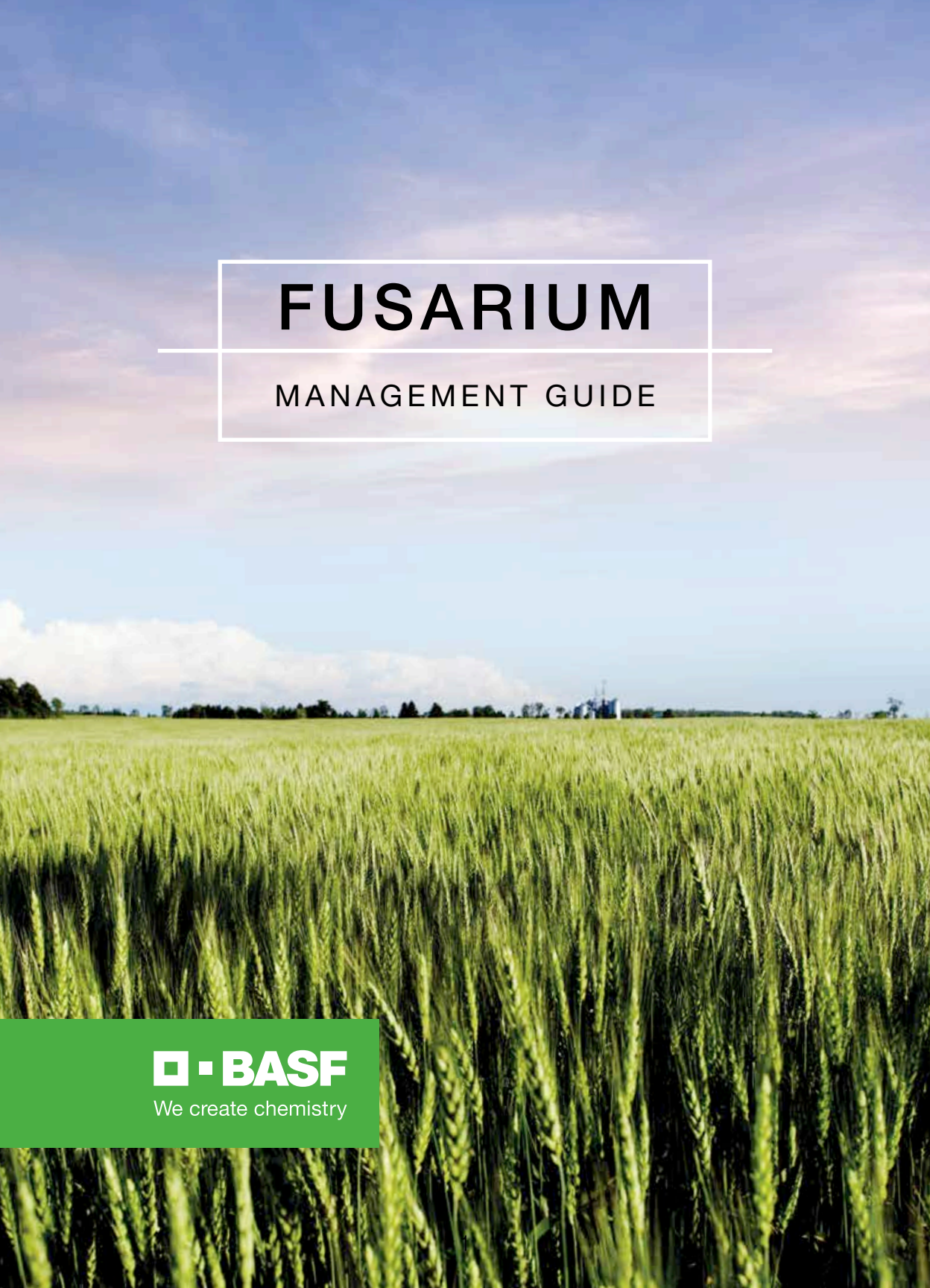
FUSARIUM

MANAGEMENT GUIDE



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We create chemistry

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The goal is to achieve quality. We can help you.

The goal for cereal producers is to grow a profitable crop that can be used to access high-quality markets. That requires a high standard for management practices, particularly in dealing with a disease like fusarium head blight (FHB), the leading disease threat in cereals in Canada.

This is a comprehensive guide on cereal production, the role that FHB can play, and the need for heightened awareness of the disease's impacts on value, quality and a crop's overall performance.

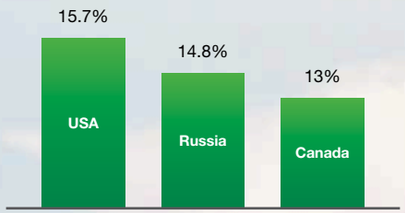
Western Canada is the nation's "bread-basket".

It is the definitive picture of Canadian agriculture: an endless field of wheat, ripening in the sun under an endless prairie sky.

For more than 100 years, wheat production has been synonymous with Western Canadian farming. It's a point of pride and a reputation that growers have nurtured through the years. As Canada's standing in world wheat production has evolved, growers have strengthened their commitment to producing their crops to the highest quality.

The World's 'Big Three' in Wheat Production

Percent of global export market



Source: World's Top Exports, May 19, 2018[1]

Our position on the global stage is a reflection of the hard work and dedication of Canadian growers. The distinction in quality that "Canadian wheat" is known for makes the effort growers put into wheat production more than worth it.

The history of Fusarium head blight

Fusarium Head Blight (FHB) has grown to be one of the biggest challenges year to year in Canadian wheat production.

Confined primarily to Manitoba.

1923 – Fusarium is discovered in Manitoba, where it was confined for nearly 60 years.[2]

1984 – FHB is confirmed in irrigated soft white spring wheat in southern Alberta.

1987 – FHB detected in Saskatchewan.

1994 – Trace levels of FHB were confirmed in all crop districts in Saskatchewan bordering on Manitoba.

2005 – FHB outbreak in Manitoba.

2008 – The disease worsened, spreading across Western Canada.

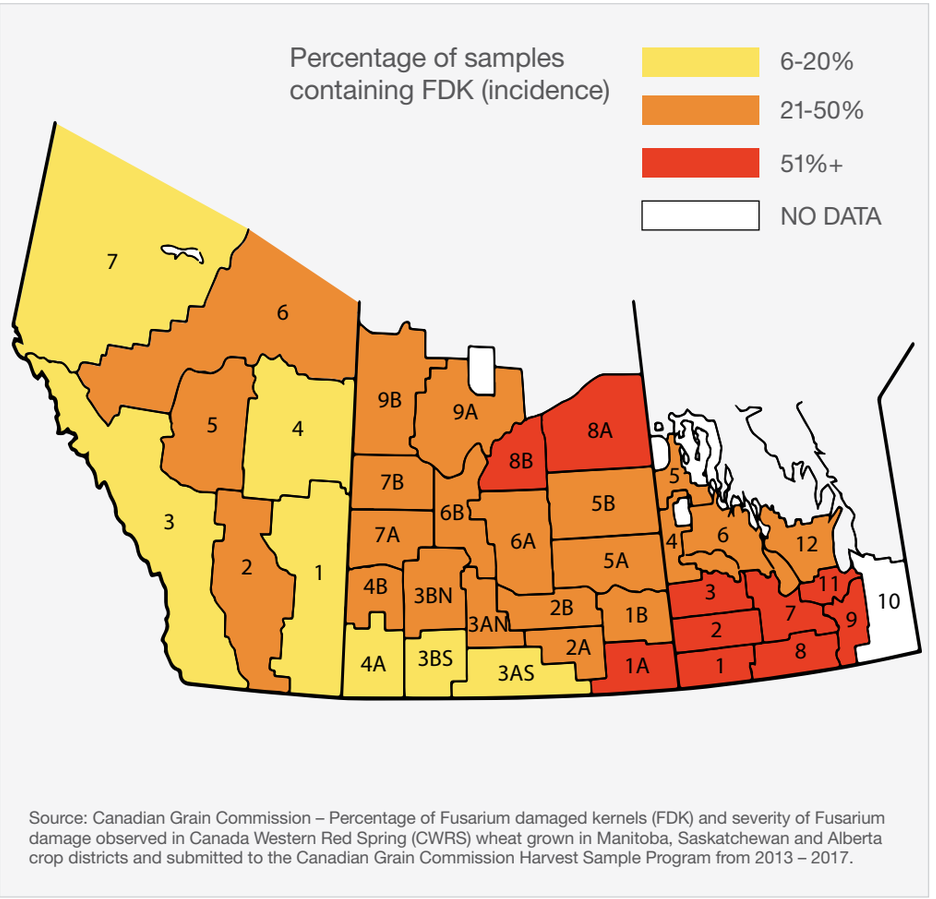
2009 – More than 10 per cent of the wheat and durum grown in southern Alberta is downgraded with fusarium-damaged kernels (FDK) above tolerance levels.

Although Fusarium head blight can infect barley, oats, rye, corn, canary seed and forage grasses, it is the disease's impact on wheat across Western Canada that is the greatest concern. **Fusarium head blight has caused $50 to $300 million in losses each year since the 1990s.**[3]

Managing fusarium begins with recognizing the risk

Higher incidences of fusarium began appearing across the Prairies in 2013 and continued through 2016, resulting in reductions in quality and lost revenue. In spite of a lower impact in 2017, growers are reminded that fusarium's pathogen persists in the soil and on residues, meaning the risk of the disease is always present.

Average fusarium frequency from 2013-2017



Source: Canadian Grain Commission – Percentage of Fusarium damaged kernels (FDK) and severity of Fusarium damage observed in Canada Western Red Spring (CWRS) wheat grown in Manitoba, Saskatchewan and Alberta crop districts and submitted to the Canadian Grain Commission Harvest Sample Program from 2013 – 2017.

Disease pathogens

Fusarium head blight can be caused by one of four different species:

- *Fusarium graminearum*
- *Fusarium avenaceum*
- *Fusarium culmorum*
- *Fusarium poae*

The most frequent and dominant cause of FHB in Western Canada is *Fusarium graminearum*. It is considered the more significant of the pathogens because of its impact on yield and grain quality, and its capability of producing several toxins.

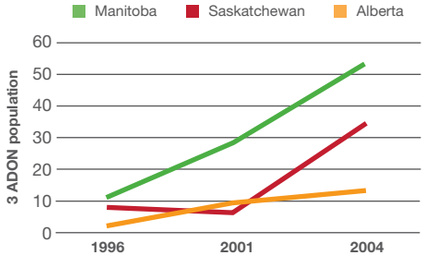
The concern with the shift to 3ADON is it produces nearly twice the amount of DON toxin as 15ADON.

What is FHB and DON? Why does it Matter?

Fusarium head blight (FHB) lowers the quality of cereals, shrinking the kernels into so-called “tombstones”. However, the disease is a threat due to the production of mycotoxins, the most common of which is deoxynivalenol (DON).

Levels of DON higher than one part per million are restricted from being fed to hogs, dairy cattle and horses. Beef cattle, sheep and poultry can be fed at levels up to five parts per million. The disease can also affect malting barley, which carries a zero tolerance level for the disease.[3]

New chemotypes of *Fusarium graminearium* produce higher levels of DON



Source: Ward et al. (2008).
Accessed at https://www.sciencedirect.com/science/article/pii/S1087184507001843?via%3Dihub

Prior to 2010, DON was expressed primarily by chemotype 15 acetyl deoxynivalenol (15ADON).

Research from across the Prairies between 2005 and 2007 found a shift to 3ADON in all three Western Canadian provinces.

The significance is that 3ADON produces roughly twice the amount of toxin as the 15ADON chemotype.[4] Its incidence in Western Canada is also on the rise, from five to six per cent to 10 per cent in 3ADON isolates in Alberta between 2007 and 2010.[3,5]

The concern with 3ADON is that it can be more aggressive, causing more severe disease symptoms and greater DON accumulation.

In spite of worries over yield losses, the main concern with Fusarium head blight is the production of DON. Animals that consume relatively high levels of DON may eat less, have a lower immune response and there could be setbacks with an animal’s reproductive system.[4]

Maximum tolerated DON levels in livestock feed.

Dairy cattle Hogs Horses	1ppm
Beef cattle Poultry Sheep	5 ppm

Spot the difference?
One sibling fed 5ppm DON in feed rations, the other eating DON-free feed.

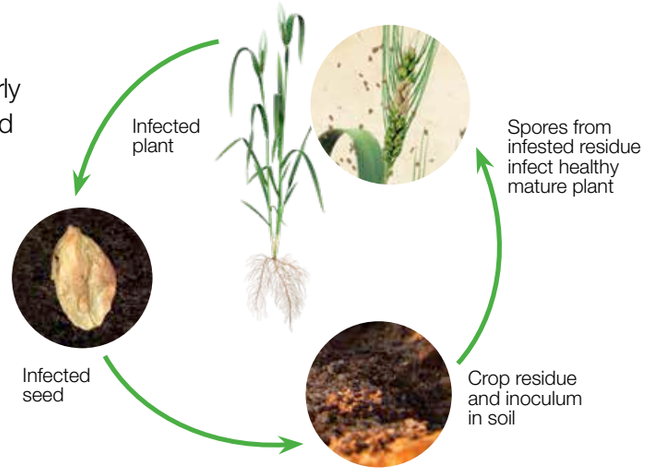
FUSARIUM HEAD BLIGHT

Fusarium lifecycle and infection

FHB needs precipitation or humid weather conditions, and air temperatures between 16 – 30°C to promote spore germination. Two different spore types are produced by Fusarium graminearum: one spread by wind and the other by splashed water droplets from rain or irrigation. Spores can also overwinter in infected seed or be infected as seedlings emerge.

Fusarium head blight can overwinter on cereal and corn residues, and infected seed.

- Flowering florets on a cereal crop are infected by germinating spores from the infected head tissues of a nearby plant.
- Spores infect the plant via openings created where flowers or anthers form on the cereal head.[4]
- Visible symptoms appear within three weeks following infection of the florets
- Infected florets have an orange or pink colouration near the base or below the glumes.
- Kernels in the affected heads will not fill properly and develop a bleached and shrivelled appearance.



Economic impact.

Lost revenues due to downgrades in quality account for Fusarium's greatest impact. In a Government of Alberta study in 2015, the value of grade loss is higher than yield loss.[6]

Downgrades Grade #1 to Grade #3 due to FHB can lead to losses of $35.11 to $100 per acre.[6]

Fusarium Grading Factor

Average over 2016-2018.

	No. 1	No. 2	No. 3
% of all Grades	59.2	20.2	9.5
Fusarium Grading Factor (% of Grade)	n/a	33.9	33.7

Grain infected with FHB can be hard to market. If your grain remains at #1 grade in a high infection year, it's possible that you'll see a hefty premium for your efforts.

Conversely, a high FDK level during a low infection year can make it more challenging to sell your grain.

It's useful to know the allowable levels for fusarium-damaged kernels among all classes and grades of wheat and durum.

FUSARIUM HEAD BLIGHT

Allowable levels of FDK in western wheat.

On average, 1% Fusarium Damaged Kernels = 1ppm DON level

Class and grade	Allowable levels of FDK (% by weight)
Canadian Western Red Spring	
No. 1 CWRS	0.25 %
No. 2 CWRS	0.8 %
No. 3 CWRS	1.5 %
No. 4 CWRS	1.5 %
Canadian Western Hard White Spring	
No. 1 CWHWS	0.25 %
No. 2 CWHWS	0.8 %
No. 3 CWHWS	1.5 %
No. 4 CWHWS	1.5 %
Canadian Western Amber Durum	
No. 1 CWAD	0.5 %
No. 2 CWAD	0.5 %
No. 3 CWAD	2.0 %
No. 4 CWAD	2.0 %
No. 5 CWAD	4.0 %
Canadian Western Extra Strong	
No. 1 CWES	1.0 %
No. 2 CWES	1.0 %
Canadian Western Soft White Spring	
No. 1 CWSWS	1.5 %
No. 2 CWSWS	1.5 %
No. 3 CWSWS	1.5 %
Canadian Western Red Winter	
No. 1 CWRW	0.8 %
No. 2 CWRW	1.0 %
No. 3 CWRW	1.5 %
Canada Prairie Spring White and Spring Red	
No. 1 CPSW	1.5 %
CPSR	1.5 %
No. 2 CPSW	1.5 %
CPSR	1.5 %
Canada Western Feed (all classes)	
4.0 %	

The Canadian Grain Commission has conducted surveys by its Grain Research Laboratory and determined Fusarium tolerance levels according to severity of Fusarium damaged kernels (FDK) by grade.[7]

A Case Example of the Cost of Fusarium Outbreak.

Initial grade	**#1 CWRS (13.5% protein)**		
Yield (bu/ac)[a]	55.5		
Average price ($/t)[b]	231.8		
Grade impact	**#1 – #2**	**#1 – #3**	**#1 – Feed**
Disease severity	0.5%	1.2%	2.2%
Price spread ($/t)[c]	7.5	22.8	66.0
Yield loss (bu/ac)	0.06	0.13	0.24
Value of grade loss ($/t)	7.49	22.75	66.04
Revenue loss ($/ac)	**11.66**	**35.11**	**100.85**

Yield, per tonne and per bushel losses resulting from quality downgrades in Canadian Western Red spring wheat.

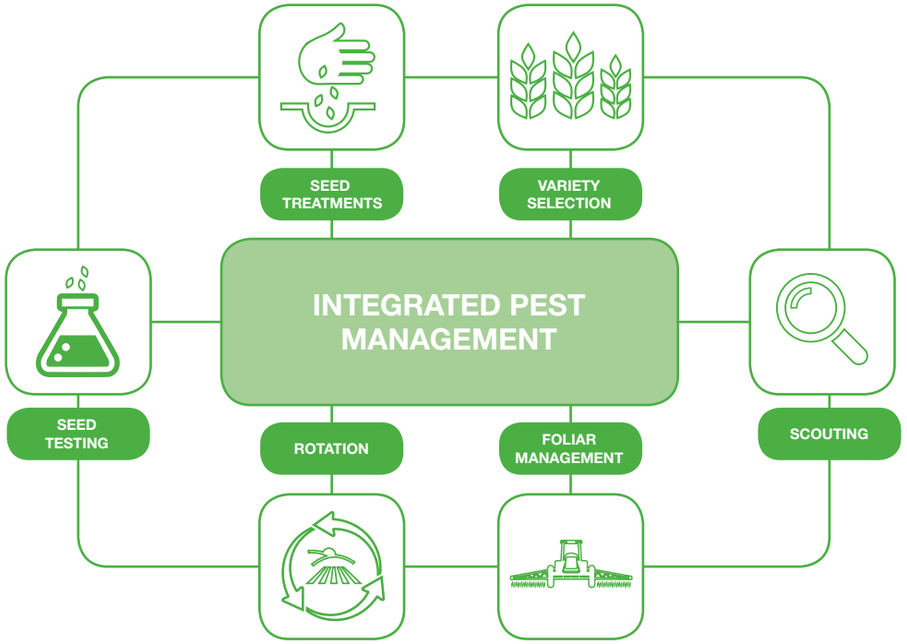
Source: "The Economic Cost of Fusarium", produced by Richard Heikkila, May 2015, For Alberta Agriculture and Forestry, Government of Alberta.

[a] Average yield 2016 (Statistics Canada, Table 32-10-0359-01)
[b] Average annual #1 CWRS price, Agriculture Financial Services Corporation (AFSC)
[c] CWRS price spread between #1 – #2, #1 – #3, #1 – Feed, AFSC and Alberta Agriculture and Forestry (AF), 2016

Integrated Pest Management

Managing for seed- and soil-borne diseases requires a multi-faceted approach and that is the strength of an Integrated Pest Management (IPM) strategic plan. It encompasses different agronomic components, including:

- Seed testing
- Seed treatments
- Variety selection
- Rotation
- Foliar management
- Scouting



There is no silver bullet for managing fusarium. It takes a multi-faceted approach.

Seed and soil management

Seeding with fusarium-infected seed will not automatically lead to a disease outbreak.[8] However, it can reduce germination, vigour, stand and establishment, and build soil inoculum levels, which is why testing seed is so important to an integrated pest management (IPM) strategy.

Always use clean, disease-free seed and select varieties with increased disease tolerances.[8]

- Treat seed (even if high quality seed lot) to fight soil-borne fusarium, since fungal spores can survive in the soil or on soil residues for years.
- Avoid soil-borne infections by rotating out of cereals for at least one year.[4]
- Increase seeding rate to promote even emergence.
- Reduce tillering to encourage uniformity, making it easier for a fungicide application to protect the majority of heads and reduce the plant's susceptibility to infection.[4,8]
- Use seeding rates specific to each type of cereal, based on the following calculation:

  (lb/ac) = desired plant population/ft² x 1,000 K wt. (g) ÷ seedling survival rate (in decimal form such as 0.90) ÷ 10.4

	Desired plant population			
	per square meter	per square foot (range)	1,000 kernel weight (grams)	seeds per pound (average)
Wheat				
Hard red	250	24 (16 – 30)	31 – 38	12,000 – 14,600
CPS	250	24 (18 – 30)	39 – 50	10,800 – 12,000
Durum	210	20 (16 – 24)	41 – 45	10,000 – 11,000
Extra strong	210	22 (20 – 24)	40 – 44	10,000 – 11,000
Soft white	210	20 (18 – 25)	34 – 36	12,600 – 14,200
Barley 2 row	210	22 (16 – 30)	40 – 50	9,000 –11,000
Barley 6 row	210	22 (16 – 30)	30 – 45	10,000 –15,000
Oats	250	24 (16 – 30)	30 – 45	10,000 –15,000
Fall rye	250	24 (16 – 25)	30 – 35	13,000 – 15,000

Seed testing is a vital first step.

It is strongly advised that growers have all cereal seed tested by an accredited seed laboratory.[8] The primary tests conducted on a seed lot include germination, vigour and pathogen analyses.

Germination Test:

Describes the percent of seeds likely to germinate under optimal growing conditions (i.e light, temperature and moisture).

Vigour Test:

Measures the ability of the seed to germinate and produce normal seedlings under adverse conditions. Germination tests are not done under conditions seeds tend to be under during seeding. Seeds that are considered viable in a germination test may not be capable of continuing proper growth and completing their life cycle. Vigour tests are done under conditions that better reflect those at seeding time and is a better indication than the germination test of the seed to create strong, healthy seedlings.

When analyzing a seed test, you want seed with high germination and vigour with minimal spread between the two values.

Pathogen Analyses

This is the most important aspect of the seed test. These tests determine how many seeds in the seed lot contain spores of a specific pathogen (e.g. total *Fusarium, F. graminearum, Cochliobolus*, etc) on the seed surface.

Although a useful tool for analysing seed quality, pathogen analyses does not indicate the level of infection that will occur in the field that season. Viable seeds can have disease spores on their surface. Seed lots can have a germination and vigour rating greater than 95 per cent and still have a high level (15 to 25 per cent) of disease present.

Results from the Pathogen Analyses, together with germination and vigour, are needed when deciding which seed lot should be used.

Seed that tests higher than:
15% total *Fusarium or Cochliobolus* should be discarded.
5% *Fusarium graminearum* should be discarded.

If levels of either of these pathogens are exceeded, growers should err on the side of caution and use a different seed source, as even premium seed treatments will not have enough activity to manage disease.

Total Fusarium		
Crop	Treat Seed	Discard Seed
Barley	0-15%	>15%
Wheat	0-15%	>15%
Durum	0-15%	>15%

Regardless of the type of cereal, the line between treating and discarding seed is quite rigid along the 15 per cent mark.

An important part of an annual crop plan.

Seed is one of the biggest annual investments in a grower's operation and treating that seed not only protects the investment, it provides an early boost at the start of the growing season. Using high quality seed and an effective seed treatment forms an unbeatable combination, limiting the introduction of pathogens into a field and managing disease pathogens on the seed and in the soil.

INTEGRATED PEST MANAGEMENT

The Right Choice, the Right Time

Seed treatments protect a grower's investment in seed.

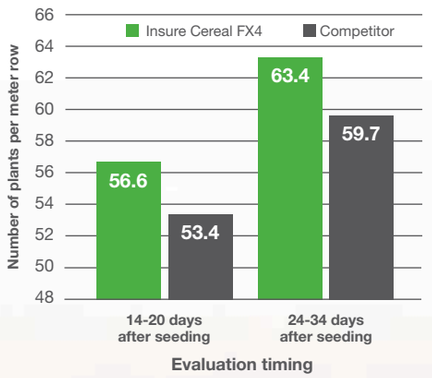
Insure® Cereal FX4 fungicide seed treatment consists of four modes of action, three of which target fusarium.

The unique translocation and mobility characteristics of Xemium® provides more consistent and continuous disease control.

- It has the benefits† of **AgCelence**® for increased germination and emergence, greater seedling vigour (both above and below ground) and enhanced ability to manage environmental stresses.‡
- In cool, wet and slow springs, that added protection can be a key benefit.

Together, they deliver a new standard of broad-spectrum protection against seed- and soil-borne diseases.

Average plant stand count



Source: BASF Research Authorization Trials, Western Canada, 2018, n=16

† **AgCelence** benefits refer to products that contain the active ingredient pyraclobstrobin

‡ All comparisons are to untreated, unless otherwise stated.

Increased seedling vigour in wheat, 28 days after seeding

Source: BASF Research Authorization Trials, Camrose, AB, 2018

Insure® Cereal FX4
Xemium® Fungicide Seed Treatment

BASF We create chemistry

AgCelence® *Expect more*

Variety selection – check the ratings.

It is vital that growers understand how varieties differ in their susceptibility to FHB. Tolerance levels can correspond to specific varieties and regional conditions. Growers should also consult the annual results and scores available from provincial field trials or made available through the Canadian Grain Commission.

Selecting resistant cultivars is another of the pillars of FHB management.

It's important to take note of Fusarium Ratings, which compare the susceptibility of different varieties. Some do have better ratings than others, yet there are no varieties that are totally resistant to FHB.

The ratings are easy to follow:

R **resistant**	**MR** **moderately resistant**	**IR** **intermediately resistant**
MS **moderately susceptible**	**S** **susceptible**	**HS** **highly susceptible**

Research suggests a strong link between cultivar resistance and fungicide application. Studies indicated that combining FHB resistant varieties with a fungicide application is more-effective in managing FHB and DON versus variety selection or seed treatment alone.[9,10]

Rotation

Reducing the build-up of soil inoculum is vital to reducing the potential for infection.

Rotate to non-host crops to reduce fusarium-infected soils and crop residues. These include canola, pulses and forage legumes, and should be considered for at least two years. That amount of time will be sufficient for the decomposition of infected residue, before the next cereal crop is seeded.[4]

Foliar Management

The period of time a cereal plant is susceptible to infection from FHB is short, as is the spray window for a fungicide application (approximately seven days).

Application of a foliar fungicide at heading can be beneficial to quality and yield, and protect against FHB along with other invasive leaf diseases like rust.

Fungicide applications are most effective when applied before fungal spores grow inside the leaf or before late onset of the latent period.

Once the symptoms appear, the damage has been done. That's why scouting for conditions and planning the timing of a fungicide application are so important. Fungicides should be applied from when the first anthers are visible to when 30 per cent of the heads are in flower in wheat.

Assessing fusarium risk

Once FHB symptoms appear, nothing can be done to reduce infection. That's why it's important to keep an eye on environmental conditions. Temperature and humidity can influence the production of ascospores and the colonization and germination of Fusarium graminearum.

12 hours of precipitation (or high humidity) is required for spores to germinate and infect tissues.

warm temperatures favour infection, with 16 to 30°C the range for optimal infection of Fusarium graminearum.

Symptoms of fusarium head blight appear towards the end of July and into August as brownish spots at the base of the glumes. Eventually, the glumes will appear to be bleached.

In wheat, FHB appears as premature bleaching of one or more spikelets in the head and could result in unfilled spikelets above the infection point. In green heads, it stands out markedly.[11]

Severity of damage to a cereal kernel depends on timing of infection. At early flowering, the infection will result in abortion of the kernels, while infection later in flowering will appear as fusarium damaged kernels (FDK). Later infections may not be visible, but the fungus may still be present. In wheat, rye and triticale, severe forms of FDK manifest as shrunken and chalky white grains.

Assessing Fusarium Head Blight Risk	Lower Risk	Medium Risk	Higher Risk
Step 1 **Predict Pathogen** Is Fusarium established here?	• Has wheat produced in this field been downgraded due to fusarium damaged kernels • Has >5% *F. graminearum* been isolated from wheat seed produced in this field? • Has >10% other *Fusarium* species been isolated from seed produced in this field? • Have any crops produced in this field experienced root rots due to *Fusarium* spp?	No No No No	By a grade > 4 years ago > 2 years ago > 2 years ago	By >1 grade Within 4 years Within 2 years Within 2 years
Step 2 **Stage Crop** When crop will be susceptible?	Stage crop at least 1 week before expected flowering date. Use experience or estimate GDD from seeding date. Anticipate Day 0, when 75% of the heads on main stems to be fully emerged, to be 1-2 days before flowering. Also consider susceptibility of crop. Seeding Date + 807 to 901 GGD°C or 1484 to 1653 GGD°F = Expected Flowering Date	Even Crop, FHB Rating G or VG	Uneven Crop, More Tillers, FHB Rating F	Uneven Crop, Many Tillers, FHB Rating P or VP
Step 3 **Watch Weather** Check FHB map.	Select the FHB forecast map for the estimated head emergence date (Day 0), and determine risk for the area. At least 12 hours of precipitation or high humidity (above 80%) is required for *Fusarium* spore germination and infection, as well as favouring temperatures ranging from 16 to 30°C (*F. graminearum* optimum is 25 to 28°C).	Low	Moderate	High
Step 4 **Crunch Numbers**	Estimated Yield (unit/acre) x Estimated Yield Savings (%) x Selling Price ($/unit) MINUS the Fungicide Application Cost ($/acre) = Expected Net Return ($/acre)	Negative Net Return	Net Return $0	Positive Net Return
Step 5 **Make a decision**	Note that foliar fungicides are registered for the suppression of FHB on wheat, rather than control. Flowering may be variable, but aim for when at least 75% of the heads on main stems are fully emerged to 50% of the heads on main stems are in flower. Ensure adequate water volumes and spray coverage to get the most benefit from application.	Mostly Low Risk? Do Not Spray	Medium Risk? Pencil it in; reassess risk before spray day	Mostly High Risk? Likely to see a benefit from a FHB fungicide

Assessing risk factors can vary from province to province. This chart displays the factors to be considered in Saskatchewan.[11]

FOLIAR SPRAY APPLICATIONS

Are you at risk for fusarium head blight?

1. Are you growing varieties with S or HS ratings for fusarium head blight (FHB)?
2. In the past three years, have you experienced downgrading due to fusarium-damaged kernels (FDK)?
3. Have you seen an increase in the incidence of FDK in your area?
4. Are you concerned about fusarium impacting your cereal crop profitability?

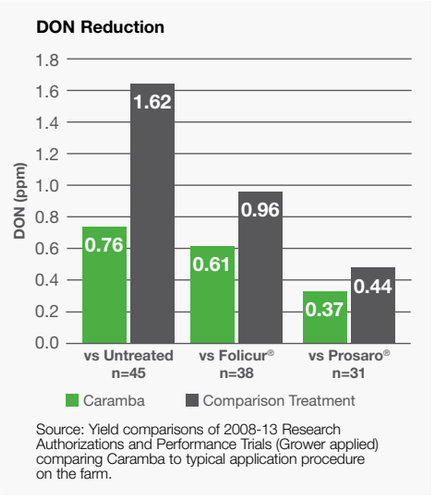
IF YES to 2 out of 4 questions.

Apply a preventative fungicide when your cereal crop is most susceptible—at flowering, particularly when precipitation and humidity is high, causing spores to germinate and infect the floret.

Caramba®
Fungicide

Using foliar fungicides

It cannot be overstated that once symptoms appear, the time to act has passed. When considering a foliar fungicide that protects against fusarium and other late leaf diseases, Caramba® is your best solution. In addition to a preventative measure for fusarium, it also reduces DON contamination and helps preserve grade quality.



Source: Yield comparisons of 2008-13 Research Authorizations and Performance Trials (Grower applied) comparing Caramba to typical application procedure on the farm.

Caramba is a Group 3 fungicide in an easy-to-use liquid formulation. Its effects in terms of disease control and reduction of DON toxins are easy to see (see graph to the right). Its effect on yield, based on eight years of research, shows more than a bushel per acre advantage over other products and more than 10 bushels per acre compared to untreated plots.

Nozzle selection

Coverage on fungicide applications is essential in reducing disease severity. Studies have shown that angled sprays are more effective at depositing the fungicide than vertical sprays. When pointed backward, the angled sprays provide additional coverage on the other side of the cereal head.

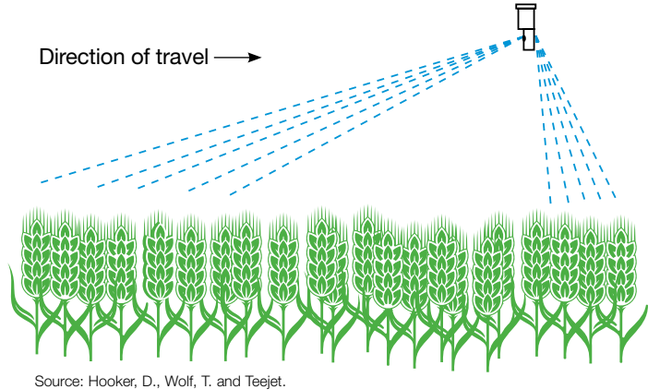
Twin nozzles that enable angled spraying are available from most manufacturers. Droplet size is another key factor in maximizing coverage. Coarser sprays are preferred when angling, to prevent the spray from dissipating with smaller droplets. It's been determined that more acute angles and coarser sprays maintain their trajectory for longer distances, thereby providing optimum coverage.

Maximize spray applications with the right nozzle and spray configuration under optimum conditions.

Correct use of application technology

Single nozzles: at 10 gpa @ normal travel speeds (12 mph) use low boom heights (30 cm), coarse sprays (>400 microns), and forward angles.

Double nozzles: at 10 gpa @ normal travel speeds – use low booms (provided appropriate overlap is achieved), coarse sprays (350-400 microns), and wide angles from vertical (>30°).



Source: Hooker, D., Wolf, T. and Teejet.

Other spray considerations

Boom height

With boom height levels, even coarse sprays can be deflected by air resistance and can stop moving in the preferred direction. Air flow dynamics can cause this to happen in a very short distance. Keeping boom heights low, **less than 25 inches above crop**, will help.

Wind speed and direction

Wind speed and direction are also factors affecting optimum coverage. Observations from the field indicate that moderate winds can over-ride droplet size or nozzle angle. Wind speeds and direction can deposit the spray to the windward side of its target, regardless of the direction of its initial release.

Water volumes

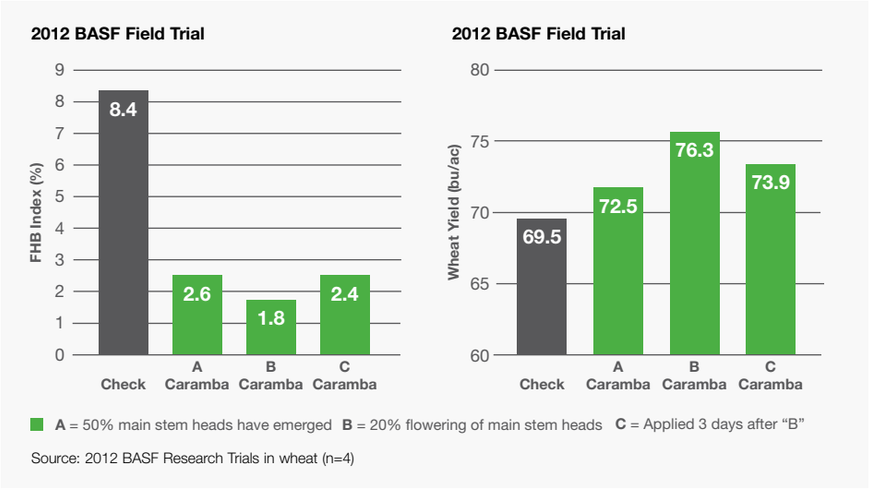
Many of the modern wheat cultivars are awned and these structures can intercept smaller droplets. Unfortunately, intercepting too many droplets will do nothing to protect the cereal head from infection. **The best method to minimize this is to maintain coarse sprays and sufficient water volumes; no less than 10 gallons per acre.**

Timing

Timing is essential for fungicide applications in wheat, which is why scouting for conditions and planning the timing for that fungicide application is vital.

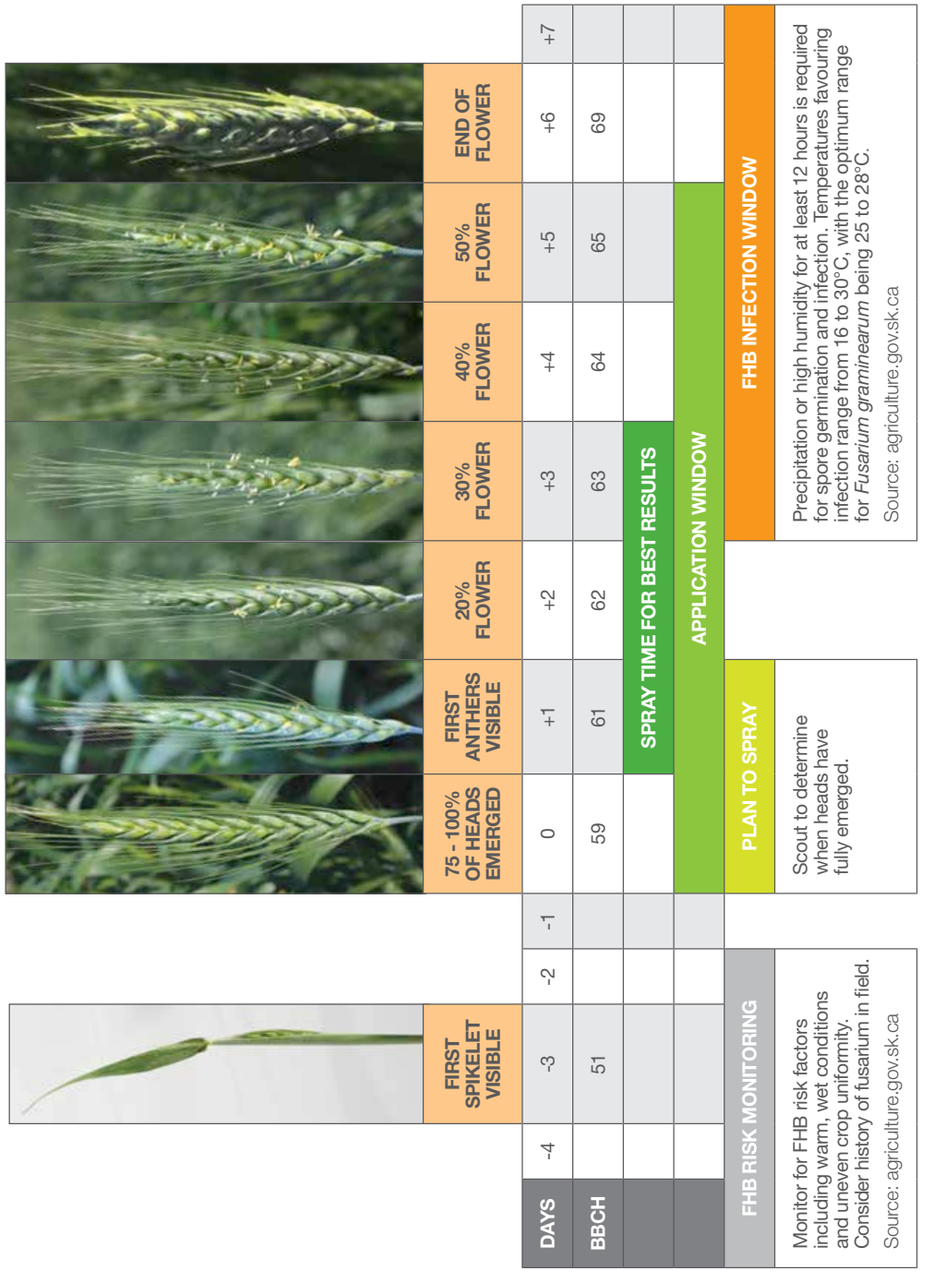
Application Window: When 75-100% of the heads emerged to 50% flowering.
Spray Time for Best Results: First Anthers visible to 30% flowering.

Timing of spray application, particularly the right day, is everything in managing for FHB.



Source: 2012 BASF Research Trials in wheat (n=4)

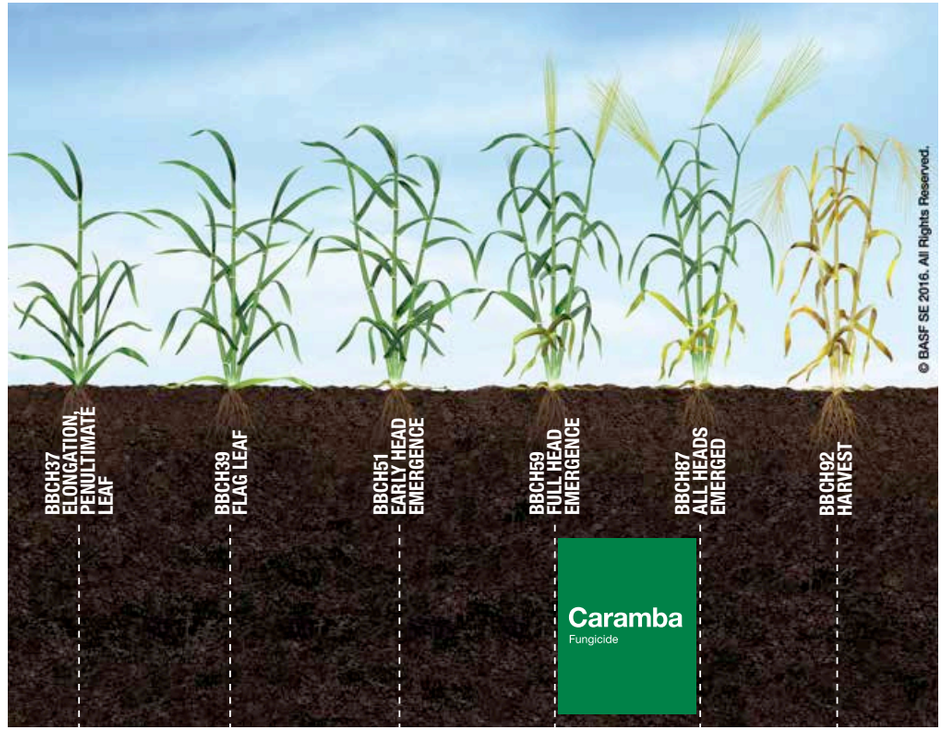
Optimal application timing for fusarium head blight (FHB).



In barley, it's important to note that there is a physiological difference which contributes most to yield.[12]

- In wheat, the biggest contributor to yield is the flag leaf.
- In barley, the penultimate leaf, (the leaf before it), is key along with the head and flag leaf sheath.
- The top leaves in the canopy are important for grain filling and yield, not the lower leaves, which are farther down in the canopy and heavily shaded.
- That calls for an adjustment in spray applications, to protect the top three leaves.

Since flowering in barley begins as the head emerges,[13] a single fungicide application at the full-head **emergence** stage is ideal.



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