1982; Hayhoe, 2003).

Snow cover is essential for winter wheat survival, not only to insulate the crop from severely cold temperatures, but to also protect it against rises in temperature to maintain its cold hardiness (Hayhoe, 2003). See **Winter Survival: Seeding Management**.

Cold hardening can be reduced and extreme temperature swings can adversely affect the survival of winter wheat. For instance, if Chinooks are severe enough to melt off the snow cover and/or warm the soil temperature above the minimum hardened temperature, they can decrease the hardiness of the crop, setting it up for injury when the temperatures drop again. That being said, Chinooks can be a valuable tool in keeping the soil temperature within the minimum cold hardiness temperature of the crop if they are not too severe.

Chinooks can be especially damaging from December to February, the time when the crop is most vulnerable to winter kill (Figure 1) (Fowler, 1982; Hayhoe, 2003). This time frame is when the crop is most vulnerable to damage from freezing, because the soil has lost most to all of the heat it had from the summer and fall.

Freeze/thaw cycles can also induce winterkill if the snow cover melts and the resulting water sits on the field. If the water remains for an extended period of time or freezes on the crop, anaerobic conditions are created and crop injury can result (Mackey, 2009).

Figures 2 and 3 are maps of the prairies and the percent chance of winterkill with Norstar as a result of weather. Not all areas of the prairies are as conducive to growing winter wheat as others. Winterkill severity ranges from under 10% to over 50% and the likelihood of these damages range from 5% to 25%. These prob-

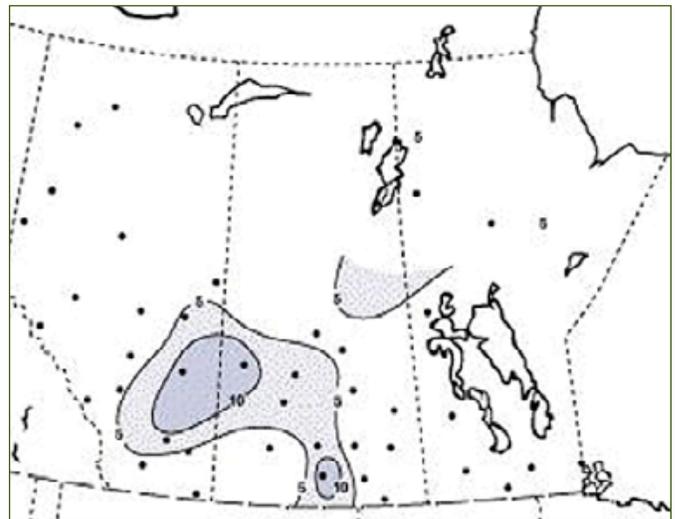


Figure 2. The percent chance that more than 50% of direct seeded Norstar winter wheat would be killed. (University of Saskatchewan, 2002)

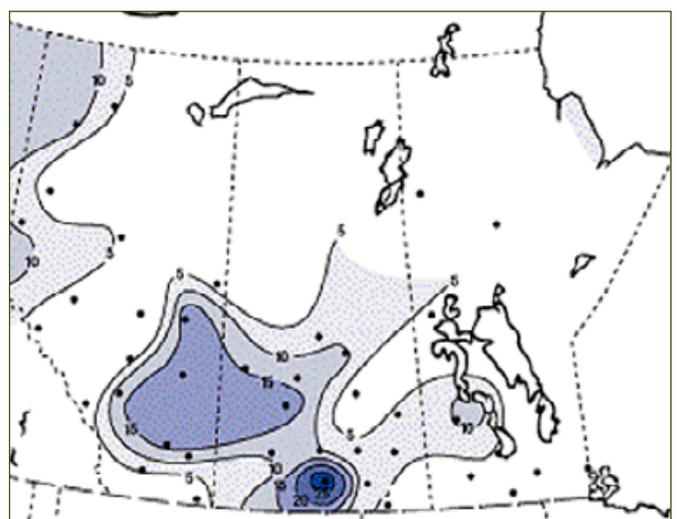


Figure 3. The percent chance that more than 10% of direct seeded Norstar winter wheat would be killed. (University of Saskatchewan, 2002)

abilities should be factored in to a producer's decision to plant winter wheat. When planting any crop for the first time, producers should begin with a relatively small acreage, and determine whether it is suitable for their region. The following section will address management practices that can minimize the risk of crop damage over the winter months.

Controllable Factors

The factors that are under a producer's control are largely management strategies that work to help the plant position itself to successfully survive the winter.

Seeding Management and Rotation

The most significant controllable factor is to seed into standing stubble. As mentioned, adequate snow cover is critical for crop survival, and stubble catches the snow, holding a relatively even snowpack over the crop.

Additionally, stubble affects the crystalline structure of the snowpack, allowing it to breathe and keep the temperature near the soil from getting too warm. This helps to prevent anaerobic conditions from occurring at the soil surface, increasing winter survival. Canola stubble is ideal, because it is tall but shatters easily, therefore decreasing potential problems with residue plugging the seed drill. See [Seeding Management](#).

Seeding date is critical because immature plants will not have sufficient energy stores to harden off and survive the winter (Beres, 2010). Inversely, crops seeded too early grow too large and may lose some of their plasticity to survive and recover from the winter (Fowler, 1982). See [Seeding Management](#) and [Calendar](#).

Other stubbles that winter wheat can be planted into include wheat, oats, rye, barley, peas and lentils. However it should be noted that pulse stubbles do not capture snow as well as the other crops, making pea stubble a viable option only in northern regions (Zones B&C) of Alberta. See [Crop Rotation](#).

Variety Choice and Selection

Not all varieties have the same level of winter hardiness, and as a result, some varieties are better suited for certain areas than others. The winter survival require-

ment can vary within a province (see Figures 2 and 3); local climatic conditions should be taken into account. See [Seeding Management](#).

Depending on where a variety was developed, it may be better suited to certain areas and conditions. (i.e. western prairies vs. eastern prairies). Furthermore, varieties differ in their resistance to diseases and insects. See [Seeding Management: Variety Selection](#).

Fertility

Winter survival can also be affected by affected nitrogen and phosphorus fertilization. Phosphorus fertilization increases plant survival by increasing the health of the roots of the plants (including the crown region). The crown is the most critical part of the plant in regard to winter survival, and the healthier the crown tissues are going into the winter, the greater the chance of the crop overwintering successfully. Figure 4 shows the relationship between phosphorus fertilization and the corresponding increase in winter survival. See [Soil Fertility](#).

If high amounts of nitrogen are plant accessible in the fall, winter survival can be adversely affected (Grant, 1984, Gusta *et. al.*, 1998). Nitrogen encourages the plant to grow quickly, resulting in lush growth with large cell sizes. When air temperatures drop, ice forms in the large water filled cells and can cause cell, and eventually, plant death. See [Soil Fertility](#).



Figure 4. The effect of phosphorus fertilization on the winter survival of winter wheat. (University of Saskatchewan, 2002)

Winter Survival

Large cells mean the plant must produce more solutes in order to lower the freezing point of the solution in the cell. This problem is compounded by the fact that the plant is more focused on lush growth than on winter hardening under high nitrogen conditions. Ideally, plants grow slowly, resulting in small cell sizes, and plants focusing on hardening off rather than vegetative growth. See Figure 5 for the negative relationship between plant available nitrogen and winter wheat survival.

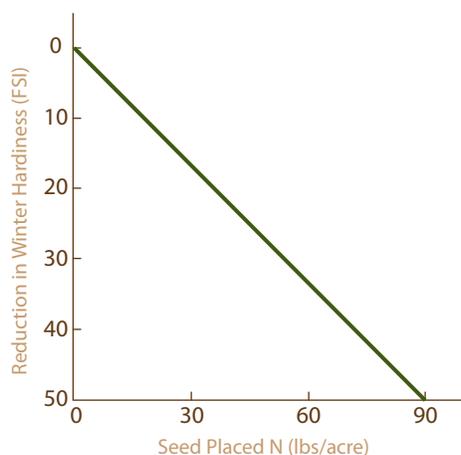


Figure 5. The effect of nitrogen fertilization on the winter survival of winter wheat. (University of Saskatchewan, 2002)

Assessing Winter Survival

One of the most challenging aspects of growing winter wheat is determining whether it survived the winter. If plants have brown, dead leaves they may not necessarily be dead. Conversely, if plants immediately turn green in colour in spring, this does not necessarily mean the plant made it through winter (Fowler, 1982). Crown tissue should be assessed to determine if the plant made it through the winter.

One test to determine whether plants made it through the winter is to dig several plants out during a warm day in early spring and place them in a warm room on a damp towel. Healthy plants will re-grow new white roots from the crown, whereas damaged tissues will turn brown. If plants are dug out on a cold day, they could be damaged, giving a false positive for winter kill.



Figure 6. A healthy winter wheat plant in the spring. Note: white crown tissue (Photo: Ducks Unlimited Canada)

Keeping records of what areas were lacking snow cover, as well as any adverse weather patterns that developed over the winter can help a producer determine what areas would be most susceptible to winter kill.

Winter wheat has a large capacity to produce tillers, which gives it the ability to recover and re-grow through damaged areas. Rather than tilling the winter wheat under, it may be more advantageous to allow the plants to recover and produce tillers. See Table 1 Improved plant recovery can be achieved through top dressing of nitrogen, early control of weeds and, when required, fungicide and insecticide applications.

Postponing the decision to terminate the stand and constant monitoring in the spring will give the producer a more accurate look at the actual condition of the stand. This approach will also allow for the establishment of benchmarks to determine the progress of the stand.

Wheat Stand (plants/square foot)	Yield (bu/ac)
7.7	47
13.3	55
19.0	58
23.0	59
25.5	59
30.4	60

Table 1. Plants/square foot and the Resulting Yield (Lafond and Gan, 1999)

Growth Stages of Winter Wheat

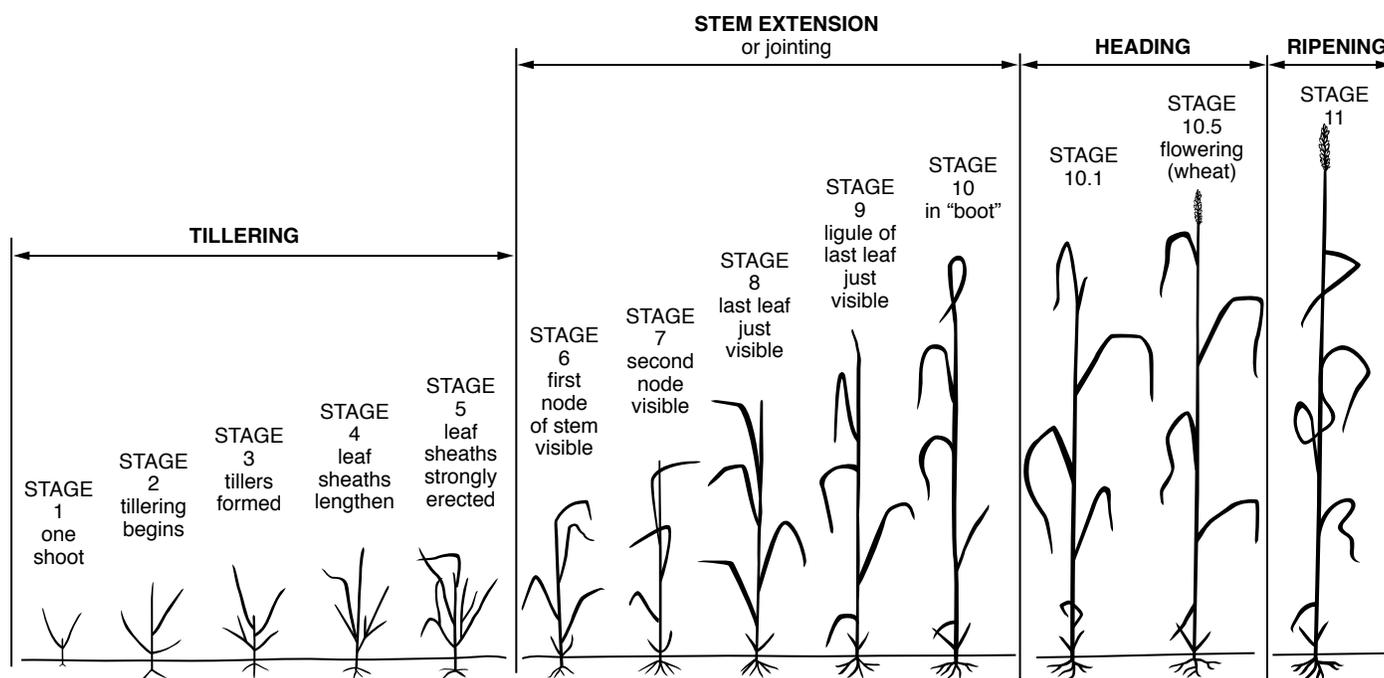


Figure 7. Winter wheat development as described by the Feekes scale of plant growth

Stage	According to Large (1954) cereals develop as follow Feekes Growth Stages
Tillering	
1	One shoot (number of leaves can be added) = «braiding»
2	Beginning of tillering
3	Tillers formed, leaves often twisted spirally. In some varieties of winter wheats, plants may be "creeping" or prostrate
4	Beginning of the erection of the pseudo-stem, leaf sheaths beginning to lengthen
5	Pseudo-stem (formed by sheaths of leaves) strongly erected
Stem Extension	
6	First node of stem visible at base of shoot
7	Second node of stem formed, next-to-last leaf just visible
8	Last leaf visible, but still rolled up, ear beginning to swell
9	Ligule of last leaf just visible
10	Sheath of last leaf completely grown out, ear swollen but not yet visible

Winter Survival

Heading	
10.1	First ears just visible (awns just showing in barley, ear escaping through split of sheath in wheat or oats)
10.2	Quarter of heading process completed
10.3	Half of heading process completed
10.4	Three-quarters of heading process completed
10.5	All ears out of sheath
Flowering (Wheat)	
10.5.1	Beginning of flowering (wheat)
10.5.2	Flowering complete to top of ear
10.5.3	Flowering over at base of ear
10.5.4	Flowering over, kernel watery ripe
Ripening	
11.1	Milky ripe
11.2	Mealy ripe, contents of kernel soft but dry
11.3	Kernel hard (difficult to divide by thumb-nail)
11.4	Ripe for cutting. Straw dead

Table 2. Feekes Growth Stages



- Agrios, George N. *Plant Pathology* 5th Edition. Oxford: Academic Press, 2005. Print.
- Alberta Agriculture and Rural Development. "Crop Enterprise Cost and Return Calculator." Government of Alberta. February 2003a. Web. Accessed October 2011. <<http://www.agric.gov.ab.ca/app24/costcalculators/crop/getsoilzone.jsp>>
- Alberta Agriculture and Rural Development. "Using the 1000 kernel weight for calculating seeding rates and harvest losses." Government of Alberta. August 2007. Web. Accessed October 2011. <[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex81](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex81)>
- Alberta Agriculture and Rural Development. *Crop Protection* 2011. Edmonton: Government of Alberta, 2011a. Print.
- Alberta Agriculture and Rural Development. "Winter Injury, Winter Kill." Government of Alberta. January 2011b. Web. Accessed September 2011. <[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/prm2445](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/prm2445)>
- Alberta Agriculture and Rural Development. "Agroclimatic Atlas of Alberta: Agricultural Climate Elements." Government of Alberta. August 2009. Web. Accessed November 2011. <[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/sag6301](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag6301)>
- Alberta Agriculture and Rural Development. "Grasshopper Management." Government of Alberta. March 2003b. Web. Accessed November 2012. <[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex6463](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex6463)>
- Alberta Agriculture and Rural Development. "Soil Group Map of Alberta." Government of Alberta. September 2002. Web. Accessed November 2011. <<http://www1.agric.gov.ab.ca/soils/soils.nsf/soilgroupmap?readform>>
- Alberta Agriculture and Rural Development. "2,4-D amine 500 - Product Information." Government of Alberta. 1995. Web. Accessed October 2011. <<http://www.agric.gov.ab.ca/app23/getproductinfo?id=128&view=plain>>
- Alberta Agriculture and Rural Development. "Alberta Fertilizer Guide." Government of Alberta. June 2004a. Web. Accessed November 2011. <[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex3894/\\$file/541-1.pdf?OpenElement](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3894/$file/541-1.pdf?OpenElement)>
- Alberta Agriculture and Rural Development. "Fertilizer application and placement." Government of Alberta. June 2004b. Web. Accessed November 2011. <[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex621](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex621)>
- Alberta Agriculture and Rural Development. "Soil Sampling and Testing." Government of Alberta. June 2004c. Web. Accessed November 2011. <[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex1341](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1341)>
- Alberta Agriculture and Rural Development. "Wheat Stem Sawfly." Government of Alberta. April 2008. Web. Accessed November 2012. <[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex3513?opendocument](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3513?opendocument)>
- Alberta Agriculture and Rural Development. "Prairie Grain Wireworm." Government of Alberta. November 2012. Web. Accessed November 2012. <[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/prm2509](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/prm2509)>
- Aubinet, M., Moureaux, C., Bodson, B., Dufranne, D., Heinesch, B., Sulea, M., Vancutsem, F., and Vilret, A. "Carbon sequestration by a crop over a 4-year sugar beet/winter wheat/seed potato/winter wheat rotation cycle." *Agricultural and Forest Meteorology* 149.3 (2009): 407-418.
- Bailey, K.L., Gossen, B.D., Gugel, R.K., and Morrall, R.A.A. Eds. *Diseases of Field Crops in Canada*. The Canadian Phytopathological Society, 2003.
- Barker, Bruce. Tips for Better Winter Wheat Production. *Top Crop Manager*, July 2001. pp. 38-40.
- BASF Canada Inc. "Technology Sheet." *Heat* 2010. 1-2. <https://agro.basf.ca/West/Products/Related_Files/HEAT_TechnicalBulletin.pdf>
- Beres, B.L., Clayton, G.W., Harker, K.N., Stevenson, F.C., Blackshaw, R.E., and Graf, R.J. "A Sustainable Management Package to Improve Winter Wheat Production and Competition with Weeds." *Agronomy Journal* 102.2 (2010a): 649-657.
- Beres, B.L., Carcamo, H.A., Weaver, D.K., Dossall, L.M., Evenden, M.L., Hill, B.D., McKenzie, R.H., Yang, R., and Spencer, D.M. "Integrating the building blocks of agronomy and biocontrol into an IPM strategy for wheat stem sawfly." *Prairie Soils and Crops Journal* 4 (2011): 54-65.
- Beres, B.L., Harker, K.N., Clayton, G.W., Bremer, E., Blackshaw, R.E., and Graf, R.J. "Weed Competitive Ability of Spring and Winter Cereals in the Northern Great Plains." *Weed Technology* 24.2 (2010b): 108-116.

References

- Beres B.L., Bremer E., Blackshaw R.E., Clayton G.W., Harker K.N., O'Donovan J.T., and Smith A.M. "Influence of N Fertilization Method on weed growth, grain yield and protein concentration in no till winter wheat." *Canadian Journal of Plant Science* 90.5 (2010): 637-644.
- Beres, B., Clayton, G., Harker, N.K., Blackshaw, R., and Graf, R. "Influence of seeding rate and cultivar on winter wheat establishment, yield, and weed competitiveness in southern and central Alberta, Canada." *Agriculture and Agri-Food Canada*. 2007.
- Bockus, William W., Bowden, Robert L., Hunger, Robert M., Morrill, Wendell L., Murray, Timothy D., Smiley, Richard W. *Compendium of Wheat Diseases and Pests* 3rd Edition. Minnesota: APS Press, 2010. Print.
- Bradshaw, J., and Wright, B. "Grasshopper Management In Emergent Winter Wheat." *Nebraska Crop Production and Pest Management Information*. Nebraska CropWatch. August 2011. Web. Accessed March 2013.
< <http://cropwatch.unl.edu/web/cropwatch/archive?articleID=4628843> >
- Bubar, C.J., Hall, L.M., and McColl, S.J. *Weeds of the Prairies*. Alberta Agriculture, Food and Rural Development, 2000. Print.
- Campbell, C. A., Selles I, F., Zentner, R. P., McLeod, I.G., and Dyck, F. B. "Effect of seeding date, rate and depth on winter wheat grown on conventional fallow in S.W. Saskatchewan." *Canadian Journal of Plant Science* 71 (1991): 51-61.
- Canadian Grain Commission. "Official Grain Grading Guide." Government of Canada. August 2012. Web. Accessed November 2, 2011.
<<http://www.grainscanada.gc.ca/oggg-gocg/ggg-gcg-eng.htm>>
- Canadian Wheat Board. 2011. Web. Accessed October 2011. < <http://www.cwb.ca/public/en/>>
- Canadian Wheat Board. 2011a. Web. Accessed October 2011.
<<http://www.cwb.ca/public/en/library/publications/popups/pdf/western/toc/2011/gfwc.pdf>>
- Canadian Wheat Board. "2011-2012 Early Payment Options for wheat, durum and barley." 2011b. Web. Accessed October 2011.
<http://www.cwb.ca/public/en/farmers/producer/1112early/pdf/guide_complete.pdf>
- Canadian Wheat Board. "Historical Payments [Dollars per bushel]:" 2011c. Web. Accessed October 2011.
<<http://www.cwb.ca/public/en/farmers/payments/historical/>>
- Canadian Wheat Board. "PRO 2011-2012 September 22, 2011." 2011d. Web. Accessed October 2011.
<http://www.cwb.ca/public/en/farmers/outlooks/PRO/pdf/1112/sep22_1112.pdf>
- Canadian Wheat Board. "Strong grain values continue in first CWB PRO for 2011-12:" 2011e. Web. Accessed October 2011.
<http://www.cwb.ca/dom/db/contracts/pool_return/pro.nsf/Web-PRPub/2011_20110228.html?OpenDocument&CropYr=2011-12>
- Canadian Wheat Board. "Weaker Market Outlooks Pressure Wheat and Durum Values in CWB PRO for 2011-12:" 2011f. Web. Accessed October 2011.
<http://www.cwb.ca/dom/db/contracts/pool_return/pro.nsf/WebPRPub/2011_20110922.html?OpenDocument&CropYr=2011-12>
- Canadian Wheat Board. "Grain values decline in latest CWB outlook for 2011-2012:" 2011g. Web. Accessed October 2011. <http://cwb.ca/dom/db/contracts/pool_return/pro.nsf/WebPRPub/2011_20111027.html?OpenDocument&CropYr=2011-12>
- Carcamo, Hector. *Overview of Winter Wheat*. Agriculture and Agri-Food Canada. 2011. Print.
- Cullen, Eileen. 2010. "Insect Diagnostics." *Winter Wheat Workshop*. University of Wisconsin Extension. 8 March 2010.
- Dow Agro Sciences LLC (1998-2011). "PrePass XC Herbicide." 2011. Web. Accessed October 2011.
<http://www.dowagro.com/ca/prod/prepass_xc.htm>
- Doyle, R. 2011. "Making the Sale." *Canadian Wheat Board Combine to Customer Alumni Conference*. Saskatoon, Saskatchewan. Jan 4-6, 2011.
- Ducks Unlimited Canada. "Agronomics." 2011. Web. Accessed October 2011. <<http://yourland.ducks.ca/cereals/index.html>>
- Ducks Unlimited Canada - Winter Cereals. "Successful Winter Wheat Seeding." 2011. Web. Accessed October 2011.
<www.wintercereals.ca/docs/seeding.pdf>
- Ducks Unlimited Canada. "Variety Selection." 2007. Web. Accessed October 2011. <<http://www.wintercereals.ca/agro-variety-selection.html>>

- Ducks Unlimited Canada - Winter Cereals. 2011. Web. Accessed October 2011. <www.wintercereals.ca>
- Ducks Unlimited Canada - Winter Cereals. "Winter Wheat and Marketing Flexibility." 2011. Web. Accessed October 2011. <http://www.wintercereals.ca/documents/FS_WWMarketing_091210FINAL_000.pdf>
- Ducks Unlimited Canada - Winter Cereals. "Growing Winter Wheat - Statistics." 2011. Web. Accessed October 2011. <<http://www.wintercereals.ca/growing-statistics.html>>
- Dunn, R. and Fleury, D. 1998. "Fact Sheet: Direct Seeding: Direct Seeded Winter Wheat." Alberta Agriculture Food and Rural Development. Agdex 112/22-1. Web. Accessed October 2011. <[www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex106?opendocument](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex106?opendocument)>
- DuPont Canada. "Out-of-Crop Weed Control Manual" 2009. Web. Accessed March 2013. <http://dupontsearch.asp.dupont.com/search?ss=&site=dupont_canada&client=en_US&output=xml_no_dtd&proxystylesheet=en_US&q=manual&ctl00%24SiteSearch%24SiteSearch2Button=>>
- Esker, P. "Disease Diagnostics and Foliar Fungicides." University of Wisconsin. October 21, 2011. Lecture.
- Food and Agriculture Organization of the United Nations. "How to Feed the World in 2050." November 2009. Web. Accessed October 2011. <http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf>
- Fowler, D.B. "Accipiter hard red winter wheat." Canadian Journal of Plant Science 91 (2011): 363-365.
- Fowler, D.B. "Date of seeding, fall growth, and winter survival of winter wheat and rye." Crop Development Center, University of Saskatchewan 42.6 (1982): 1060-1063.
- Fowler, D.B. "Peregrine hard red winter wheat." Canadian Journal of Plant Science 90 (2010): 853-856.
- Fowler, D.B., Graham, M.L., and Ashford, R. "Influence of Fall Applied 2,4-D and MCPA Amine on Cold Hardiness and Other Agronomic Characteristics of Winter Wheat and Rye." Canadian Journal of Plant Science 66. (1987): 837-843.
- Fowler, D.B., Lafond, G.P. and Loepky, H. "Seeding depth in relation to plant development, winter survival and yield of no-till winter wheat." Agronomy Journal 81.1 (1989): 125-129.
- Fryza S., and Fabio, M. "How Do Canadian Wheat Producers' Make Marketing Decisions?" Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO. April 18-19, 2011.
- Garland-Campbell, K.A., and Skinner, D.Z. "The relationship of LT50 to prolonged freezing survival in winter wheat." Canadian Journal of Plant Science 88. (2008): 885-889.
- Gaudet, D. A. Personal Communication. 2011.
- Geddes, E. 2011. "Combine to Customer Short Course." Canadian Wheat Board Combine to Customer Alumni Conference. Saskatoon, Saskatchewan. Jan 4-6, 2011.
- Glogoza, Phillip. "Fact Sheet: Cereal Leaf Beetle." North Dakota State University Extension Service. May 2002. Print.
- Government of Saskatchewan - Agriculture. "Economic Thresholds of Insect Pests." 2011. Web. Accessed March 2013. <<http://www.agriculture.gov.sk.ca/Default.aspx?DN=a4d74761-d683-4e68-8c5e-60f592bc4ee8>>
- Government of Saskatchewan - Agriculture. "Chemical Weed Control in Direct Seeding Systems." March 2004. Web. Accessed October 2011. <<http://www.agriculture.gov.sk.ca/Default.aspx?DN=668d091c-b5e0-48c9-a85c-7434d653bec2>>
- Government of Saskatchewan - Agriculture. "Wheat Stem Sawfly." December 2006. Web. Accessed November 2012. <<http://www.agriculture.gov.sk.ca/Default.aspx?DN=f9423245-0426-441b-b49b-4b2bf4c8f75c>>
- Grain Research and Development Center. 2009. Web. November 2011. <http://www.wheatcurlmite.org/index.php?option=com_frontpage&Itemid=1> Accessed
- Graf, R.J. "Winter Wheat, One Plant Breeder's Perspective." University of Alberta. 2011. Presentation.
- Graf, R.J., Briggs, K.G., and Sieusahai, G. "Choosing the Best Crop Varieties for Your Farming Operation." University of Alberta. Edmonton, AB. 20 October 2011. Class Lecture.

References

- Grant, C.A., and Stobbe, E.H. "The effect of n and p fertilization on winter survival of winter wheat under zero-tilled and conventionally tilled management." *Canadian Journal of Soil Science* 64. (1984): 293-296.
- Green, M. 1998. "Fact Sheet: Direct Seeding: Anhydrous Ammonia Use at Seeding." Alberta Agriculture Food and Rural Development. Web. Accessed November 1, 2011.
<[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex3444/\\$file/519-20.pdf?OpenElement](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3444/$file/519-20.pdf?OpenElement)>
- Gusta, L.V., O'Conner, B.J., and Lafond, G.L. "Phosphorus and nitrogen effects on the freezing of norstar winter wheat." *Canadian Journal of Plant Science* 79. (1998): 191-195.
- Hayhoe, H.N., and Andrews, C.J. "Analysis of spatial and yearly variation in winter survival of winter wheat." *International Journal of Biometeorology* 42 (1999): 189-200. Print.
- Hayhoe, H.N., Lapen, D.R., and Andrews, C.J. "Using weather indices to predict survival of winter wheat in a cool temperature." *International Journal of Biometeorology* 47 (2003): 62-72. Print.
- Hein, G. L., Campbell, J. B., Danielson, S. D., and Kalisch, J. A. Management of the Army Cutworm and the Pale Western Cutworm. University of Nebraska-Lincoln Extension, Institute of Agriculture and Natural Resources. 2006. Print.
- Hodgson, E.W., and Karren, J.B. 2008. "Fact Sheet: Russian Wheat Aphid." Utah Pests. Print.
- International Maize and Wheat Improvement Center. "Cutworms, extended information." 2010. Print.
- Iriki, N., Gaudet, D. A., Tronsmo, A. M., Matsumoto, N., Yoshida, M., and Nishimune, A. Low Temperature Interactions Under Snow. Hokkaido: Hokkaido National Agricultural Experimental Station, 2001. Print.
- Karren, Dr. Jay B., and Thomas A. Reeve. "Russian Wheat Aphid in Utah." Utah: Utah State University Extension Entomology 67, 1989. Print.
- Kher, S.V., Dossdall, L.M., and Cárcamo, H.A. "The Cereal Leaf Beetle: Biology, Distribution and Prospects for Control." *Prairie Soils and Crops* 4. (2011): 32-41.
- Lafond, G. P., and Fowler, D. B. "Soil Temperature and water content, seeding depth and simulated rainfall effects on winter wheat emergence." *Agronomy Journal* 81. (1989): 609-614.
- Lafond, G. P., May, W. E., and Irvine, B. "The yield potential of winter wheat established in a dry seedbed and at different seeding depths." *Canadian Journal of Plant Science* 85. (2005): 889-892.
- Lipps, P. E. "Fact Sheet: Take All Disease of Wheat." Ohio State University Extension. 29 October 2011. Web.
- Loeppky, H., Lafond, G. P., and Fowler, D. B. "Seeding depth in relation to plant development, winter survival and Yield of No-till winter wheat." *Agronomy Journal* 81. (1989): 125-129.
- Mackey, B., and Skinner, D.Z. "Freezing tolerance of winter wheat plants frozen in saturated soil." *Field Crops Research* 113. (2009): 3.
- Manitoba Agriculture, Food and Rural Initiatives. "Cutworms in Field Crops." 2011. Web. Accessed November 2012.
<<http://www.gov.mb.ca/agriculture/crops/insects/fad06s00.html>>
- Maine Potato IPM Program. Wireworms. University of Maine: Cooperative Extension 206, 2001. Print.
- McCalla A.F. "World Food Prices: Causes and Consequences." *Canadian Journal of Agricultural Economics* 57. (2009): 23-34.
- McCallum B.D., and DePauw R.M. "A review of wheat cultivars grown in the Canadian prairies." *Canadian Journal of Plant Science* 88. (2008): 649-667.
- McKenzie, R., Schatz, W., and Middleton, A. "Fact Sheet: Fertilizing Winter Wheat in Southern Alberta." Alberta Agriculture and Rural Development. 2000. Accessed November 2011.
<[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex96/\\$file/112_542-1.pdf?OpenElement](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex96/$file/112_542-1.pdf?OpenElement)>
- McKenzie, R., Middleton, A., and Zhang, M. "Optimal time and placement of fertilizer with direct and conventionally seeded winter wheat." *Canadian Journal of Soil Science* 81. (2001): 613-622.

- McKenzie, R., Bremmer, E., Grant, C., Johnston, A., DeMulder, J., and Middleton, A. "In-Crop application of nitrogen fertilizer on grain protein concentration in spring wheat in the Canadian prairies." *Canadian Journal of Soil Science* 86. (2006): 565-572.
- McKenzie, R.H., Bremer, E., Middleton, A. B., Pfiffner, P. G., Dunn, R. F., and Beres, B. L. "Efficacy of high seeding rates to increase grain yield of winter wheat and winter triticale in southern Alberta." *Canadian Journal of Plant Science* 87. (2007): 503-507.
- McKenzie, R., Middleton, A., Pfiffner, P., and Bremer, E. "Evaluation of Polymer-Coated Urea and Urease Inhibitor for Winter Wheat in Southern Alberta." *Agronomy Journal* 102.4. (2010): 1210-1216.
- McKenzie, R., and Middleton, A. "Fact Sheet: Phosphorous Fertilizer Application in Crop Production." Alberta Agriculture and Rural Development, Agdex 542-3. 1997. Web. Accessed November 2011. <[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex920/\\$file/542-3.pdf?OpenElement](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex920/$file/542-3.pdf?OpenElement)>
- McKenzie, R. Personal Communication. November 2011.
- Miles, C. A., Roozen, J., Jones, S. S., Murphy, K., and Chen, X. Growing Winter Wheat in Western Washington. Washington State University Extension, November 2009. Web. Accessed October 2011.
- Montana State University Extension. "Pale Western and Army Cutworms in Montana." 2000. Web. Accessed March 2013. <<http://extn.msu.montana.edu/Publications/ESCatalog/ANRPublicCatalogAGlist.asp>>
- Mukhopadhyay, K., and Thomassin, P. J. "Macroeconomic effects of the Ethanol Biofuel Sector in Canada." *Biomass and Bioenergy* 35. (2011): 2822-2838
- Nielsen, D. C., Benjamin, J. G., and Vigil, M. F. "Evaluating decision rules for dry land rotation crop selection." *Field Crops Research* 120. (2011): 254-261
- Nufarm Limited. "Clean Start – Product Information." 2008. Web. Accessed October 2011. <<http://www.nufarm.ca/CA/CleanStartCleanStartPlus>>
- Peel, M. D., Riveland, N., Franzen, D., Glogoza, P., McMullen, M., and Zollinger, R. "Winter Wheat Production in North Dakota." North Dakota State University. September 1997. Web. Accessed November 1, 2011.
- Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. "World Population Prospects: The 2010 Revision." 2010. Web. Accessed March 2013. <<http://esa.un.org/unpd/wpp/index.htm>>
- Puchalski, B. J. Personal Communication. 2001.
- Purdue University. "Cereal Leaf Beetle." Indiana: Field Crops IPM, 2009. Print.
- Schillinger, W. F., Paulitz, T. C., Kennedy, A. C., and Young, D. L. "Diverse no-till irrigated crop rotations instead of burning and plowing continuous wheat." *Field Crops Research* 115. (2010): 39-49.
- Shea, G., Botha, J., and Hardie, D. "Fact Sheet: Russian Wheat Aphid." Agriculture Western Australia. July 2000. Print.
- Smith, J.D. "Snow molds of winter cereals: guide for diagnosis, culture, and pathogenicity." *Canadian Journal of Plant Pathology* 3.1. (1981): 15-25.
- Strelkov, S. Personal Communication. 2011.
- Top Crop Manager. "Winter Wheat's Rebirth." Top Crop Manager. July 2001: 6-7. Print.
- University of Saskatchewan. "Winter Wheat Production Manual." 2002. Web. Accessed October 2011. <http://www.usask.ca/agriculture/plantsci/winter_cereals/Winter_wheat/contents.php>

Index

0-0-62	22	Chinooks.....	3, 60
11-51-0	22	CleanStart	34, 35
12-51-0.....	22	Cleavers.....	30, 35
19-3-0-22S.....	22	Cold acclimation	15
2,4-D.....	32, 34, 35	Common Bunt.....	12, 13, 50, 56
20-0-0-24S.....	22	Common Chickweed.....	35
21-0-0-24S	22	Cost Determination and Comparison	6
44-0-0	22	Cow Cockle.....	36
46-0-0	22	Crop Protection Guide..	33, 38, 43, 46, 47, 50, 51, 52, 55, 56
82-0-0	22	Crop Rotation.....	19, 25–28, 40, 49, 50, 52, 56, 57, 61
AAC Gateway	12, 13, 15	Currency	7, 9
AC Bellatrix.....	13, 14	Cutworm.....	37, 41–42
AC Readymade	12, 13	CWGP	8, 9, 10, 11, 13
AC Tempest	12, 13	CWRW.....	6, 7, 8, 9–10, 11, 12, 13, 15
Accipiter	13, 15	Dandelion	34, 36
Acclimation	59	Delayed seeding	33
Acres of winter wheat grown.....	9	Demand.....	6, 7, 8
Additional cost	6, 40	Disadvantages.....	5, 26–27
Advantages of Winter Wheat for Weed Control.....	31	Diseases.....	3–4, 11, 13, 14, 15, 16, 27, 33, 44, 49–57, 61
Advantages to Growing Winter Wheat	5	Downy Brome	36
Alberta Seed Guide	11	Early Seeding	5, 15
Anhydrous ammonia.....	22	Emerson	12, 13, 15, 50, 55
Annual Smartweed.....	35	Environmentally Smart Nitrogen	22
Annual Sow Thistle.....	35	ESN	22, 24
Annual Weed Life Cycle.....	30	Ethanol	7, 8, 10, 11
Army Cutworm.....	37, 41–42	Express Pro	34
Assessing Winter Survival	62	Express SG	34
Benchmark Sampling	20	Fall band	24
Big Shocks.....	7, 9	Fall Weed Control	32
Broadview	12, 13, 15	Fertility	3–4, 14, 19–24, 26–27, 33, 61
Canada Thistle.....	35	Fertilizer.....	3, 4, 19, 20, 22, 23, 24, 33, 57
Canadian Wheat Board.....	6, 7, 8, 9, 10	Field Horsetail.....	36
Carfentrazone	34, 35	Field Preparation.....	16, 27
CDC Buteo	12, 13, 14	Flixweed	36
CDC Clair	12, 13	Florasulam.....	34
CDC Falcon	9, 12, 13, 14	Flourish.....	12, 13, 14, 15, 49, 51
CDC Harrier.....	12, 13	Foxtail Barley	36
CDC Kestrel.....	12, 13	Freeze/Thaw cycles	3, 60
CDC Osprey	12, 13, 14, 31	Frost.....	3, 4, 15, 22, 28, 37, 38
CDC Ptarmigan	12, 13	Fusarium Head Blight	4, 5, 10, 12, 13, 50, 55
Cereal Leaf Beetle	4, 37–38, 50	Germination.....	16, 17, 24, 29, 30, 31
		Glyphosate	32, 33, 34
		Green bridge.....	5, 13, 15, 26, 27, 49, 50, 52, 54



Grasshopper.....	3, 27, 37, 43
Green Foxtail	36
Growing season.....	9, 17, 24, 28, 31, 43
Guide to Soil Testing.....	20
Harden off	59, 61
Harrowing	16
Heat.....	21, 34, 35
Hemp Nettle.....	36
Herbicide Timing.....	33
Herbicide Selector	35
Higher seeding rates	17
Higher Yield	14, 33
Horizon	32
Japanese Brome	36
Kochia.....	35, 36
Lady's Thumb	35
Lamb's Quarters.....	36
Late seeding	33
Lodging Resistance	11, 12, 14, 15
Making a Variety Choice.....	11, 16
Marketing.....	7–10, 13
Maturity.....	5, 11, 12, 14, 15, 22, 29, 41, 43, 46, 55
McClintock	13
Micronutrients	22–23
Moats.....	13, 15, 49, 51
Narrow Leaved Hawks Beard	34, 36
Nitrogen	19, 22, 24, 26, 61, 62
Nitrogen fertilizer recommendations.....	19
Norstar.....	13, 14, 60
Nutrient Management.....	3, 4, 19–24
Online Calculators	6
Osprey	12, 13, 14, 31, 32
Pale Western Cutworm.....	41, 42, 37
Peregrine	12, 13, 15
Perennial.....	3, 4, 19, 27, 30, 35, 36
Phosphorus	20, 22
Phosphorus fertilizer recommendations	20
Pintail.....	12, 13, 15, 49, 51
Potassium	19, 21, 22
Potassium fertilizer recommendations.....	19, 21
Pre-Seed Burnoff	32, 34
Preceding crops.....	26–27
PrePass	35
Price	5, 6, 7, 8, 9, 10, 22
Profit Potential.....	5
Prostrate Pigweed.....	36
Protein	5, 6, 9, 10, 11, 12, 14, 15, 19, 20, 23, 24
Pygmy Flower	36
Quackgrass.....	30, 36, 57
Radiant	12, 13, 14, 32, 44, 50, 51, 54
Random Sampling	20–21
Redroot Pigweed	36
Refine Extra.....	32
Residue	16, 26, 27, 28, 52, 55, 57, 61
Rotation	3, 4, 5, 6, 15, 19, 25–28, 32, 40, 49, 50, 52, 53, 56, 57, 61
Round Leaved Mallow	36
Russian Wheat Aphid	12, 13, 37, 45, 46, 63, 64
Saflufenacil	34
Scentless Chamomile.....	36
Seed place.....	24
Seeding Shallow.....	17, 21, 33
Seeding Date	12, 13, 15, 16, 33, 61
Seeding Depth.....	17, 24, 33
Seeding Management	3, 11–17, 33, 60, 61
Seeding Rate.....	17, 32, 43, 47
Seeding rate calculation	17
Seedling survival rate	17
Shepherd's Purse	30, 36
Snow cover.....	3, 26, 28, 53, 60
Snow mold.....	4, 26, 49, 53
Soil Fertility.....	3, 4, 19–24
Soil sampling	20, 21
Soil test.....	3, 19, 20, 21, 22, 33
Soil Zones of Alberta	25
Sow Thistle	35, 36
Speculators.....	7, 9
Split Application	24
Spring Broadcast.....	24, 33
Stand density.....	33
Stinkweed	30, 34, 36
Stork's Bill.....	36
Stripe Rust.....	4, 13, 26, 27, 49, 50, 51
Stubble Height.....	16, 28

Index

Submitting Soil Samples.....	21
Sulphur	19, 20, 22
Sulphur fertilizer recommendations	19, 20
Sunrise	12, 13, 15
Supply.....	7, 9
Swainson	15
Take-All.....	50, 55, 57
Tan Spot	4, 26, 27, 49, 52
Toadflax	36
Tribenuron-methyl.....	34
Urea.....	41
Variety Selection.....	11, 13
Variety selection tool.....	11
Variety List.....	12, 14
Variety Yield Potentials	12
Volunteer Barley	36
Volunteer Canola & other mustards	25, 34, 36, 42
Volunteer Oats	27, 36
Volunteer Wheat	36, 46, 51
Weed control.....	29, 31, 32, 33, 34
Weed Life Cycle.....	30
Weed scouting.....	29
Well-developed crown.....	15
Wheat Curl Mite	12, 13, 37, 44, 50, 54
Wheat Stem Sawfly.....	37, 40, 41
Wheat Streak Mosaic Virus	3, 4, 12, 13, 26, 27, 44, 50, 54
Wild Buckwheat	34, 36
Wild Oats	27, 31, 36
Winter Annual Weed Life Cycle.....	30
Winter Hardiness, all varieties	5, 13, 15, 59, 60, 61, 62
Winter Survival ...	3, 4, 6, 11, 12, 13, 15, 17, 19, 25, 26, 59-64
Winter Wheat Life Cycle.....	29
Wireworms.....	4, 37, 46, 47
Yield.....	5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 22, 23, 24, 26, 29, 32, 33, 34, 35, 39, 49, 50, 51, 52, 55, 56, 57, 62



