Addressing concerns for Alberta's agricultural productivity

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In completion of PLNT 670

Why should we be concerned?

- **White headache**
  (https://www.producer.com/2019/10/white-headache/)
  - “We just didn’t get enough sun and heat to get the crops dried down.”
  - “Seventeen (percent moisture) is the new dry for wheat in our area. I don’t think there’s been a bit of dry wheat or barley — or anything for that matter — that’s come off dry so far.”
- **The Sprout: Snowmageddon leaves $3 billion of Alberta crop in fields**
  (https://ipolitics.ca/2018/10/12/the-sprout-snowmageddon-leaves-3-billion-of-alberta-crop-in-fields/)
  - **“**Last night, one Alberta county declared a state of agricultural disaster. “

Table: Estimates of Harvest Progress as of December 3, 2019

	% Combined					
	South	Central	N East	N West	Peace	Alberta
Spring Wheat*	97.5%	92.0%	90.0%	95.5%	65.3%	89.8%
Durum Wheat	99.3%	99.6%	---	---	---	99.3%
Winter Wheat	100%	100%	100%	---	---	100%
Barley*	98.6%	94.5%	92.3%	93.6%	56.1%	93.1%
Oats*	97.5%	92.3%	82.9%	93.7%	63.8%	85.3%
Fall Rye	100%	100%	100%	---	---	100%
Triticale	100%	99.8%	---	---	---	99.8%
Mixed Grain	99.0%	95.9%	---	---	---	96.0%
Mustard	98.9%	100%	---	---	---	99.3%
Canola*	95.3%	91.0%	81.7%	91.6%	66.4%	84.5%
Dry Peas*	100%	96.1%	98.7%	99.5%	88.2%	96.7%
Lentils	100%	100%	---	---	---	100%
Chickpeas	100%	100%	---	---	---	100%
Flax	99.1%	73.8%	99.0%	---	---	92.7%
Potatoes	88.7%	100%	---	98.0%	---	89.8%
All Crops this week	**97.6%**	**92.9%**	**86.9%**	**93.1%**	**67.7%**	**89.6%**
Major Crops* this week	**97.5%**	**92.6%**	**87.1%**	**93.7%**	**68.0%**	**88.8%**
All Crops Nov. 29, 2016	**100%**	**93.2%**	**81.0%**	**82.4%**	**84.6%**	**89.7%**

Source: AF/AFSC Crop Reporting Survey

And it's a recurring problem…

Estimates of Crop Harvest Progress as of October 30, 2018

	% of Combined					
	South	Central	N East	N West	Peace	Alberta
Spring Wheat *	94.3%	96.3%	98.3%	93.6%	96.2%	96.1%
Durum Wheat	94.6%	100.0%	---	---	---	95.4%
Winter Wheat	99.8%	100.0%	100.0%	---	---	99.8%
Barley *	98.1%	95.1%	96.3%	88.6%	95.5%	95.6%
Oats *	94.8%	94.2%	96.2%	89.6%	95.2%	93.7%
Fall Rye	99.7%	100.0%	100.0%	---	---	99.9%
Canola *	91.8%	95.1%	93.6%	80.4%	92.8%	91.7%
Dry Peas *	99.6%	99.6%	99.8%	99.8%	93.8%	98.6%
Lentils	99.7%	100.0%	---	---	---	99.7%
Flax	96.2%	83.8%	100.0%	---	---	94.6%
Potatoes	99.0%	100.0%	---	100.0%	---	99.1%
All Crops	**95.5%**	**95.9%**	**96.1%**	**87.2%**	**94.2%**	**94.7%**
Major Crops	**95.2%**	**95.8%**	**96.1%**	**87.2%**	**94.2%**	**94.5%**
Last Week (Major Crops)	**85.0%**	**75.3%**	**79.4%**	**65.6%**	**76.1%**	**77.7%**
November 1, 2016 **	**96.3%**	**70.0%**	**67.9%**	**55.2%**	**79.3%**	**76.0%**

**: Major crops (reported for abbreviated survey), **: All crops*

Source: AF/AFSC Crop Reporting Survey

Estimates of Crop Harvest Progress as of October 31, 2017

	Per cent of Combined					
	South	Central	N East	N West	Peace	Average
Spring Wheat	100.0%	99.9%	98.3%	97.5%	97.3%	98.9%
Durum Wheat	100.0%	100.0%	---	---	---	100.0%
Barley	100.0%	99.8%	97.5%	96.8%	96.8%	98.9%
Oats	100.0%	99.7%	97.6%	98.7%	95.6%	98.2%
Winter Wheat	100.0%	100.0%	100.0%	---	---	100.0%
Canola	99.9%	99.3%	98.2%	96.9%	92.9%	97.5%
Dry Peas	100.0%	100.0%	100.0%	99.6%	100.0%	100.0%
Lentils	100.0%	100.0%	100.0%	---	---	100.0%
Chick peas	100.0%	100.0%	---	---	---	100.0%
Mustard	100.0%	100.0%	---	---	---	100.0%
Flax	99.8%	99.6%	99.5%	---	---	99.7%
All crops	**100.0%**	**99.7%**	**98.2%**	**97.2%**	**95.3%**	**98.6%**

Source: AF/AFSC Crop Reporting Survey

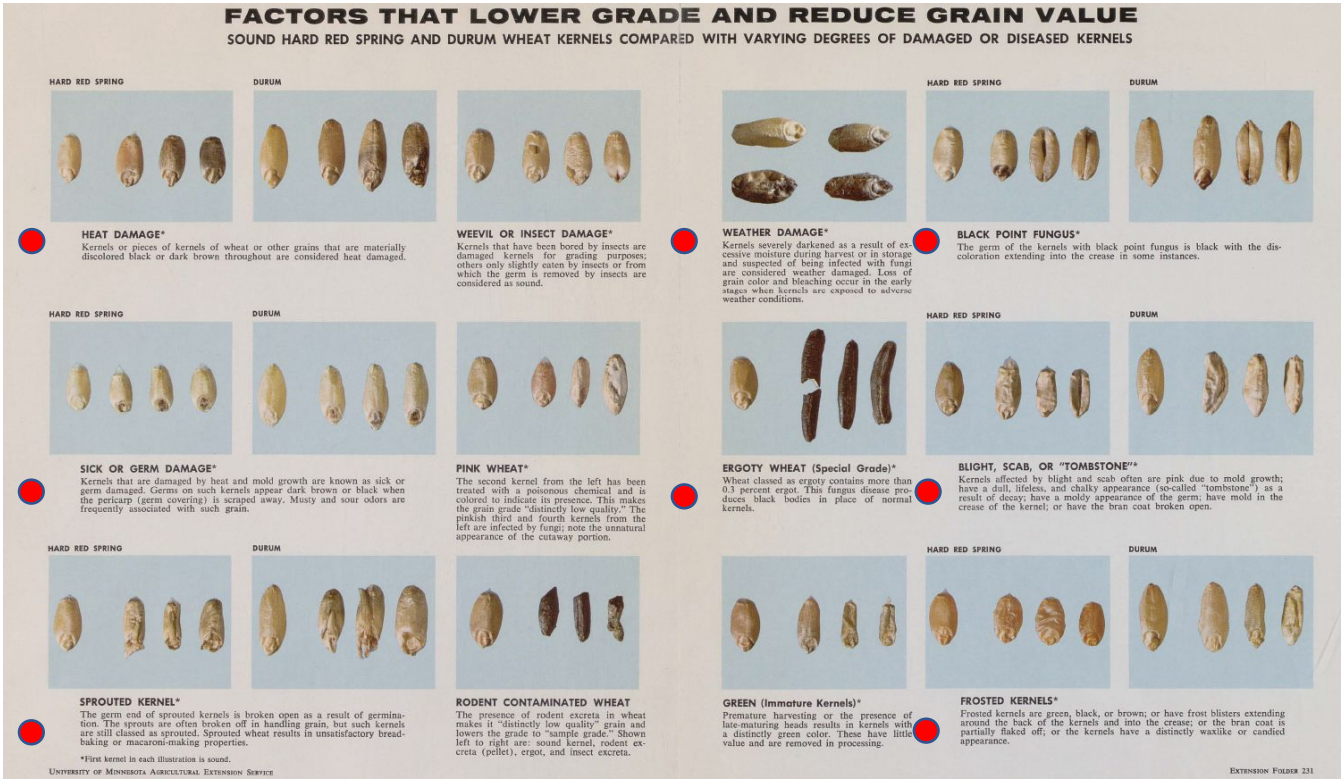
Estimates of Crop Harvest Progress as of November 29, 2016

	Per cent of Combined					
	South	Central	N East	N West	Peace	Average
Spr. Wheat	100.0%	92.7%	85.4%	83.5%	85.3%	90.8%
Dur. Wheat	100.0%	100.0%	---	---	---	100.0%
Barley	100.0%	92.6%	72.8%	77.0%	81.0%	88.7%
Oats	100.0%	90.6%	66.5%	70.6%	79.3%	77.1%
W. Wheat	100.0%	100.0%	100.0%	---	---	100.0%
Canola	100.0%	92.8%	78.5%	83.5%	83.6%	86.8%
Dry Peas	100.0%	98.3%	99.8%	98.5%	93.0%	98.5%
Lentils	100.0%	100.0%	---	---	---	100.0%
Chick peas	100.0%	100.0%	---	---	---	100.0%
Mustard	100.0%	100.0%	---	---	---	100.0%
Flax	100.0%	91.1%	57.5%	---	---	92.9%
All crops	**100.0%**	**93.2%**	**81.0%**	**82.4%**	**84.6%**	**89.7%**

Source: AF/AFSC Crop Reporting Survey

Estimates of Regional Crop Harvest Progress, Alberta						
	Per Cent Combined					
	South	Central	NE	NW	Peace	Alberta
	As of November 3, 2015					
Spring Wheat	100.0%	99.7%	99.6%	100.0%	99.8%	99.8%
Durum Wheat	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%
Barley	100.0%	99.7%	99.9%	99.9%	99.7%	99.8%
Oats	100.0%	99.5%	99.8%	99.8%	99.8%	99.7%
Canola	100.0%	99.5%	99.5%	98.1%	99.3%	99.3%
Dry Peas	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
All Crops	**100.0%**	**99.6%**	**99.6%**	**99.1%**	**99.5%**	**99.7%**
	As of October 20, 2015					
All Crops	**99.7%**	**93.9%**	**94.2%**	**95.6%**	**97.7%**	**96.3%**
Source: AF/AFSC Crop Reporting Survey						

What does the wet weather do to grain quality?



FACTORS THAT LOWER GRADE AND REDUCE GRAIN VALUE

SOUND HARD RED SPRING AND DURUM WHEAT KERNELS COMPARED WITH VARYING DEGREES OF DAMAGED OR DISEASED KERNELS

HARD RED SPRING

DURUM

HEAT DAMAGE*

Kernels or pieces of kernels of wheat or other grains that are materially discolored black or dark brown throughout are considered heat damaged.

WEEVIL OR INSECT DAMAGE*

Kernels that have been bored by insects are damaged kernels for grading purposes; others only slightly eaten by insects or from which the germ is removed by insects are considered as sound.

WEATHER DAMAGE*

Kernels severely darkened as a result of excessive moisture during harvest or in storage and suspected of being infected with fungi are considered weather damaged. Loss of grain color and bleaching occur in the early stages when kernels are exposed to adverse weather conditions.

BLACK POINT FUNGUS*

The germ of the kernels with black point fungus is black with the discoloration extending into the crease in some instances.

SICK OR GERM DAMAGE*

Kernels that are damaged by heat and mold growth are known as sick or germ damaged. Germs on such kernels appear dark brown or black when the pericarp (germ covering) is scraped away. Musty and sour odors are frequently associated with such grain.

PINK WHEAT*

The second kernel from the left has been treated with a poisonous chemical and is colored to indicate its presence. This makes the grain grade "distinctly low quality." The pinkish third and fourth kernels from the left are infected by fungi; note the unnatural appearance of the cutaway portion.

ERGOTY WHEAT (Special Grade)*

Wheat classed as ergoty contains more than 0.3 percent ergot. This fungus disease produces black bodies in place of normal kernels.

BLIGHT, SCAB, OR "TOMBSTONE"*

Kernels affected by blight and scab often are pink due to mold growth; have a dull, lifeless, and chalky appearance (so-called "tombstone") as a result of decay; have a moldy appearance of the germ; have mold in the crease of the kernel; or have the bran coat broken open.

SPROUTED KERNEL*

The germ end of sprouted kernels is broken open as a result of germination. The sprouts are often broken off in handling grain, but such kernels are still classed as sprouted. Sprouted wheat results in unsatisfactory bread-baking or macaroni-making properties.

*First kernel in each illustration is sound.

RODENT CONTAMINATED WHEAT

The presence of rodent excreta in wheat makes it "distinctly low quality" grain and lowers the grade to "sample grade." Shown left to right are: sound kernel, rodent excreta (pellet), ergot, and insect excreta.

GREEN (Immature Kernels)*

Premature harvesting or the presence of late-maturing heads results in kernels with a distinctly green color. These have little value and are removed in processing.

FROSTED KERNELS*

Frosted kernels are green, black, or brown; or have frost blisters extending around the back of the kernels and into the crease; or the bran coat is partially flaked off; or the kernels have a distinctly waxlike or candied appearance.

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EXTENSION FOLDER 231

So what if the quality is a bit lower?

Example of how grain prices are affected by quality

- 4 grades for wheat – Grade 1, 2, 3 and 8 (feed grade)
- Market prices given online are for grade 1 and 2 -> $197.50/ton
- Grade 3 is $10 lower
- Feed grade grain can be 30%-70% discounted depending on the cause!

Additional problems…

- Lodging
- Pre harvest sprouting
- Fungal contamination
- Hormone and signalling regulation
- Other agronomic practices
- Consumer acceptance

Our recommendations:

- Short-term:
  - ***Agricultural Productivity Initiative* Survey**
  - **Improve farmer acceptance of Best Agronomic Practices**
  - **Strategies for improved consumer acceptance of GMO**

Survey

Agricultural Productivity Initiative Survey

Personal information

Please tell us a bit about yourself…		
Last name		
First name		
Mailing address		
Number	Street	
City	Province	Postal code

General harvest information

Please rate your harvest on the following:					
	Fantastic				**Very Unhappy**
1. Weather conditions for taking it off	•	•	•	•	•
2. Grade when you (or 3rd party) tested it	•	•	•	•	•
3. Grade you were given at the elevator	•	•	•	•	•

Did you send a sample to get an official grade?	Yes	No	Date

Agricultural Productivity Initiative Survey
Crop information

Crop type		Manufacturer	
Cultivar Name			
Planting date		Harvest date	
Final grade at sale		Yield (ton/acre)	
Fertilizer application			
Date	Mixture	Manufacturer	
Pesticide application			
Date	Target	Manufacturer	
Did you use any of the following:			
Biocontrols		Yes	No
Date	Brand	Manufacturer	
Plant growth regulators (ethelphon, etc)			
Date	Brand	Manufacturer	

Improving Farmer Acceptance

Large Scale Commercial

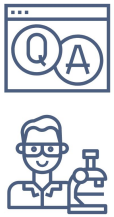
Family Operated

Strategies to improve consumer acceptance on genome editing

- Invest in advertisements about genome editing and its applications.

- Create profiles and pages on social media and share fact–checked information on a regular basis.

- Conduct live interviews and Q&A's with scientists to engage and interact with the general public.



- Create a user–friendly website with interactive resources like quizzes and surveys.

- Conduct talks and workshops in schools and universities to raise awareness on food production challenges and how genome editing plays a role.

- Participation in agricultural fairs, increasing awareness and acceptance of genome editing among farmers and conducting surveys to gather peoples opinions.

Our recommendations:

- **Long-term:**

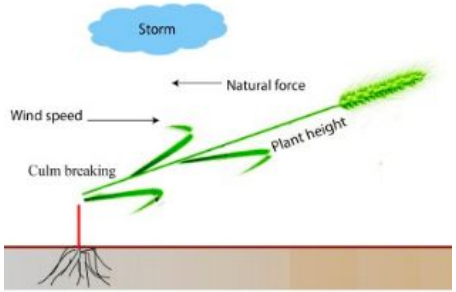
Agricultural Productivity Research Initiative

- **Research Partnerships between research institutions and industry for:**
  - Lodging resistance
  - Early germination resistance
  - Hormone treatments
  - Best agronomic practices

- **Improved regulatory framework for genome editing**

Physical damage (lodging)

- Displacement of the plant from its original position.
- Difficult harvesting.
- Decreased grain size, number and weight.
- Susceptibility to fungal diseases.



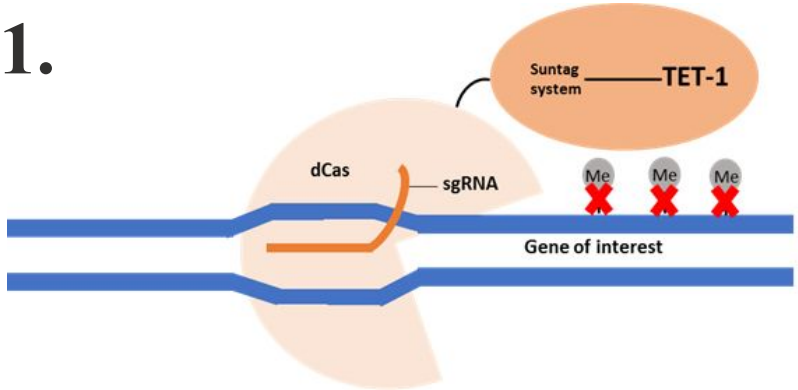
- Management practices.
- Dwarf and semi-dwarf varieties.
- Plant growth regulators.

Strategies for improving cellulose content and lodging resistance

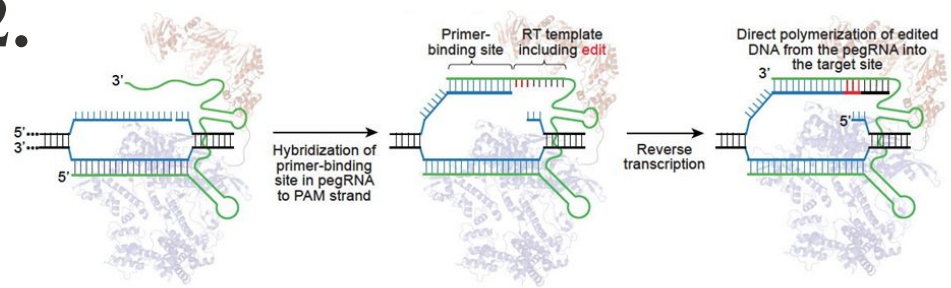
1. Epigenome editing for overexpression of CesA genes in different species.

2. Prime editing for SNPs and mutations related to lodging resistance.

1.



2.



Modified from Anzalone et al., 2019

Agronomic solutions for lodging

Plant growth regulators (PGRs)

✓Provide stem strength, shorten plant height, and prevent lodging (Xu et al 2017).

✓ E.g. Chlormequate chloride and Ethephon decrease plant height along with enhanced grain production in wheat.

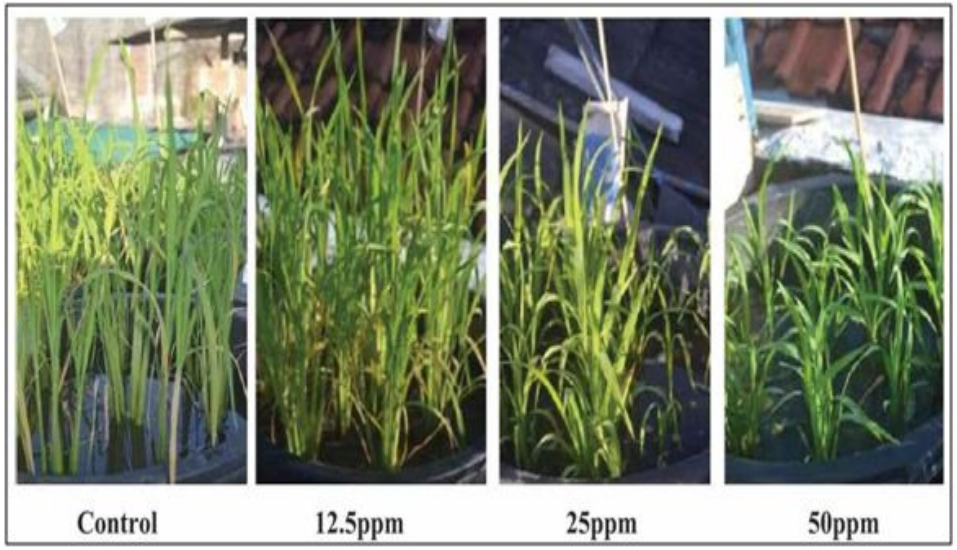
✓ Paclobutrazol enhanced lignin in the stem cell wall. Hua et al (2014) studied the effect of Paclobutrazol in canola.

Intercropping and mixed cropping

✓Intercropping can provide better lodging resistance (Assefa and Ledin 2001).

✓ Cai et al (2019) reported mixed cropping of two wheat cultivars, 'Shannong8355' (lodging-resistant) and 'Shannong15' (SN15, lodging-susceptible)

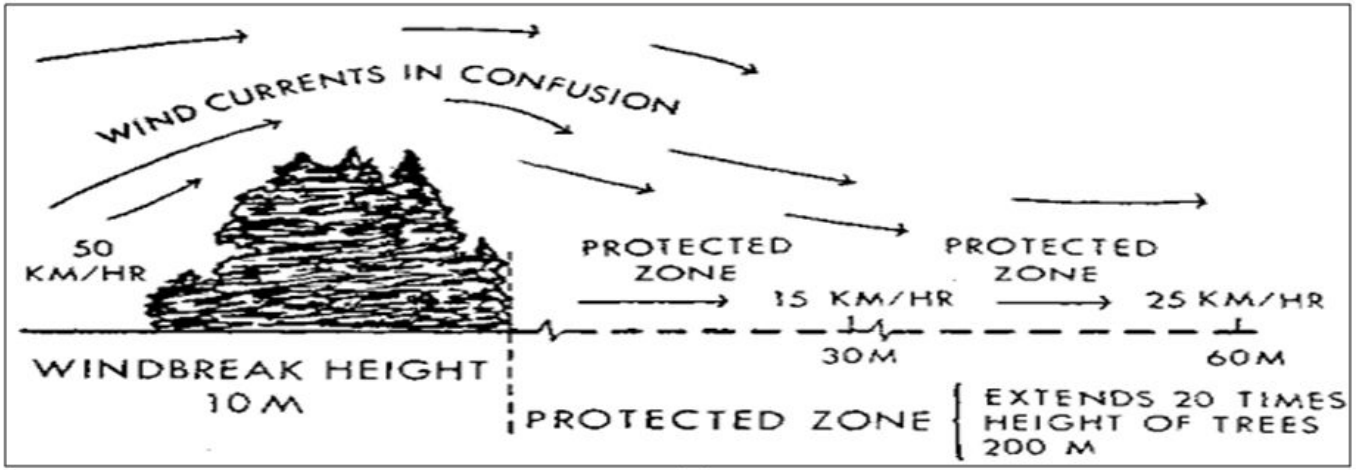
✓ In Alberta, pea-canola (Peaola).



Effect of Paclobutrazol on rice stalk height

Pea-Canola intercrop (Peaola)

Wind shelters/windbreaks



Frost management

Weather monitoring	Agronomical solutions
➢ Frost forecasting	➢ Cold air drainage
➢ Weather maps site wise	➢ Nutrition management
	➢ Soil management
	➢ Irrigation

Dormancy and early germination

a.k.a... Pre-Harvest Sprouting

- grains and oilseeds

canola

https://www.canolawatch.org/2019/09/18/pre-harvest-scouting-things-to-look-for-this-week/

wheat

https://grdc.com.au/resources-and-publications/groundcover/groundcover-133-march-april-2018/sprouting-grain-puts-a-dampener-on-quality

- lack of dormancy

Née, G., *et al.* (2017).
https://ars.els-cdn.com/content/image/1-s2.0-S1369526616301339-gr1.jpg

Dormancy and early germination

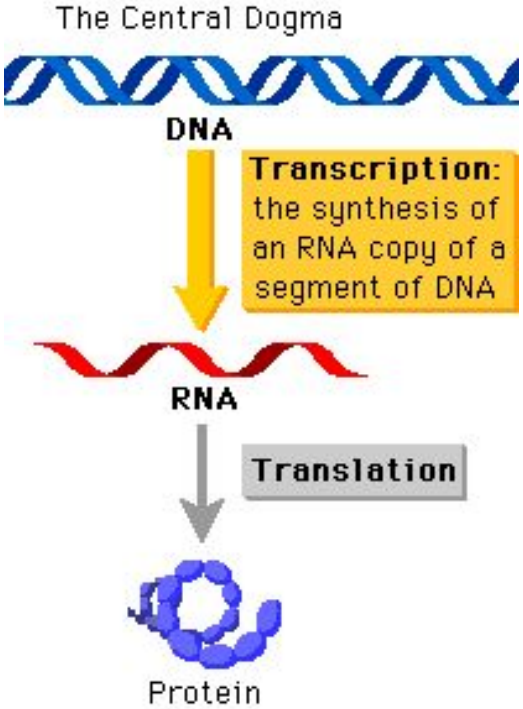
Potential Solutions for PHS

1) Genetic modification

-**which category of "genes"?**

<u>e.g. phytohormones</u>

-**which "level"**



http://www.phschool.com/science/biology_place/biocoach/transcription/images/centdog.gif

->epigenetic modification

->editing on small RNAs

->enzyme engineering

Dormancy and early germination

Potential Solutions: genetic modification

a) miR156 (small RNA) (rice)

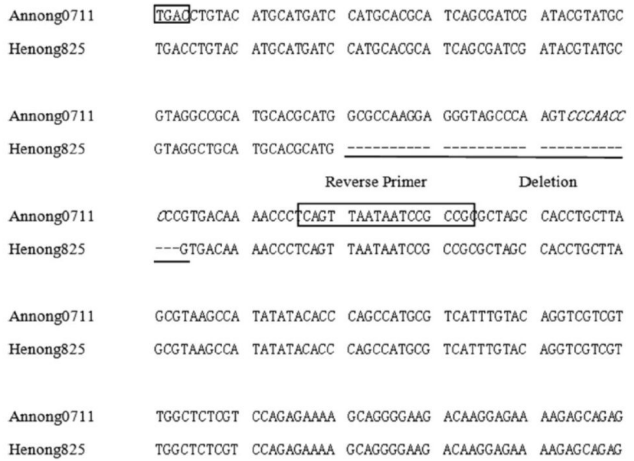
miR156 knockdown reduce germination

(Miao et al., 2019)

b) promoter(wheat)

(H. Jiang et al., 2018)

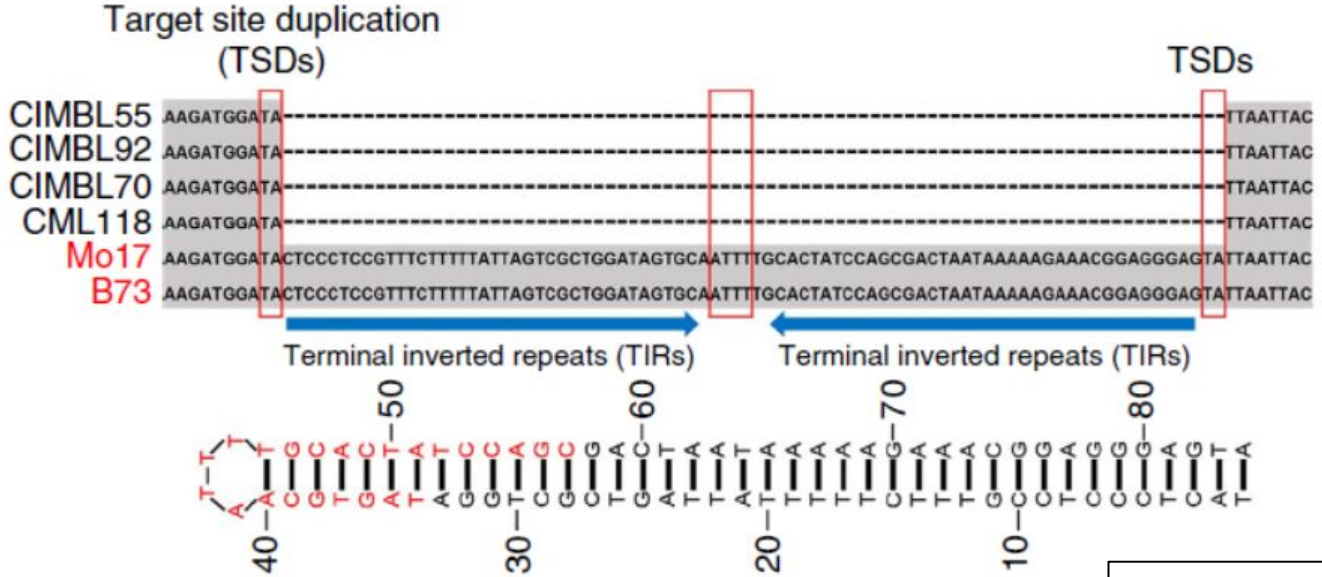
Annong: PHS resistant
Henong: PHS susceptible
InDel changes the PHS trait



Dormancy and early germination

Potential Solutions: genetic modification

c) TE in promoter (maize)



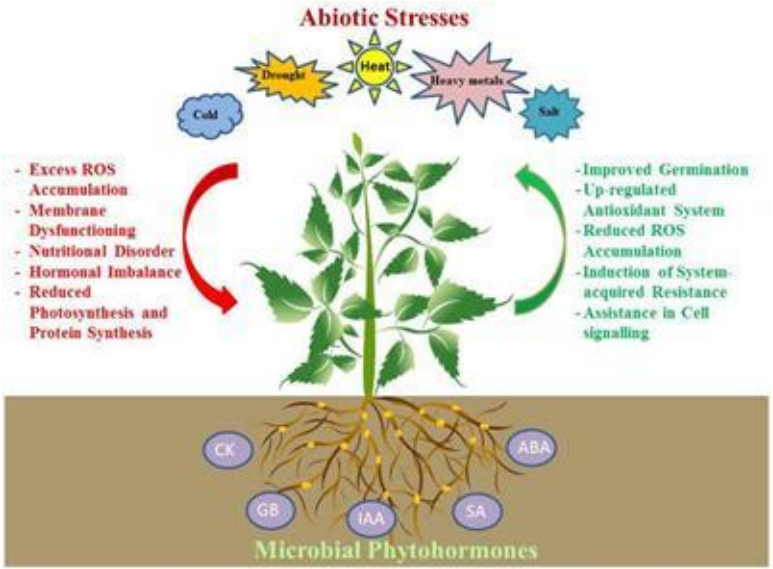
drought-sensitive: B73 & Mo17
drought-tolerant: CIMBL55, 92, 70 and CML118
DNA methylation is involved in the regulation (Mao et al., 2015)

Dormancy and early germination

Potential Solutions for PHS

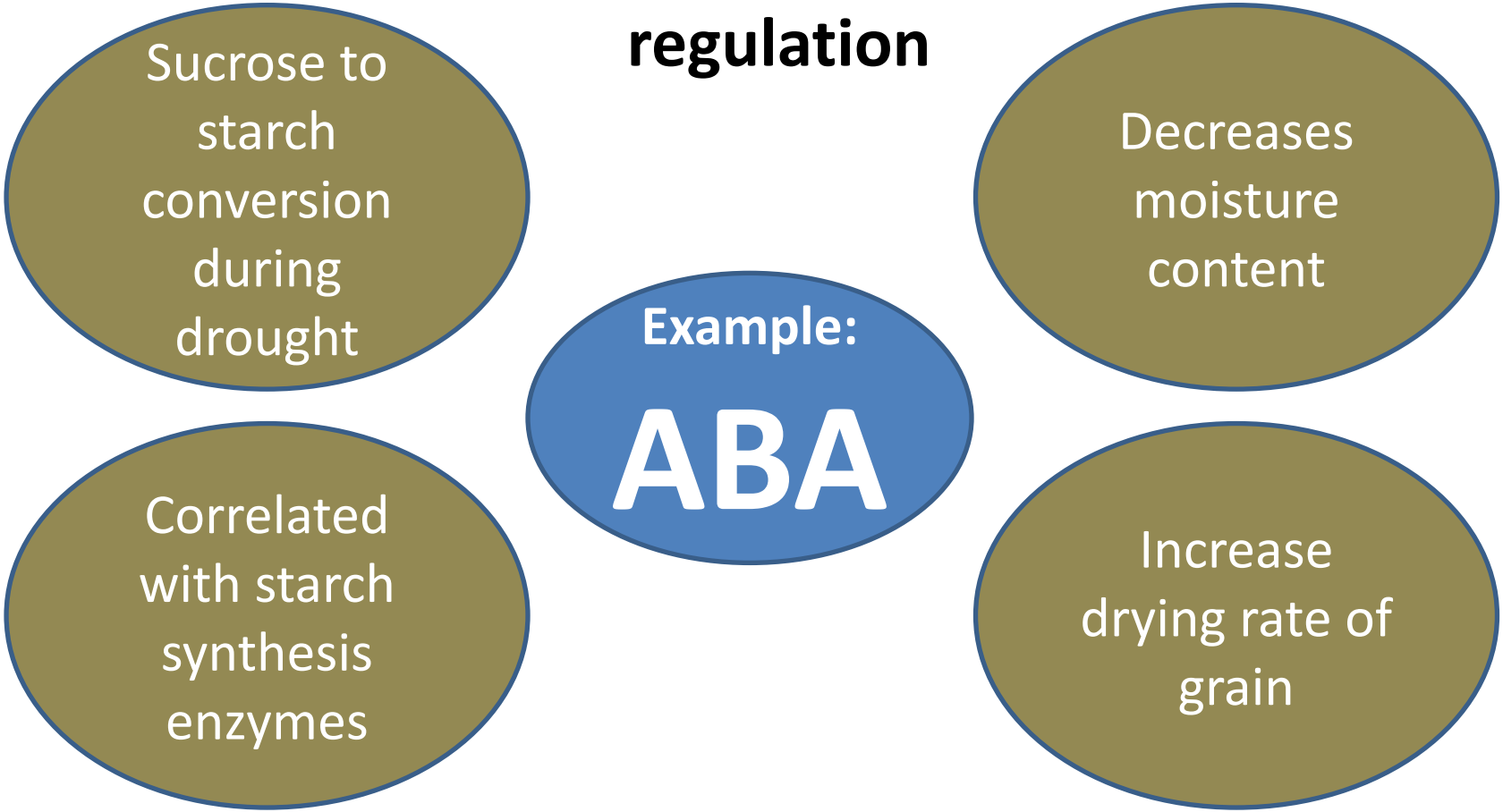
2) Bio-controls
-use bacteria to help plants!

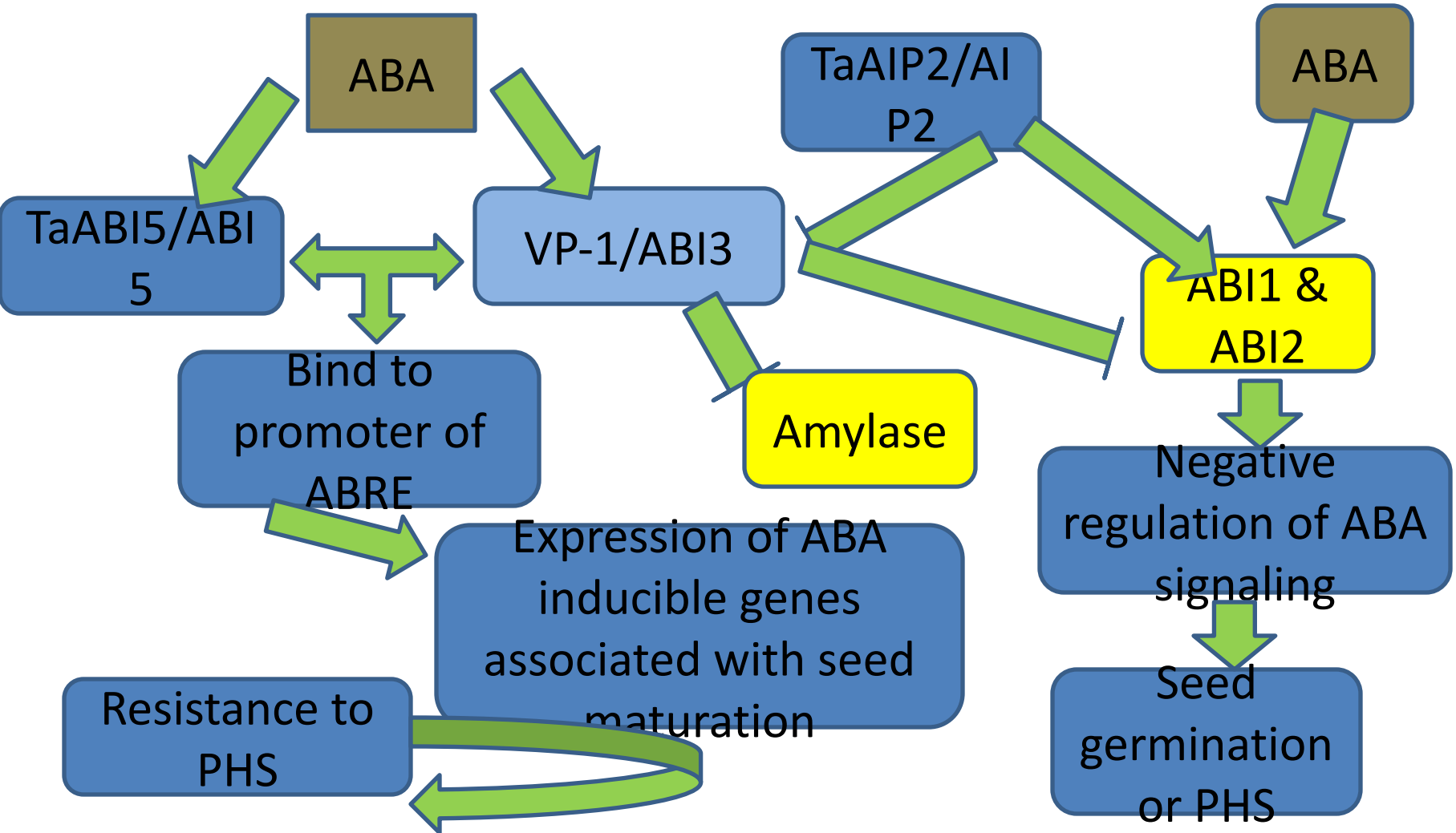
- CRISPR could apply on bacteria
- The bio-control could benefit other problems
- It may be faster than developing a new crops



Egamberdieva, D. et al., (2017)
https://www.frontiersin.org/files/Articles/278255/fmicb-08-02104-HTML/image_m/fmicb-08-02104-g001.jpg

Phytohormone and signalling regulation

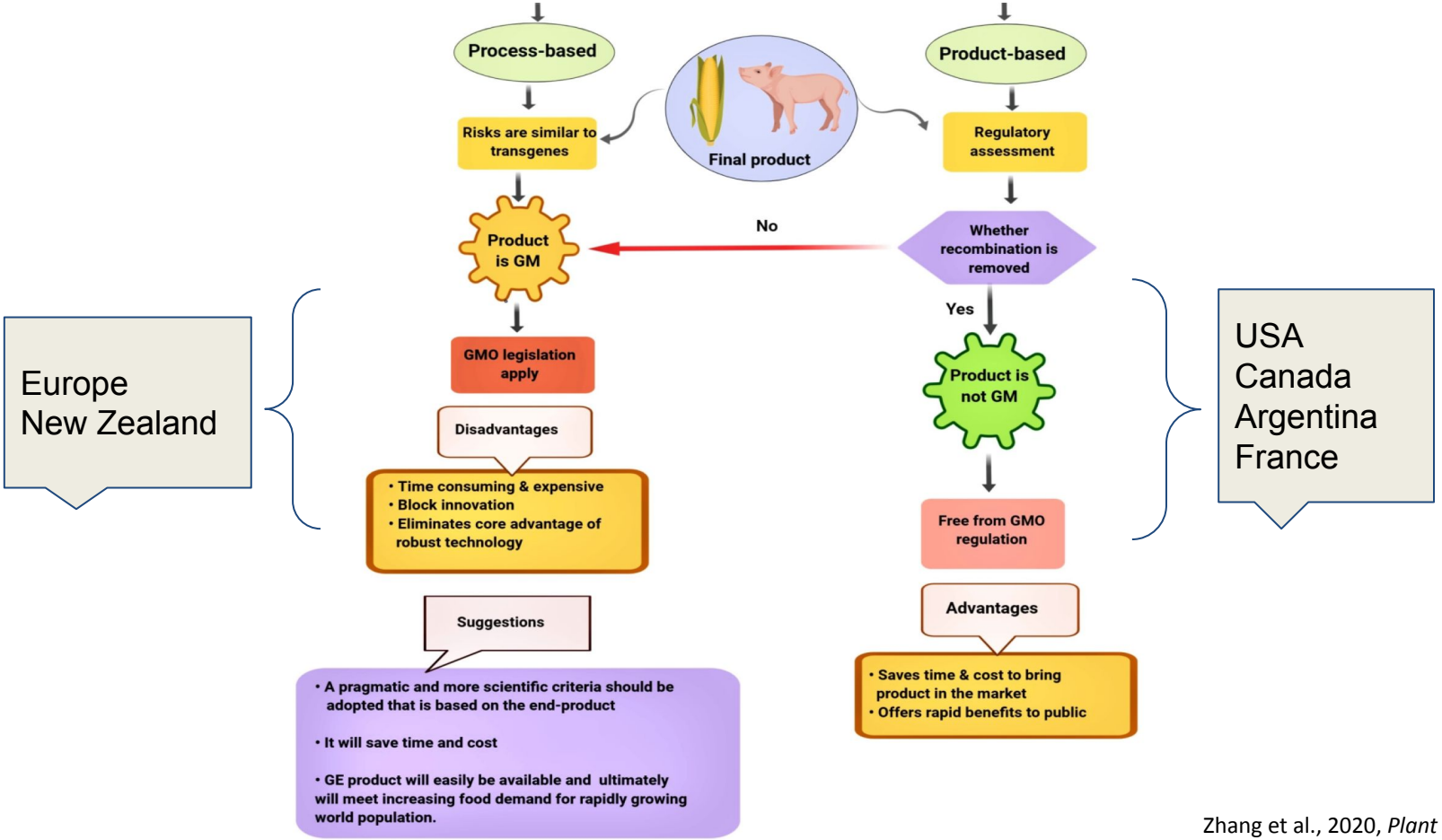



ABA
TaABI5/ABI 5
VP-1/ABI3
TaAIP2/AI P2
ABA
ABI1 & ABI2
Bind to promoter of ABRE
Amylase
Negative regulation of ABA signaling
Expression of ABA inducible genes associated with seed maturation
Resistance to PHS
Seed germination or PHS

Genes	Expression	ABA sensitivity	Refrences
TaVP-1A from PHS resistant varieties of wheat (*T. boeoticum)*	Upregulation	Increase ABA sensitivity irrespective of concentration of ABA and therefore expression of ABA inducible gene expression	*Feng et al., 2017,* Chang et al 2011
TaVP-1B from PHS resistant varieties of wheat (*T. durum)*	upregulation	Increase ABA sensitivity irrespective of concentration of ABA and therefore expression of ABA inducible gene expression	Chang et al 2010, *Feng et al., 2017*
TaAIP2	Downregulation	Increase ABA sensitivity and provide resistance to PHS	
	Upregulation increase expression of ABI21 and ABI2 and decrease expression of VP-1/ ABI3 by degrading VP-1/ABI3	Decrease ABA sensitivity and ABA responsive genes and form crop susceptible to PHS and increase germination rate	Gao et al., 2014, Zhang et al., 2005
ABI5 in *Arabidopsis* and TaABI5 in Wheat	Interact with VP-1	Increase expression of ABA inducible genes by binding to Em promoter of ABRE	Utsugi et al., 2020
ABI1 and ABI2	Negative regulators of ABA signaling, suppressed by VP-1 Expression increase in the presence of ABA	In expression increase ABA sensitivity decreases	Suzuki et al., 2003
ThVp-1d from wheat grass (*Thinopyrum sp.)*	Can be use to form transgenic wheat with ThVP-1 gene	Give PHS resistance	Kocheshkova et al., 2017

Reframing of ethical guidelines and Regulatory policies

Regulatory overview of genome editing



Zhang et al., 2020, *Plant Biotechnol. J.*

Summary

-Short term processes:

-gather additional information to better assess problem

-alleviate and mitigate crop damage and value loss

-outreach to improve support for program

-Long term solution:

-not going to be a single solution to fix everything

-multiple research avenues maximise possibility of solution