Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Canada

The Wheat midge scourge: decades of combat

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The problem…

Orange wheat blossom midge

Sitodiplosis mosellana Géhin (Diptera:Cecidomyiidae)

"the most serious insect pest of spring wheat in western Canada"
(Wise and Smith 2009)

2

The problem: Why?

Losses of >C$50 million in Manitoba and C$130 million in Saskatchewan in 1995

(Lamb 1998; Lamb *et al.* 1999)

Impact of Outbreaks (SK)

Year	Ha Sprayed	Crop Loss
1995	510,000	$130 million
1996	490,000	$110 million
1997	280,000	$ 70 million

"the most serious insect pest of spring wheat in western Canada"
(Wise and Smith 2009)

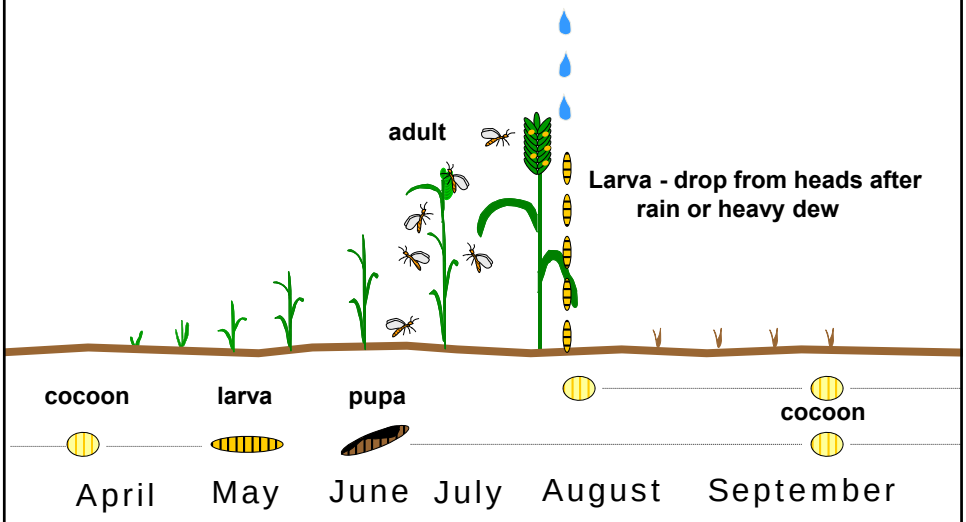
3

Damage to kernels

AAFC – Saskatoon Research Centre

4

Life Cycle of Wheat Midge

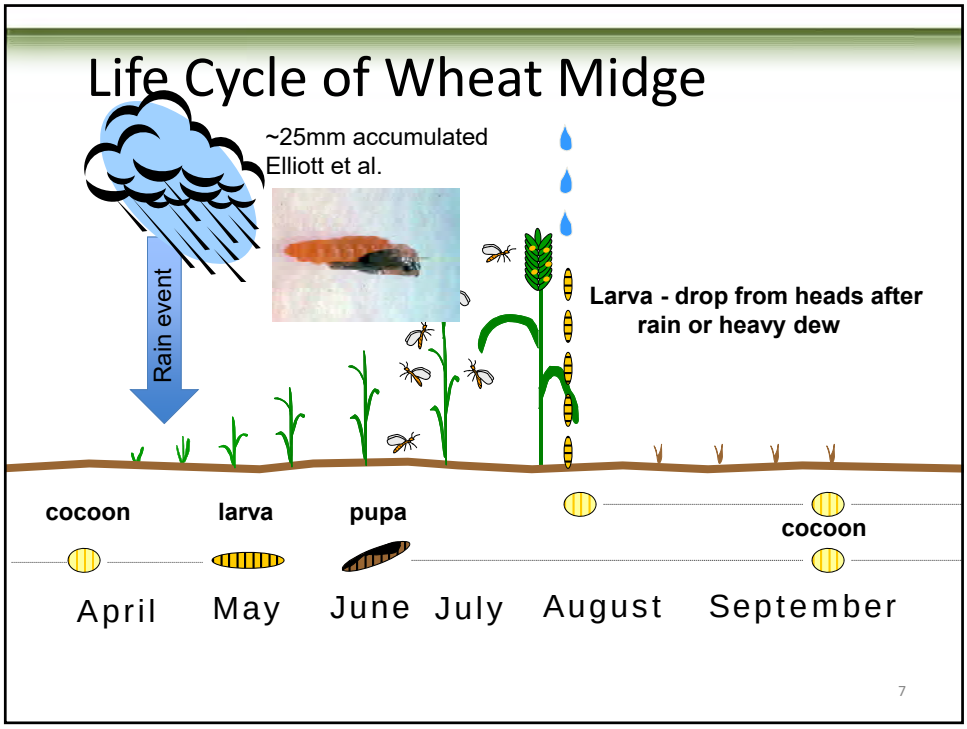


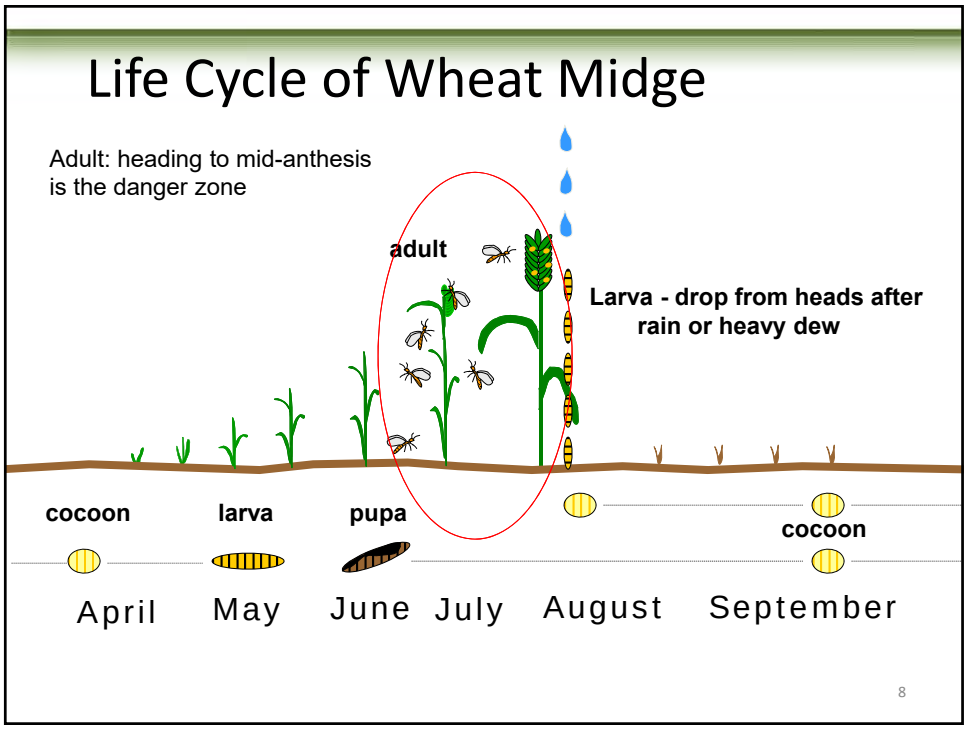
One generation per year
Adult, egg, larva (3 instars), pupa

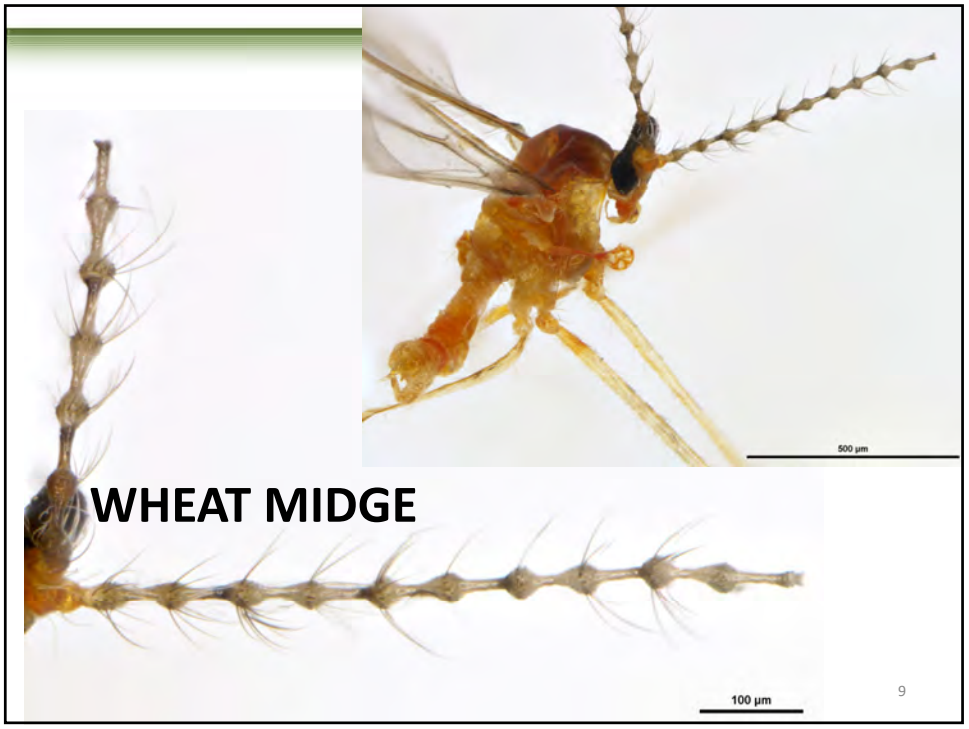
5

Life Cycle of Wheat Midge

6


Life Cycle of Wheat Midge
~25mm accumulated
Elliott et al.
Rain event
Larva - drop from heads after rain or heavy dew
cocoon
larva
pupa
cocoon
April
May
June
July
August
September
7


Life Cycle of Wheat Midge
Adult: heading to mid-anthesis is the danger zone
adult
Larva - drop from heads after rain or heavy dew
cocoon
larva
pupa
cocoon
April
May
June
July
August
September
8



WHEAT MIDGE

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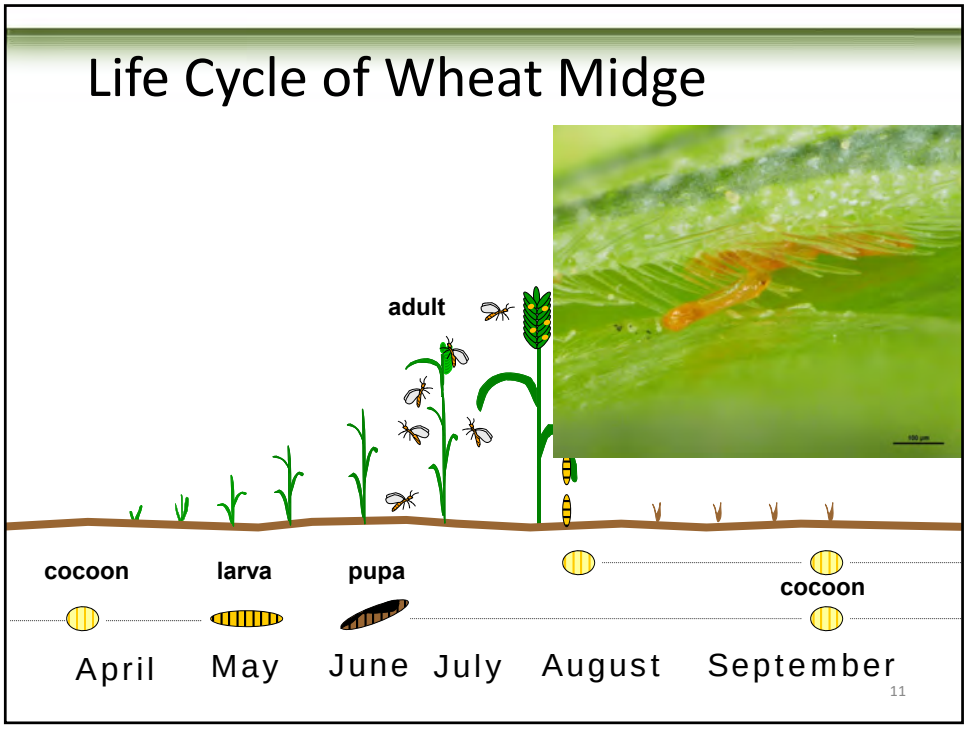

Life Cycle of Wheat Midge
adult
cocoon
larva
pupa
cocoon
April
May
June
July
August
September
11


100 µm
12

Damage: 1st-2nd instar

Three-four larvae per floret are common, but in severe infestations it can be much higher

adult

Larva - drop from heads after rain or heavy dew

pupa

cocoon

April May June July August September

13

Damage: 1st-2nd instar

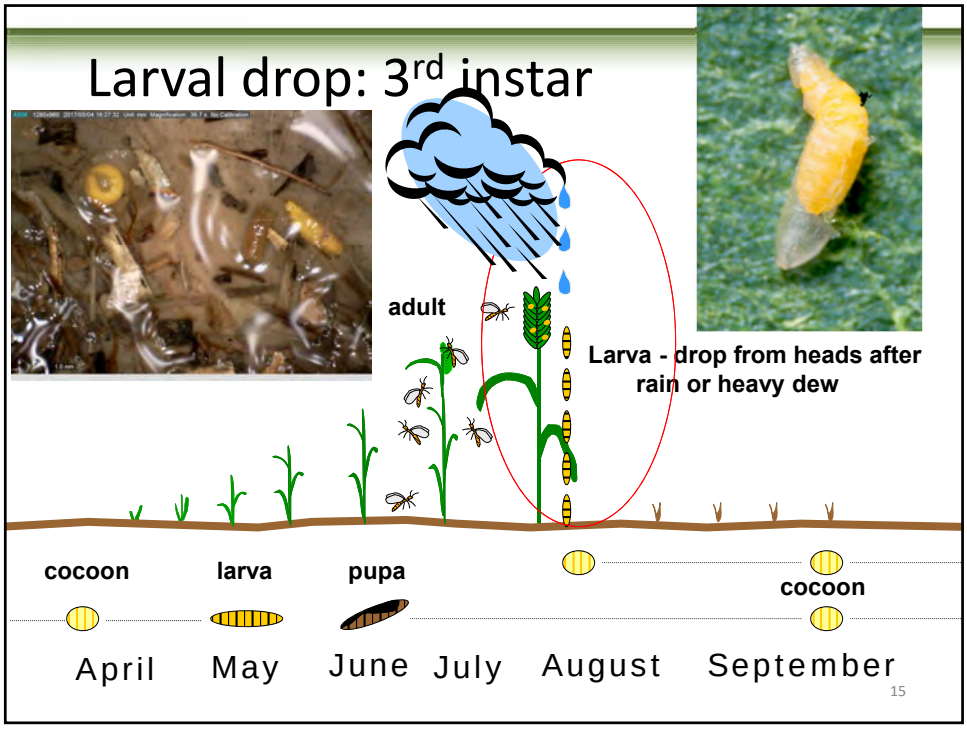
Three-four larvae per floret are common, but in severe infestations it can be much higher

Larva - drop from heads after rain or heavy dew

cocoon

April May June July August September

14


Larval drop: 3rd instar
adult
Larva - drop from heads after rain or heavy dew
cocoon
larva
pupa
cocoon
April
May
June
July
August
September
15

All three larval instars

17

Infestation to yield loss

Damage Relationship (SK):

Kernels Infested	Decrease	
0%	-	
30%	40%	
60%	65%	
90%	79%	*Olfert et al. 1985*

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Assess your risk for next year

- Was your wheat crop downgraded by midge last season?
- Irrigated field?
- Check your region on the forecast maps

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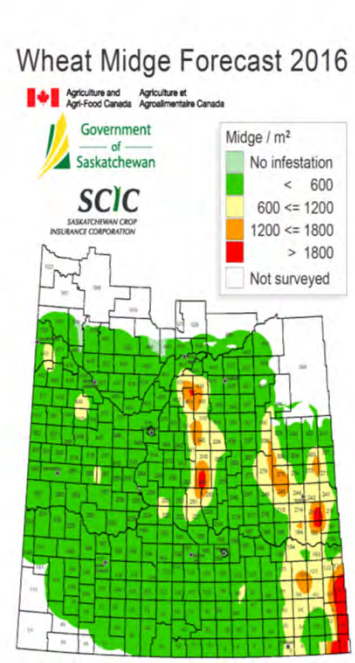
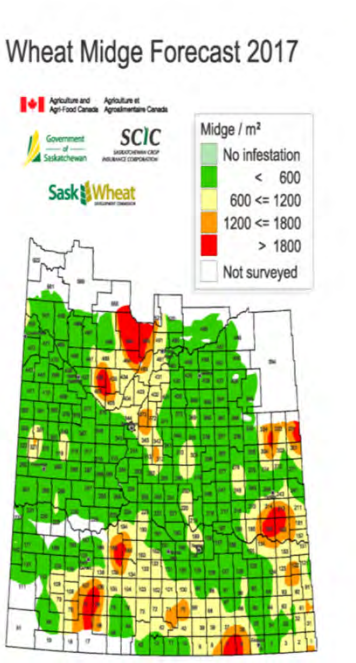
Midge Forecasting maps: soil coring

20





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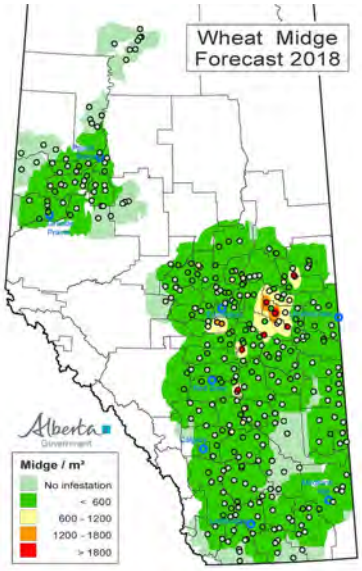
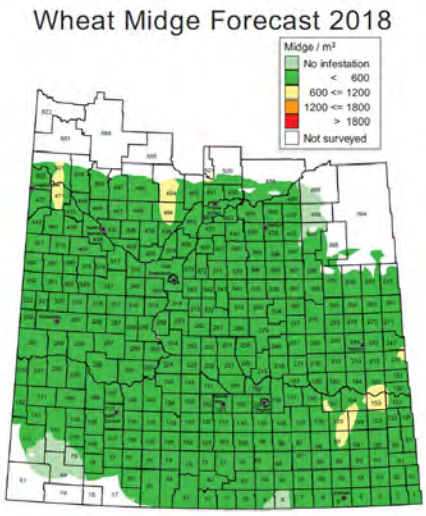
2018 Forecast: AB



www.gov.ab.ca
Alberta: Pheromone trapping network results posted in June and July

22

2018 Forecast: SK



SK: No pheromone trapping network

Maps posted on
Prairie Pest Monitoring Network
Blog
Subscribe!

420 samples

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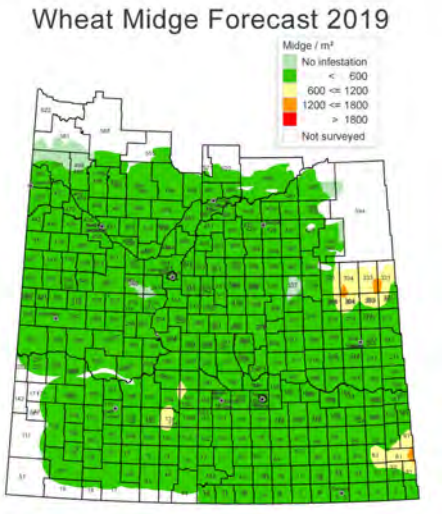
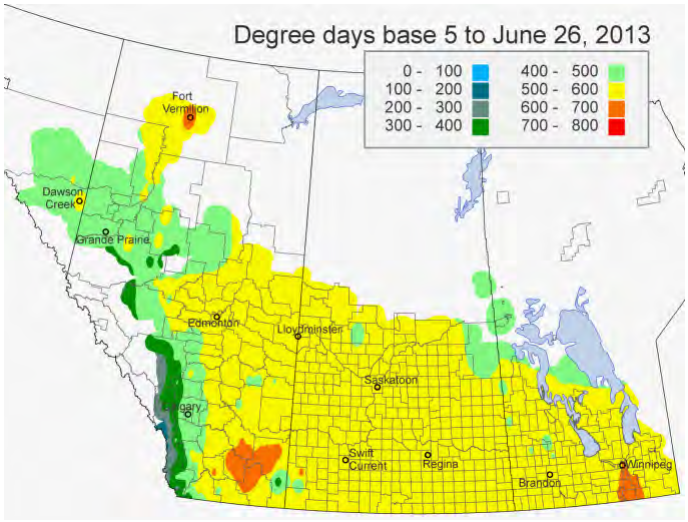
2019 Forecast: SK



420 samples

24

Forecasting adult emergence



Emergence	Dº D (>5ºC)
10%	693 (±2.8)
50%	784 (±2.5)
90%	874 (±3.2)

Elliott et al. 2009

Wheat Midge Management

- Conventional spring wheat requires regular monitoring when crop is in a susceptible stage
- Susceptible stage – when the wheat head becomes visible until crop flowering (anthesis)
- susceptibility drops dramatically at the onset of anthesis due to natural resistance from the build-up of ferulic acid
  - Elliott and Mann

Start of susceptibility

Wheat no longer susceptible

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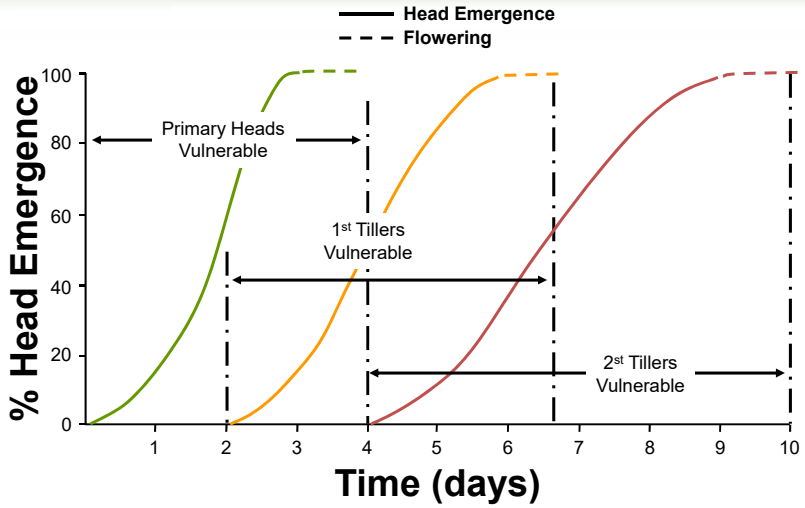

Susceptibility of primary and tillering heads of CWRS wheat to wheat midge damage

Battle Plan

- Scout adult activity at start of crop susceptibility
- Insecticidal spray
- Plant midge-tolerant wheat varieties

Scouting

- Visual scout: successive evenings
- "farmers, count adults at sunset during the period from heading to flowering" (Elliott and Mann 1996)
- yellow sticky cards
- pheromone traps

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Economic Thresholds

- **Economic Thresholds for Wheat Midge: visual**
- a) **To maintain optimum grade:** 1 adult midge per 8 to 10 wheat heads during the susceptible stage.
- b) **For yield only:** 1 adult midge per 4 to 5 heads. At this level of infestation, wheat yields will be reduced by approximately 15% if the midge is not controlled.
- Also, inspect the developing kernels for the presence of larvae and larval damage.

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Example: 7 midge per 5 heads

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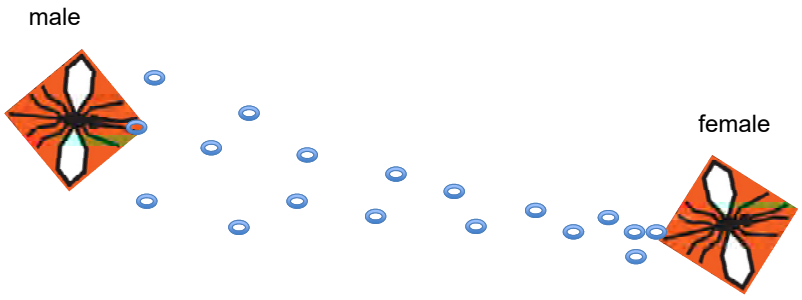
Pheromone trapping: Fatal attraction



2,7-nonanediyl dibutyrate

Gries et al. 2000

32

Pheromone trapping: Fatal attraction

2,7-nonanediyl dibutyrate

33

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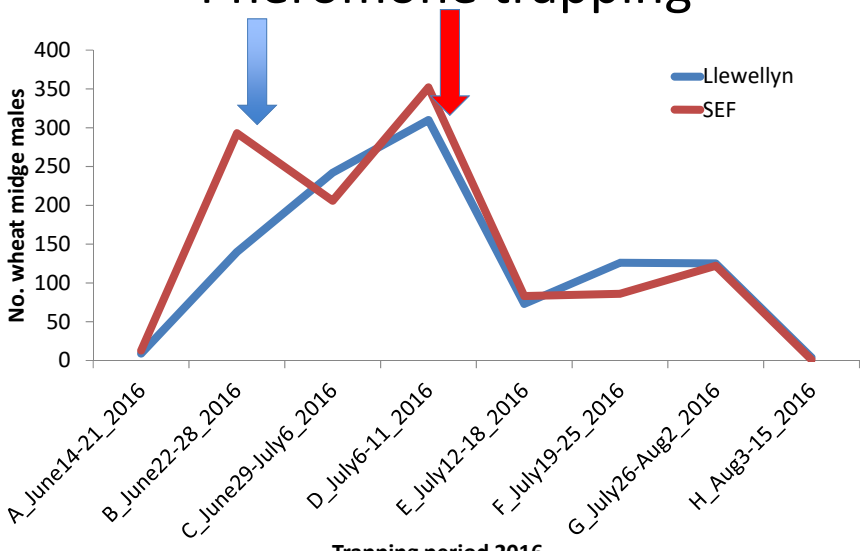
Pheromone trapping



UK rough ET 20-30/2 days
(Bruce et al. 2007)

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Insecticides

- Lorsban (chlorpyrifos products)
- Cygon/Lagon (dimethoate)
- Lorsban, 48-72 hour residual and kills already laid eggs.
- WM are more active in the evening, best time to spray
- Avoid later season sprays: <u>preserve parasitoids</u>

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Wheat midge parasitism
Biological control

- Three parasitoids attack wheat midge larvae in Western Canada (Doane, 1992).
- *Macroglenes penetrans* is the dominant species and did not need to be introduced.
- *Platygaster tuberosus* and *Euxestonotus error* were introduced near Langenburg, SK in the early 90s.

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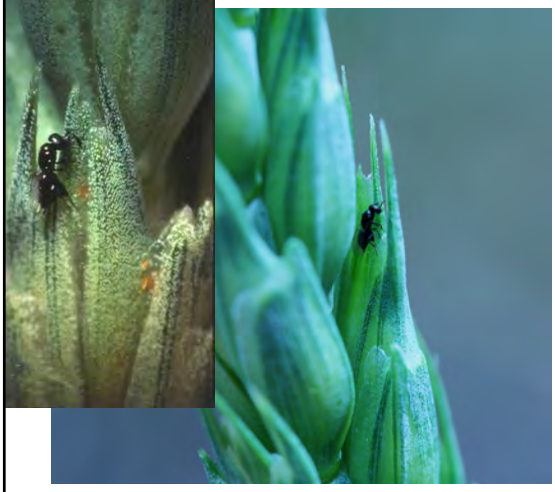
Macroglenes penetrans



Egg parasitoid

30-40% reduction of next year's wheat midge population

Spraying WM popn late kills parasitoids: emerges 4-5 days after wheat midge

(Smith et al. 2004, Wise et al. 2009)

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Macroglenes penetrans

Macroglenes penetrans is the dominant species. Naturally present in North America Discovered in SK in 1984

At $16.00/ha, the total saving in pesticide costs were over $200 million in the 1990's

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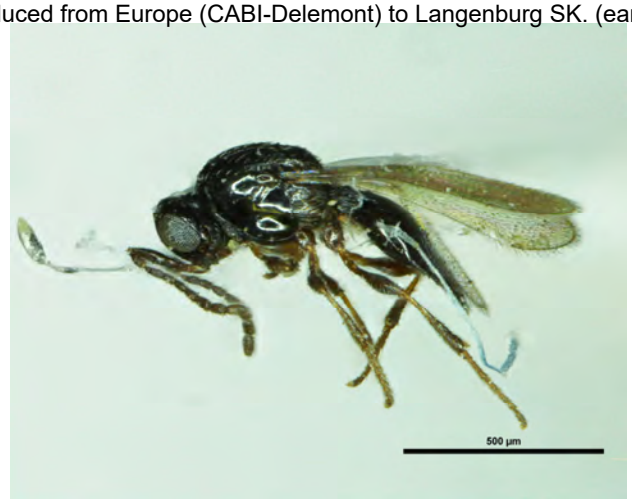
Euxestonotus error

Introduced from Europe (CABI-Delemont) to Langenburg SK. (early 1990s)



Pinned by John Doan. Image by Andrew Rigby for Tyler Wist Nov 2016

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Platygaster tuberosula

Introduced from Europe (CABI-Delemont) to Langenburg SK. (early 1990s)

22% parasitism in the release area

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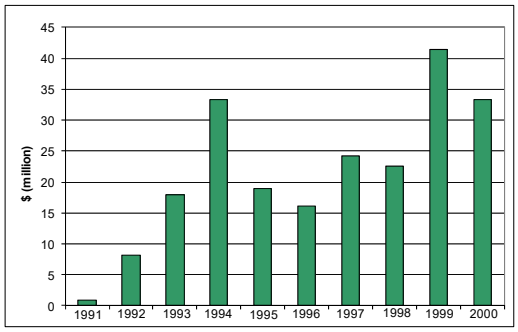
Farm Savings Due to Parasitoid



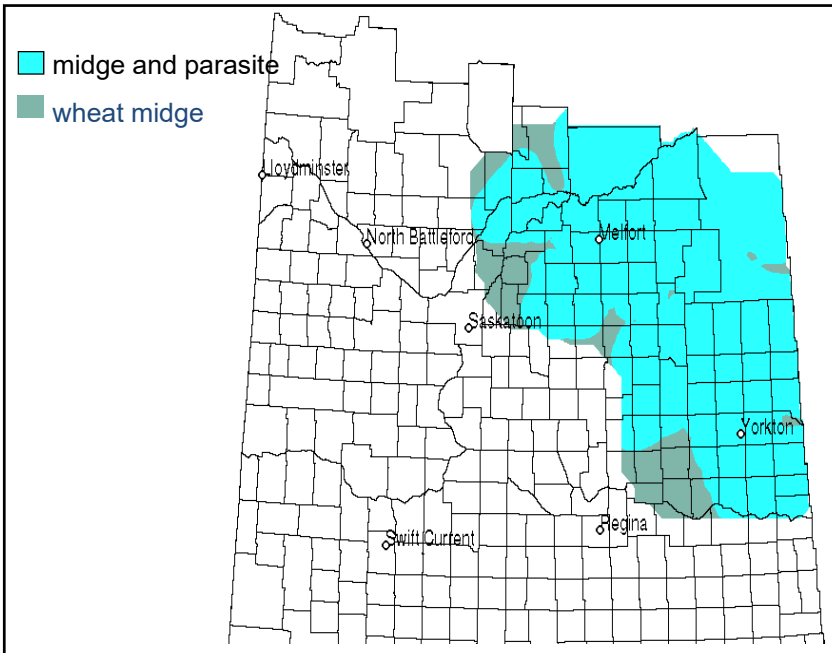
Olfert et al. 2009

- ✓ 1991-2000, there were ~15.5 million ha of wheat that did not require a pesticide application because parasitism reduced the density of viable wheat midge below 600/m2
- ✓ At a cost of $16.00/ha, the total saving in pesticide costs alone were over $200 million in the 1990's

Farm Savings Due to Parasitoid

"Estimated value of the parasitoid, due to reduction in insecticide costs in Saskatchewan alone, was estimated to be in excess of $**248.3 million** in the 1990s."
Olfert et al. 2009

- ✓ 1991-2000, there were ~15.5 million ha of wheat that did not require a pesticide application because parasitism reduced the density of viable wheat midge below 600/m2
- ✓ At a cost of $16.00/ha, the total saving in pesticide costs alone were over $200 million in the 1990's



Series of maps show expansion of wheat midge infestations in SK (1990's) and the success of parasite (*M. penetrans*) establishment

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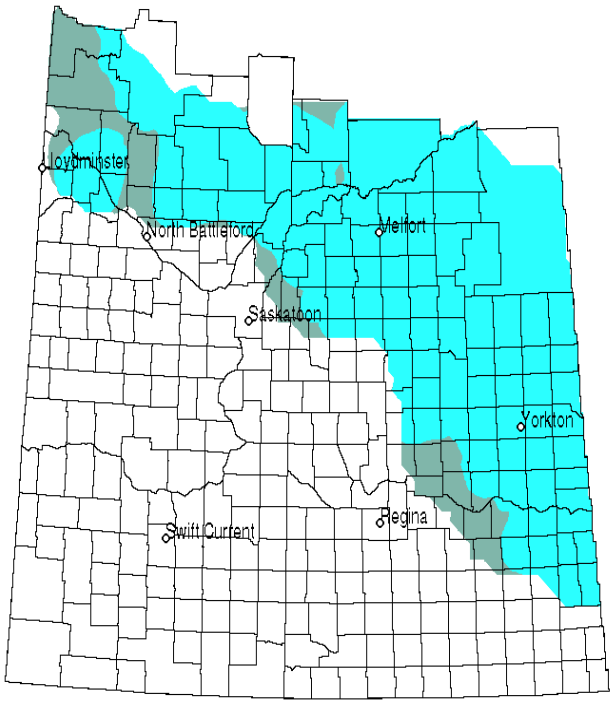

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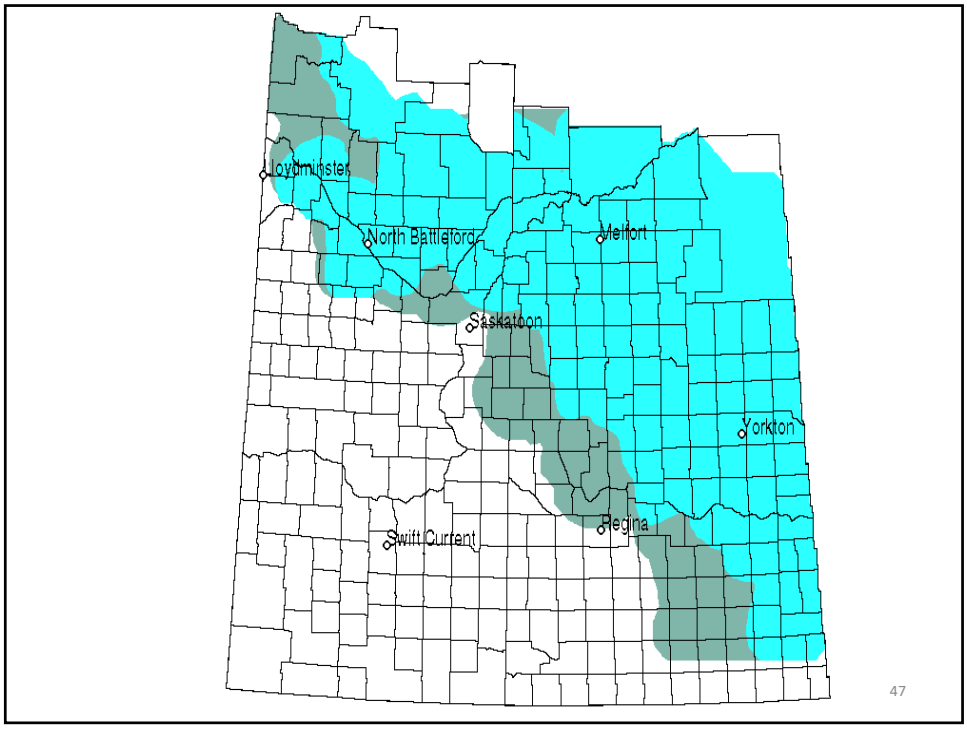
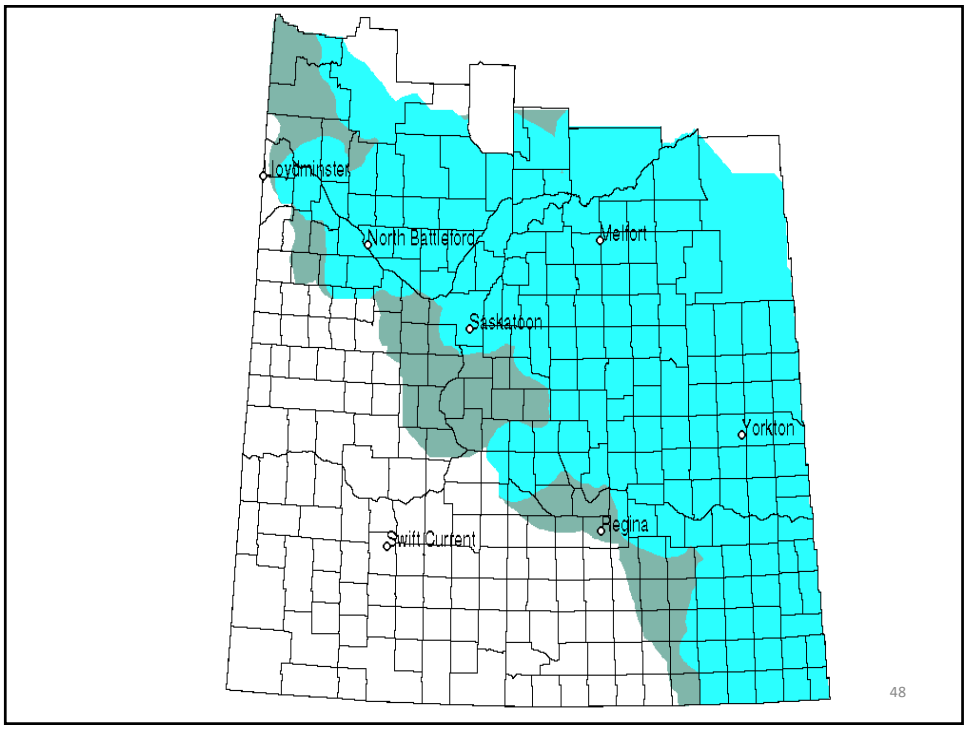

Loydminster
North Battleford
Melfort
Saskatoon
Yorkton
Regina
Swift Current
47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Yorkton
Regina
Swift Current
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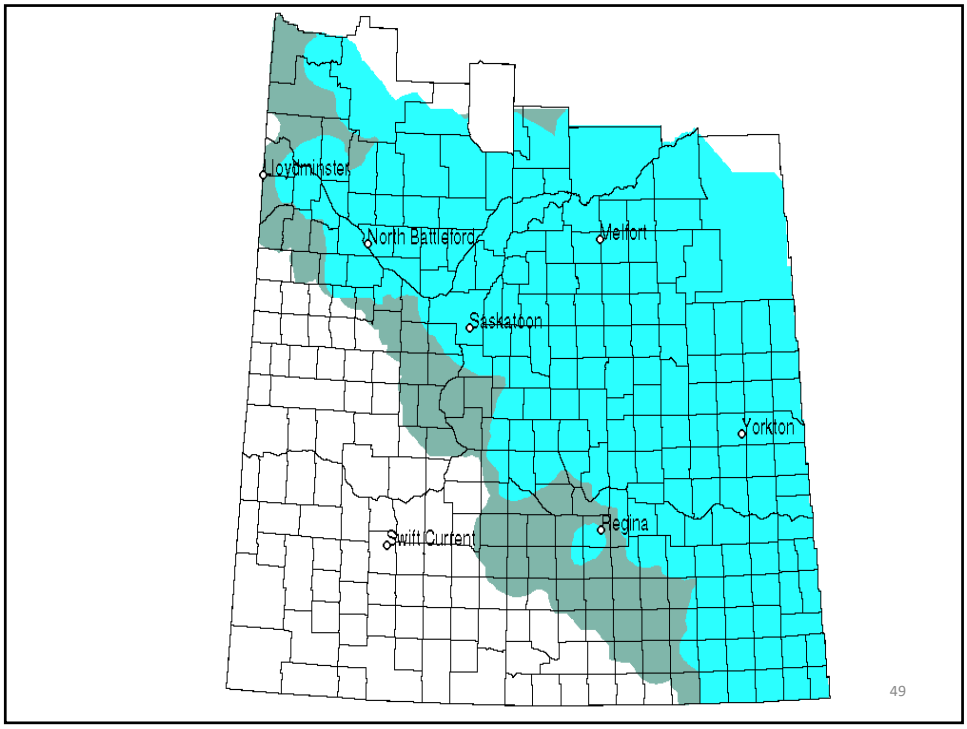
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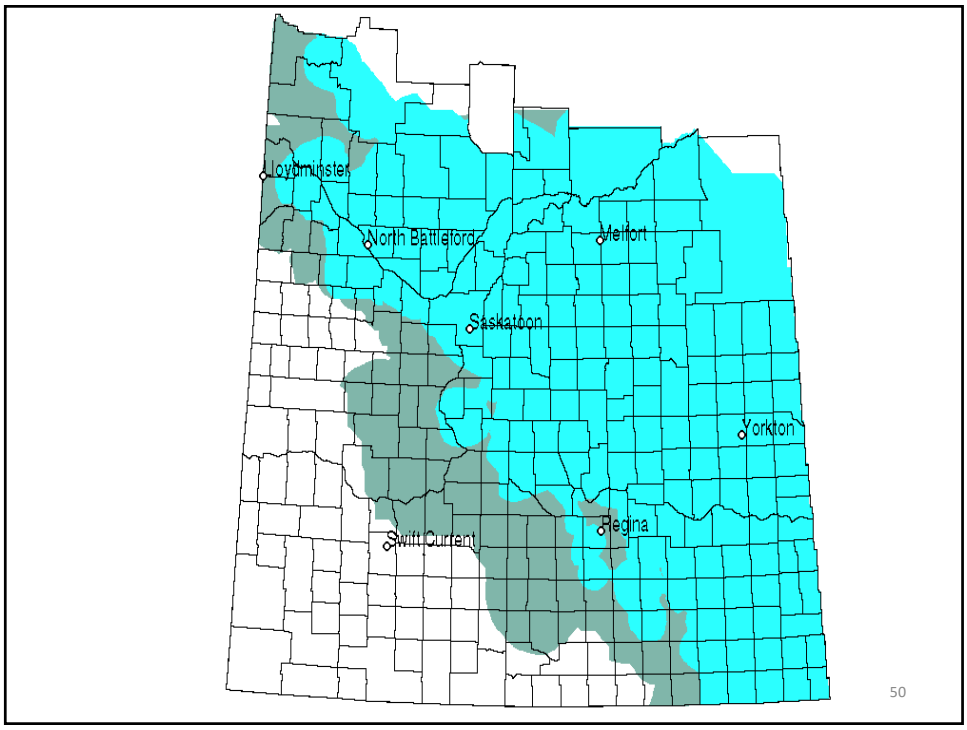
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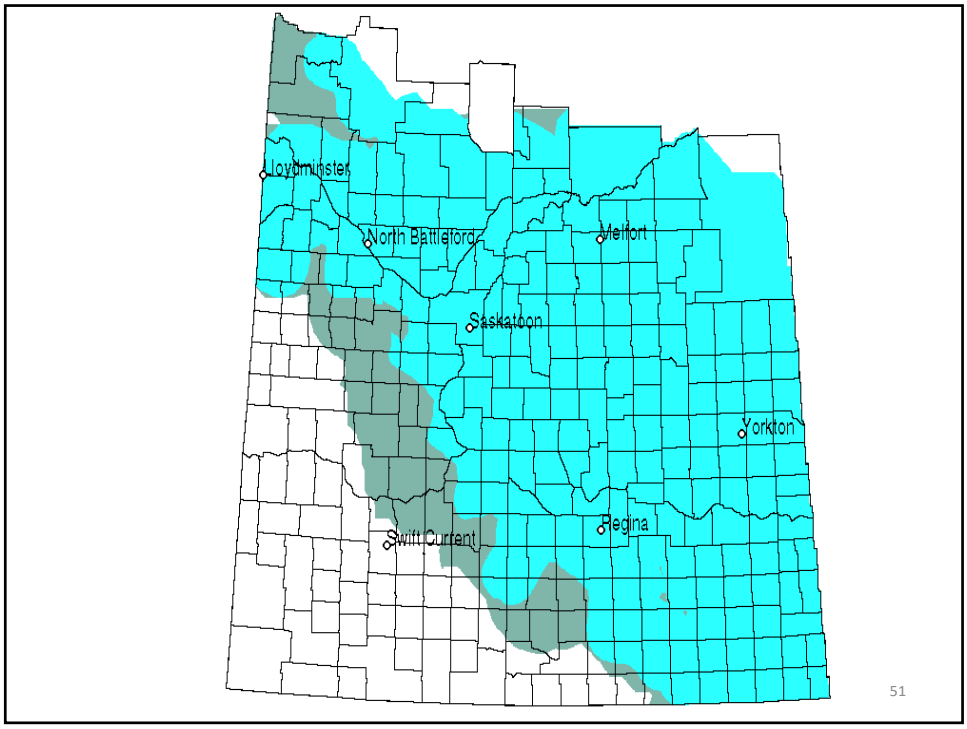
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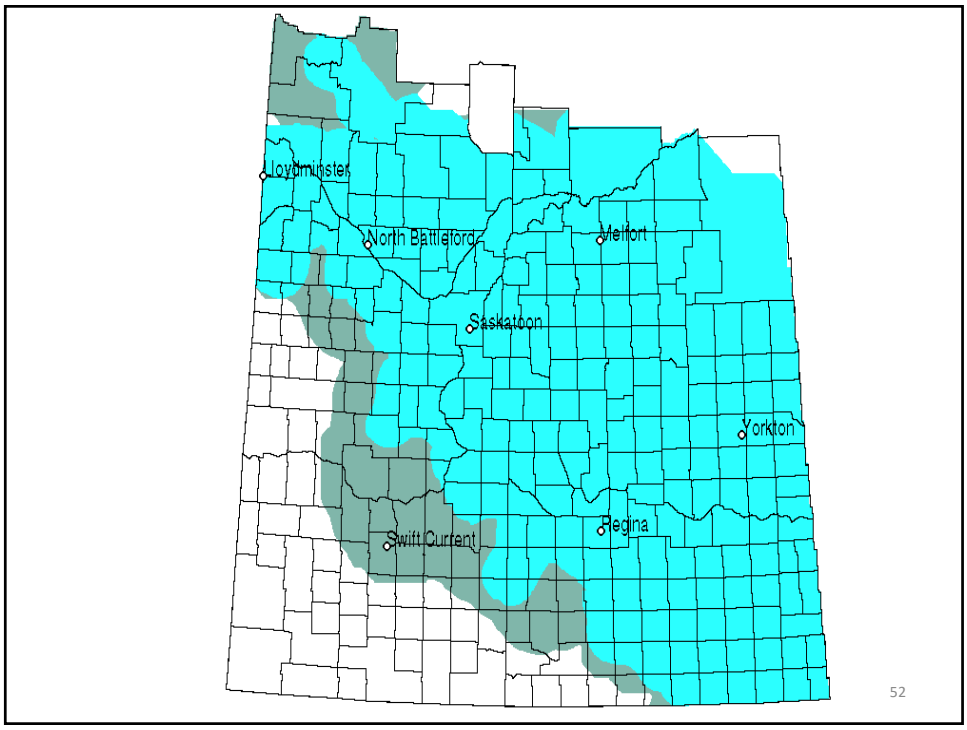
Lloydminster
North Battleford
Melfort
Saskatoon
Yorkton
Regina
Swift Current
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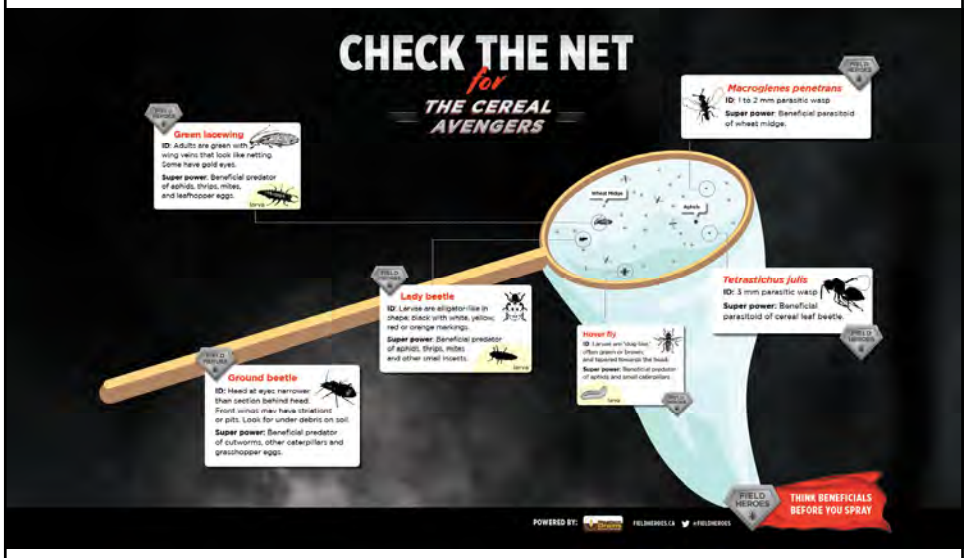
Wheat Midge - Predators

- Spiders and lady beetles feed on eggs (on heads)
- Staphylinids and Carabids feed on larvae and pupae (in soil)

SK STUDY (Floate *et al*. 1990)

- Lab: *Bembidion quadrimaculatum (9)*; *B. obscurellum (15); Agonum placidum (43)*; *Pterostichus corvus* (48)
- Field: Daily predation of all four – up to 86 midge larvae/m^2



Midge Tolerant wheat (MTW)

- *Sitodiplosis mosellana* 1 (*Sm*1) (Lamb *et. al.* 2000, McKenzie et. al. 2002, Ding et al. 2000)
- *Sm*1 gene. Late 1990s AAFC breeders crossed this naturally occurring trait into red spring wheat (CWRS and Extra Strong) from "Clark" winter wheat = Unity VB in 2007 (Fox *et al.* 2010).

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- 2010: AC® Unity VB, AC® Goodeve VB, AC® Glencross VB

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- 2017: 20 varieties with *Sm*1, CWRS, CPSR, CWES, CWAD, and GP/SP

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- 2010: AC® Unity VB, AC® Goodeve VB, AC® Glencross VB
- 2017: 20 varieties with *Sm*1, CWRS, CPSR, CWES, CWAD, and GP/SP
- 2018: 28 varieties with *Sm*1

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Midge tolerant wheat (MTW)

- 2015 – MTW on approximately 1/3 of prairie wheat acres
- 2016 – available in CWRS, CWES, CPSR classes.
- One CWAD (durum) Varietal blend (VB) (AAC Marchwell) widely available
- limited release, CDC Carbide durum.
- VB options available with both midge and fusarium head blight tolerance http://www.midgetolerantwheat.ca
- Refer to the Provincial Seed Guides and seed sellers for wheat suitable to your area

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Midge Tolerant Wheat - Varieties

Tolerant Variety	Refuge Variety	Class
AC® Unity VB	AC® Waskada	CNHR
AC® Goodeve VB	AC Intrepid	CWRS
AC® Glencross VB	AC® Burnside	CWES
AC® Fieldstar VB	AC® Waskada	CWRS
AC® Shaw VB	AC Domain	CWRS
CDC Utmost VB	Harvest	CWRS
AC® Conquer VB	5701PR	CPSR
AC® Vesper VB	AC® Waskada	CWRS
AC® Enchant VB	AC Crystal	CPSR

At least another 10 varieties since 2017

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*Sm*1 mode of action

- 1st instar larva starts feeding (gall forming midge)
- Plant reacts quickly to larval feeding and increases ferulic and p-coumaric acid levels (Ding et al. 2000)
- Larvae stop feeding and starve to death

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MIDGE TOLERANT WHEAT
Plant · Protect · Preserve

There is NO Plan B.

Midge tolerant wheat protects your crop against devastating pest damage, but it's up to you to protect the technology.

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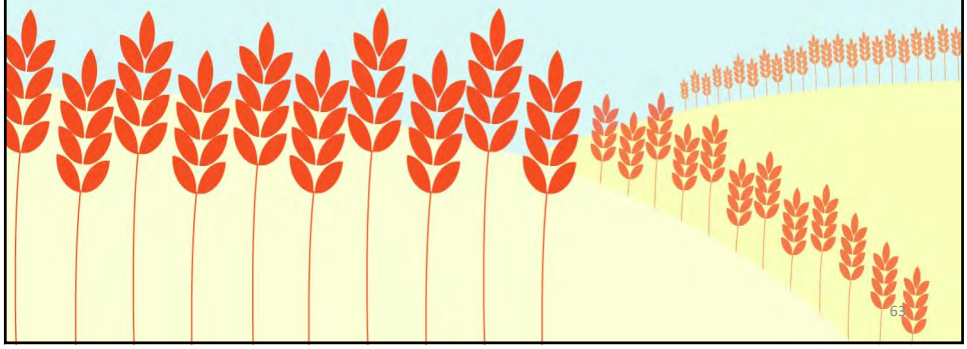
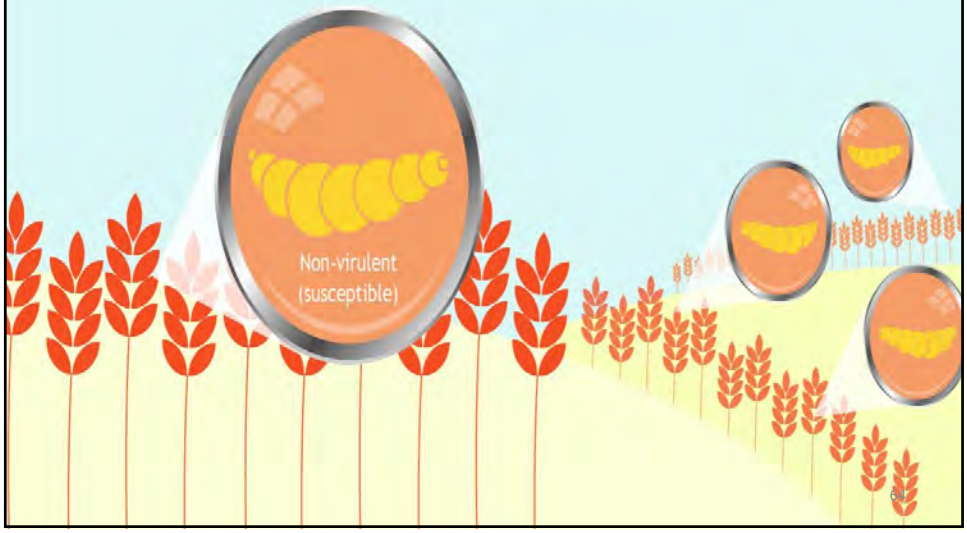
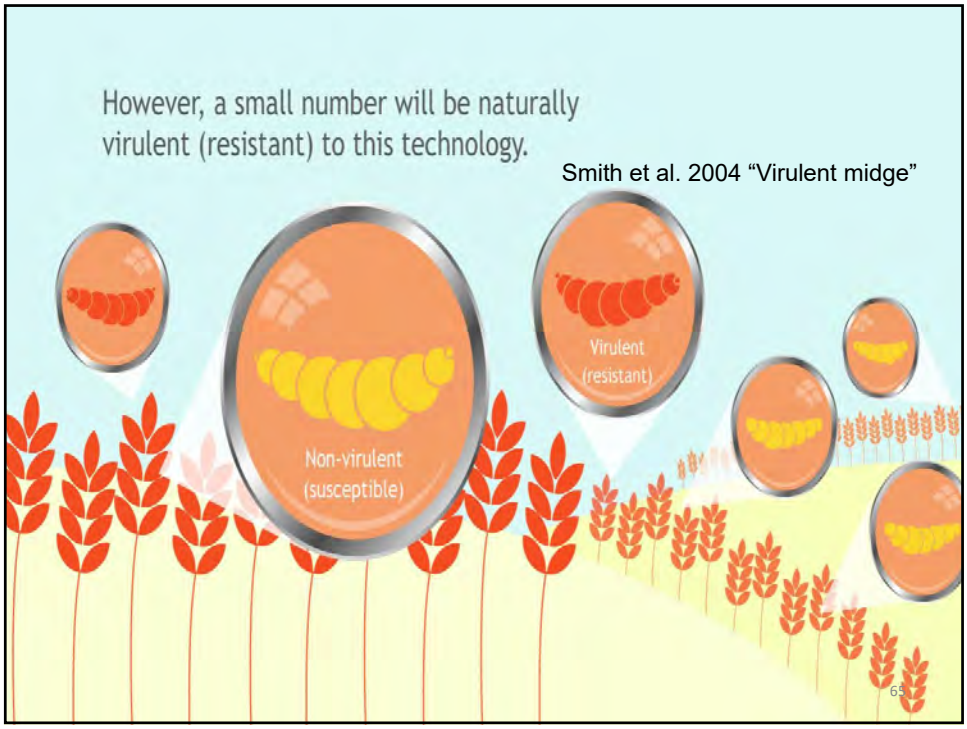
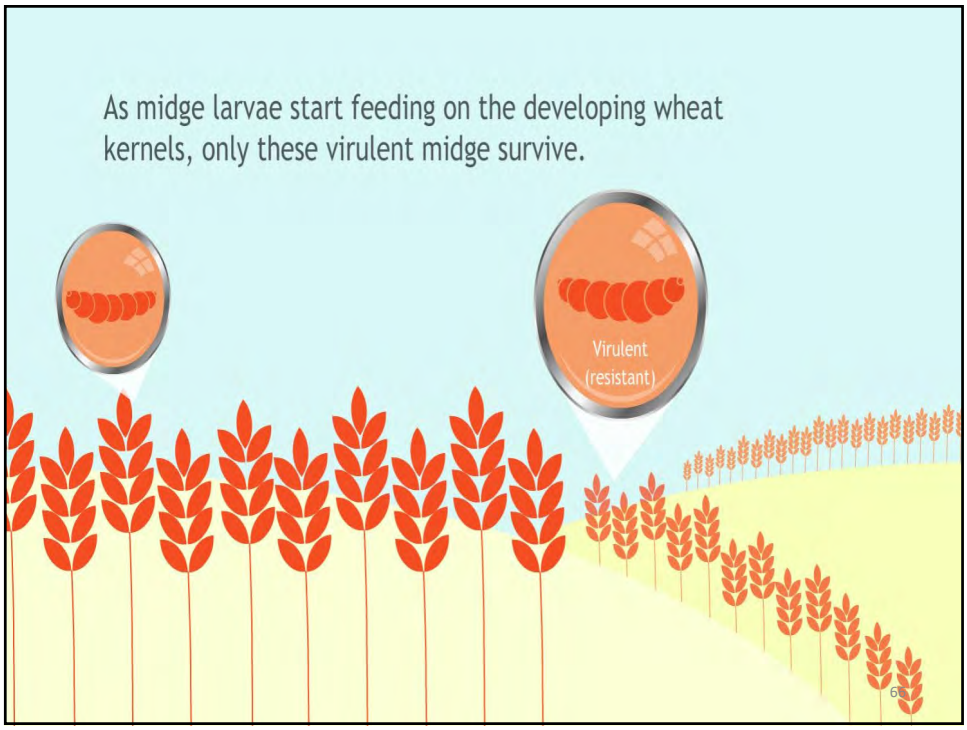
Without a proper refuge system, the field is planted with just the single variety of midge tolerant wheat.



In a natural wheat midge population, the majority of midge are non-virulent (or susceptible) to the midge tolerance gene.




However, a small number will be naturally virulent (resistant) to this technology.
Smith et al. 2004 “Virulent midge”
Non-virulent (susceptible)
Virulent (resistant)


As midge larvae start feeding on the developing wheat kernels, only these virulent midge survive.
Virulent (resistant)


As adults, the virulent midge would mate only with each other.
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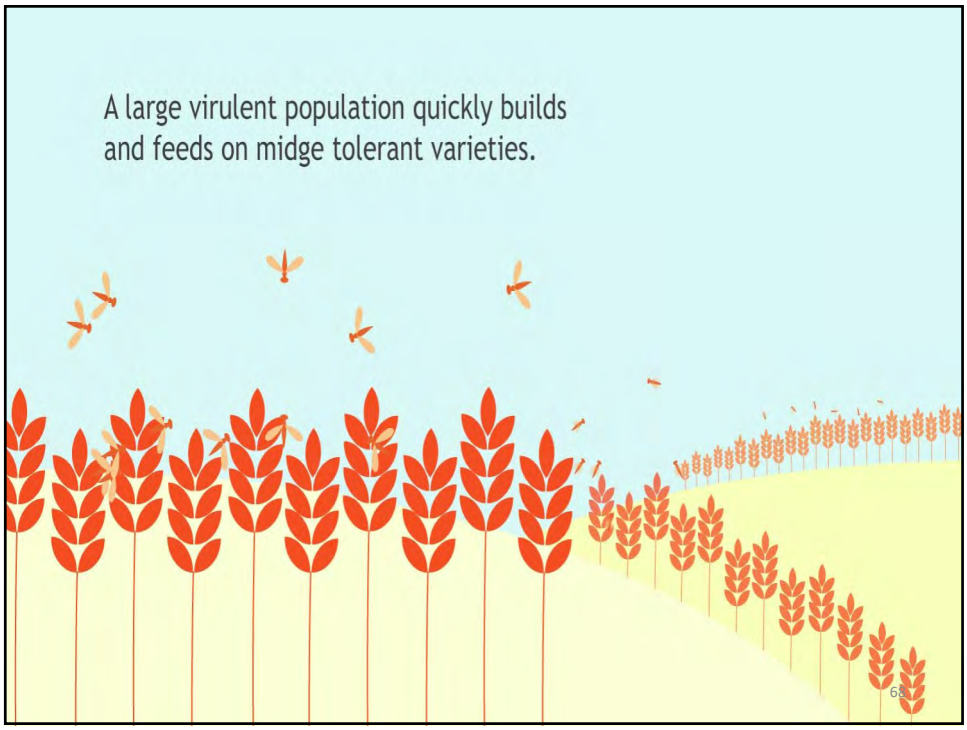
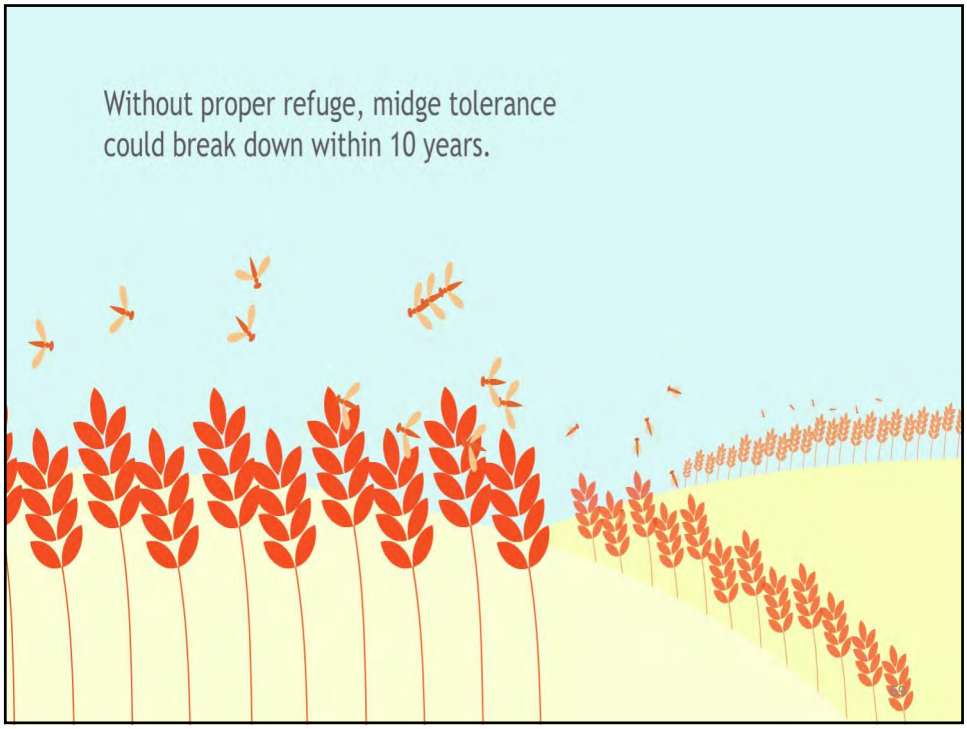
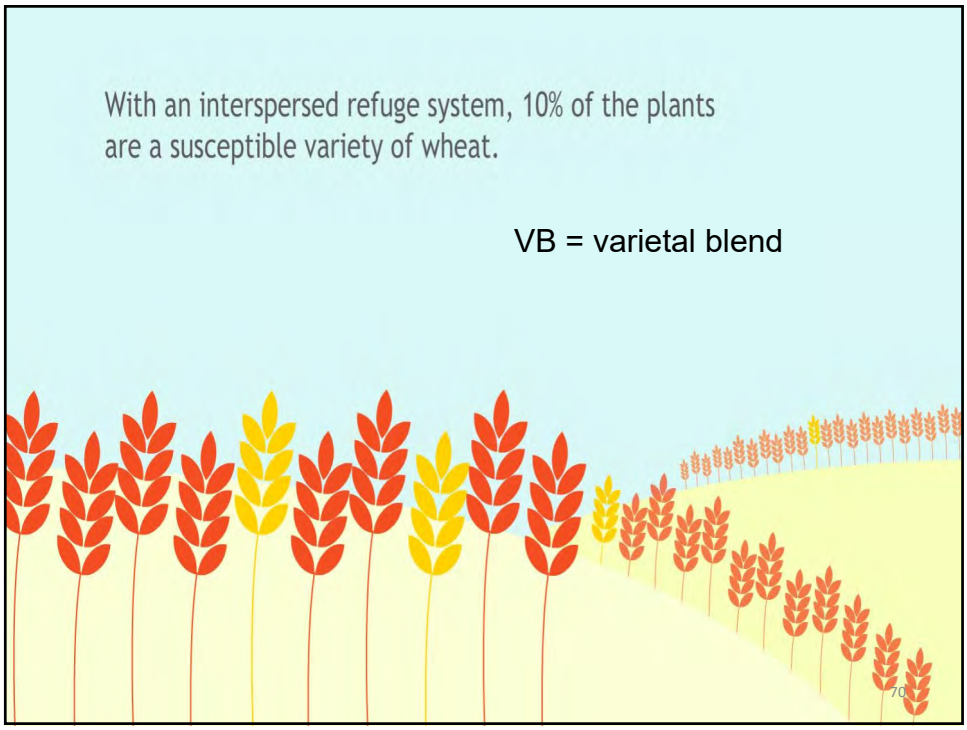
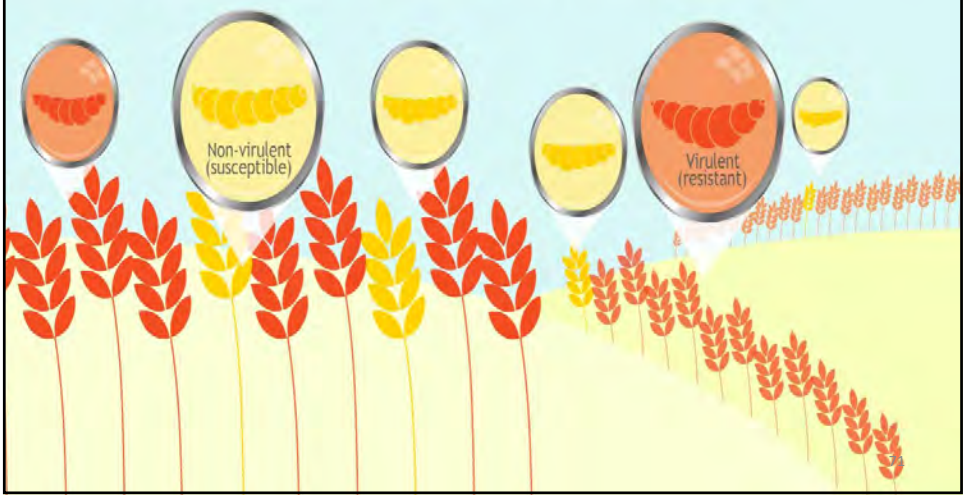

A large virulent population quickly builds
and feeds on midge tolerant varieties.
68


Without proper refuge, midge tolerance
could break down within 10 years.


With an interspersed refuge system, 10% of the plants
are a susceptible variety of wheat.
VB = varietal blend

As the natural population of non-virulent midge larvae and virulent (resistant) midge larvae feed on the wheat kernels, some non-virulent midge will survive on the 10% susceptible plants.

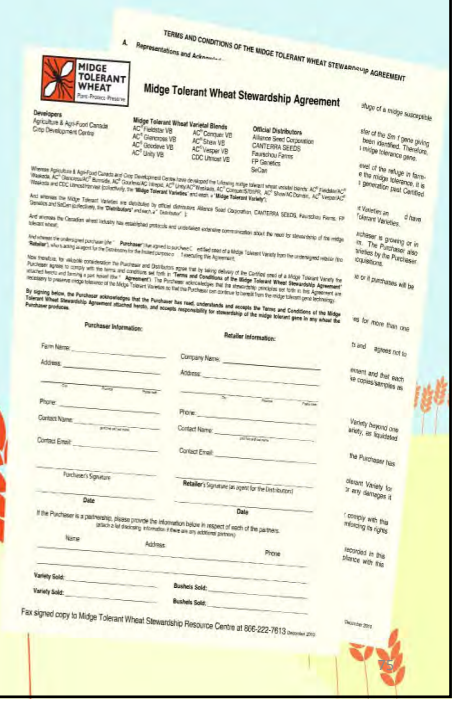


As adults, the non-virulent midge would inter-mate with the virulent midge

The offspring of this cross would be non-virulent, since non-virulence is the dominant trait.

This prevents a build up of a large virulent midge population, and could extend the life of midge tolerance to 90 years or longer.

Farmers interested in planting a midge tolerant wheat variety will be required to sign a Midge Tolerant Wheat Stewardship Agreement.


TERMS AND CONDITIONS OF THE MIDGE TOLERANT WHEAT STEWARDSHIP AGREEMENT

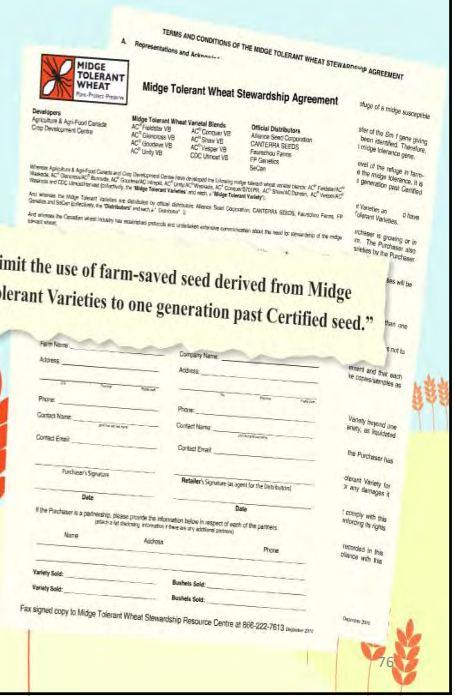
MIDGE TOLERANT WHEAT

Midge Tolerant Wheat Stewardship Agreement

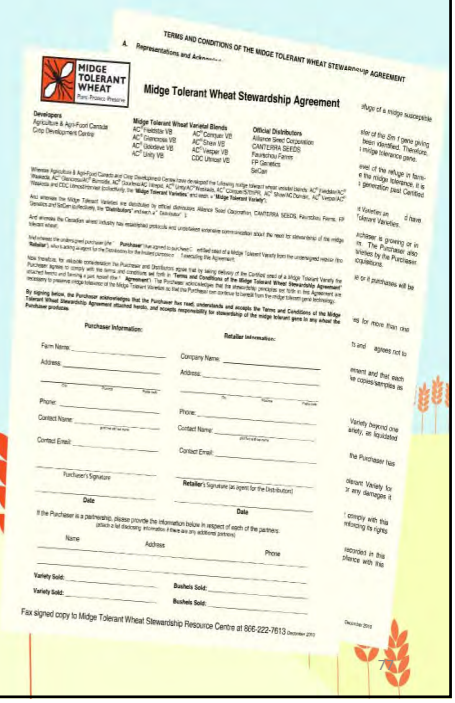
Fax signed copy to Midge Tolerant Wheat Stewardship Resource Centre at 866-222-7613

This agreement states that farm-saved seed must be limited to one generation past Certified seed...

Why?


"limit the use of farm-saved seed derived from Midge Tolerant Varieties to one generation past Certified seed."

This limitation is critical to ensure the refuge remains at the desired level of 10% of the plant population.


TERMS AND CONDITIONS OF THE MIDGE TOLERANT WHEAT STEWARDSHIP AGREEMENT

MIDGE TOLERANT WHEAT

Midge Tolerant Wheat Stewardship Agreement

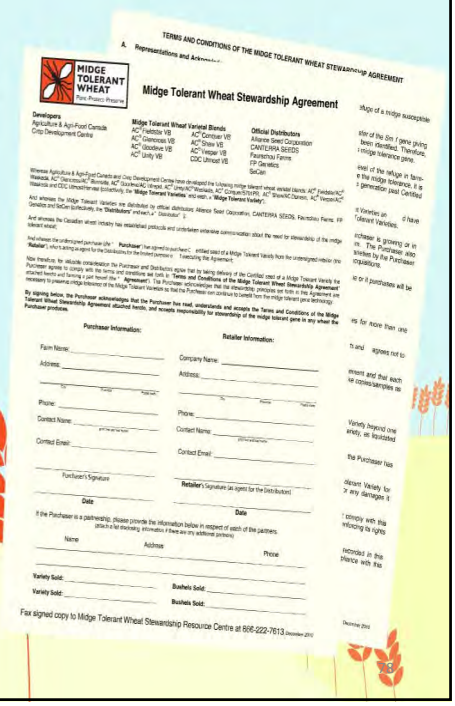
Developers

Midge Tolerant Wheat Varietal Blends

Official Distributors

Fax signed copy to Midge Tolerant Wheat Stewardship Resource Centre at 866-222-7613

The refuge in farm-saved seed may change substantially over multiple generations and not provide adequate protection.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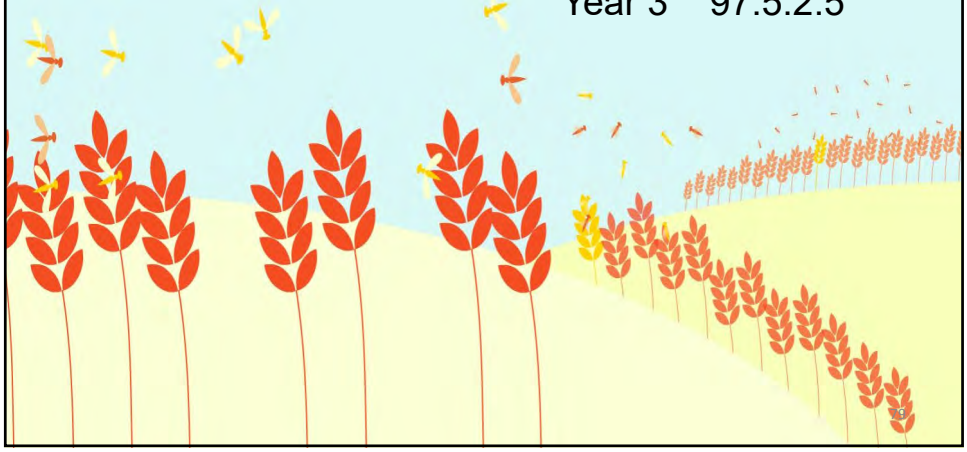
For example, under an extremely heavy midge infestation, the susceptible refuge variety could sustain up to 50% yield loss.

Year 2	95:5
Year 3	97.5:2.5



By understanding and following the stewardship agreement limitations on farm-saved seed, you can realize these benefits for years to come:

1. Prevent an estimated $36 per acre loss from midge damage.
2. Reduce reliance on insecticide applications.
3. Gain more flexibility in crop rotations and seeding dates.

Without the proper 10% refuge, midge tolerance could break down within 10 years.

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MIDGE TOLERANT WHEAT
Plant·Protect·Preserve

Contact your local retailer or visit www.midgetolerantwheat.ca to learn more.

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Soft White spring wheat

- *Sm*1 naturally found in many white spring wheat varieties, recent genetic markers

PROBLEM! …no refuge. No VB. No stewardship

- AC Sadash, AAC Chiffon, AAC Indus
- Mix 1 bushel AC Andrew to 9 bushels SWS *Sm*1

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WM resistance traits Oviposition Deterrence (OD)

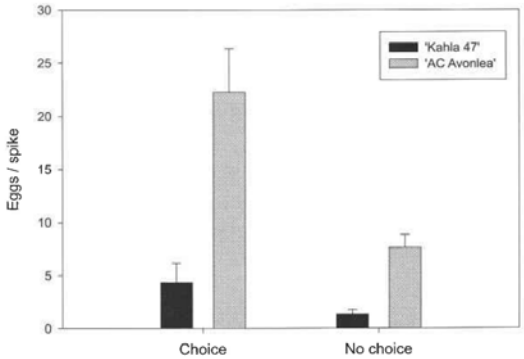


FIGURE 3. Mean (± SE) number of eggs of *Sitodiplosis mosellana* per spike on 'Kahla 47' and 'AC Avonlea' durum wheat in choice (six tests pooled) and no-choice tests (five tests pooled) in the laboratory.

Lamb *et al.* 2001

OD in Reeder, Parshall, Waskada, Key10 and durum wheat, Kahla and Kahla-47

OD Reduces oviposition by **>50%** (Lamb *et al.* 2000, 2001, 2002)

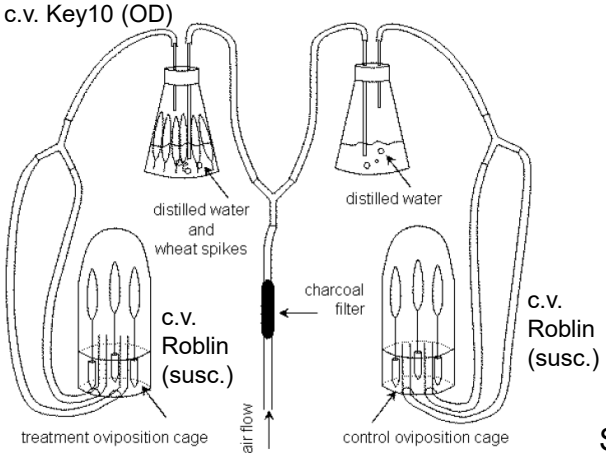
Antixenosis resistance

Wheat Cluster: Collaborative project with UManitoba: Ale Costamagna

84

WM resistance traits: OD

c.v. Key10 (OD)



Antixenosis resistance

25 ± 3 eggs/♀ 24% less 41 ± 7 eggs/♀

Gharalari et al. 2011

Stacking OD and *Sm*1
UManitoba: Ale Costamagna

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Potential WM resistance traits

Jones Fife winter wheat: Robert Graf AAFC Lethbridge

"Hairy glumes"
Mechanical resistance?

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Potential WM resistance traits

Mechanical resistance?

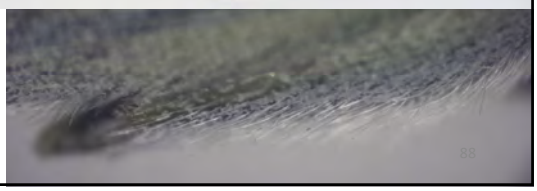
Jones Fife x CDC Stanley: in seed increase

87

Potential WM resistance traits

CDC Teal: Pierre Hucl CDC breeder

Mechanical resistance?



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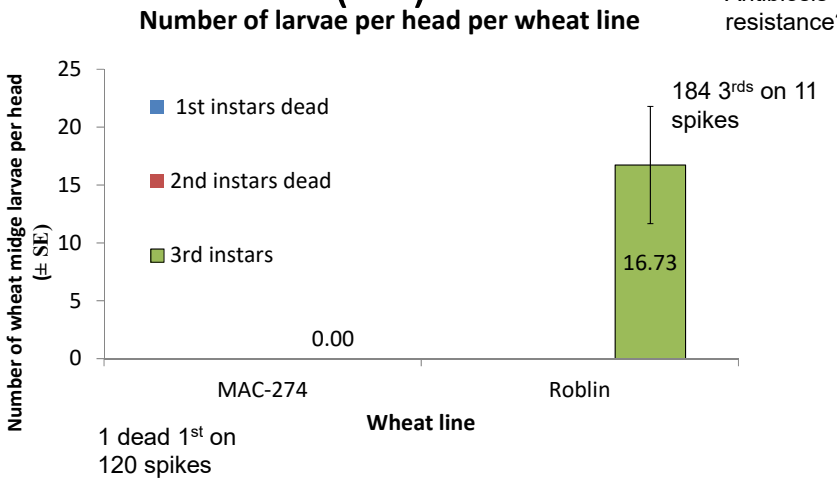
WM resistance traits: Egg Antibiosis (EA)

Antibiosis resistance?



EA trait: Curt McCartney AAFC Morden

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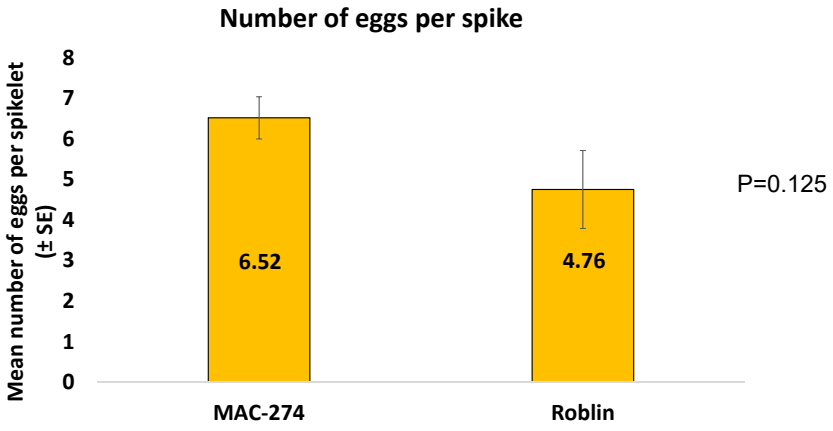
WM resistance traits: Egg Antibiosis (EA)

Antibiosis resistance:
Not reduced oviposition



P=0.125

EA trait: Curt McCartney AAFC Morden

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Acknowledgements

- Jill Sauter and Synthesis-Network for MTW infographics
- Techs and summer students of the Wist lab
- ADF, Western Grains, SaskWheat, Alberta Wheat, Manitoba Wheat
- Four decades of WM researchers
- Dr. Owen Olfert for life cycle slides

Questions?

"When we kill off the natural enemies of a pest, we inherit their work" – **Carl Huffaker**

ie. Not late in the WM flight period

@FieldHeroes

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