Crop Management Decisions in Hail Damaged Crops

SUMMARY

Alberta is the hail capital of Canada. Extreme weather events frequently cause large amounts of damage to houses, cars and agricultural crops. Farmers are particularly left to the fate of mother nature when it comes to hailstorms. Crop losses from hail damage vary with intensity, timing and spatially. Producers have few options available after hail damage other than reseeding, silaging/greenfeeding or waiting to harvest what remains. Recently, many companies are suggesting that various products including foliar fungicides, nutrient blends and biostimulants are effective at helping crops recover from stress caused by wind and hail. The claims include restoring yield and improving vertical orientation for better crop harvestability.

This project was established to test products under different hail intensities and crop stages to determine if a recovery product could be effective. Damage was inflicted using a hail simulator at light (33%) and heavy (67%) intensity at three growth stages, tillering, flag leaf and flowering. Crop adjusters with the Agriculture Financial Services Corporation (AFSC) assisted with calibrating the hail simulators and by assessing actual crop damage on research trials to be confident that they are not over or underpaying.

Research was conducted during 2016-2018 at Farming Smarter in Lethbridge (southern AB), InnoTech Alberta in Vegreville (central AB) and SARDA in Falher (Peace region).

The principle outcome was that yields loss depends largely on what growth stage is the crop is damaged, they by intensity. The recovery products applied did not affect yield.

Fungicide application marginally improving yields in some site years, but the nutrient blends did not. None of the products helped improved yield after a damage event. We cannot conclude that a timely application may not result in a benefit however after nine site years of data, the likelihood of a positive response is very low, as is a return on investment.

Future work for hail research should focus on early damaged crops to evaluate reseeding options with several short season crops. It may also be beneficial to explore field scale trials that focus on understanding the spatial distribution of hail events.

BACKGROUND

Prior to this project there was very little to no scientific data or knowledge in Alberta to support difficult management decisions faced by farmers after a hail event.

Examples of questions include:
How do I assess the level of damage and spatial distribution?
What is the opportunity for regrowth?
How long will the crop be delayed?
What are the implications to crop quality?
Should the crop be harvested for feed?
Should the crop be sprayed with a fungicide or foliar nutrient?
Should the crop be sprayed with a growth regulator/growth promoter?
How long should you wait for crop adjusters results to make decisions?
How do I deal with uneven maturities?
When should I spray a desiccant or swath?
Should I swath or straight cut?
How do I manage storage?

Farmers must consider many variables related to these questions, such as crop type and value, crop stage, level of damage, geographical location and spatial distribution of damage, weather conditions following the event, insurances levels and payouts, feed availability and prices and irrigation.

We proposed our study to answer as many of the above questions as possible.

Objectives:

1. Evaluate the response of wheat crops to simulated hail damage at different growth stages
2. Evaluate the agronomic/economic effect of using fungicides and nutrient blends on wheat crops that are damaged by simulated hail
3. Identify potential management practices to improve crop growth, harvestability and yield after hail damage
4. Develop a practical method for simulating hail damage

Deliverables:

1. Hands on training and education of all stakeholders to make more informed decisions about fungicide application following a major abiotic stress event, particularly at critical stages of crop development.
2. Reduction in unnecessary applications of plant protection and health enhancing products to allow producers to save money and the environment.
3. Encourage producers to institute long-term strategies for effective, efficient and profitable adaptation of innovative environment friendly plant protection technologies.
4. Increase collaboration with industry and public partners.
5. Encourage producers, agronomists and agricultural businesses to seek scientific evidence of efficacy, performance and the economics of new products and practices under local conditions.
6. Provide unbiased, research-based information to stakeholders – publications?
7. Highlight the utility of the high-quality information produced by applied research associations.

There were no deviations to the objectives or deliverables for this project. We are pleased with results of this project and it has already had a significant impact with growers across Alberta and beyond.

METHODS

Crop responses to natural hailstorms is difficult to study due its unpredictability and variability. There is no way to control the timing, severity or spatial variance of the storm. In addition to this it is impossible to compare treatments to an area without damage to serve as an untreated check for reference. For this reason, to properly control the independent variable, we opted to design and build a hail simulator for use in small plot research trials.

In order to get a snapshot of the range of possible hail events we choose to implement a 3x3x3 factorial arrangement of a randomized complete block trial with 4 replicates (Appendix I, Figure 1). These factors included timing of the damage, intensity and the application of recovery products. Using those timing allowed approximately two weeks between simulated damages to cover the main hail periods through the wheat growing season. The first two factors addressed *Objective 1. Determine the response of wheat crops to simulated hail damage at different growth stages.* The final factor addressed *Objective 2. Evaluate the agronomic/economic effect of using fungicides and nutrient blends on pulse crops that are damaged by simulated hail.*

The first factor "timing" relied on the use of the hail simulators to damage the wheat at three timings with respect to critical growth stages of the crop. For this, hail damage was applied at early vegetative timing (tillering), mid timing (flag-heading) and late reproductive timing (flowering and later).

The second factor 'intensity' consisted of hail simulation at three damage severity levels including a check (0% damage), light (33% damage), and heavy (67% damage). Calibrating the intensity levels of hail simulator machine used for this study was performed by damaging test strips with the hail simulator. First, we recorded the number of passes required for complete defoliation and adjusted according to achieve the desired defoliation level. The drums were run at a constant speed to simulate the terminal velocity of hail. The height was adjusted based on the stage of the crop. The hail simulator was designed, fabricated and field tested by Farming Smarter in 2015 for a similar project on pulses scheduled to start in 2016 (machinery descriptions for each site are in Appendix II, Figure 1-3).

The third factor consisted of the application of "hail rescue products" including nutrients with a hail recovery or stress recovery claim in advertising, labels or websites. Fungicides from the triazoles and strobilurins groups are systemic compounds and have been found in several studies having both fungitoxic and growth regulatory effects on cereal and broad leaf crops. For example, triazoles type fungicide compounds have been demonstrated to lowering the production of a plant growth hormone, gibberellins (GA), (Fletcher et al. 2000) and protecting plants from various environmental stresses caused by diseases, drought, chilling, ozone, heat, and air pollutants (Davis et al. 1988 and Fletcher and Hofstra 1988). Strobilurins fungicides lower ethylene production in plants (Grossmann 1997), resulting in delayed senescence (Bollmark et al. 1990) with a prolonged photosynthetic activity of green tissues and a better management of stress (Grossmann et al. 1999). Additionally, for this factor, a check treatment was included with no nutrient or fungicide application.

In order to study hail damage to wheat we thought the best way to do replicated research was to answer "*Objective 4. Develop a practical method for simulating hail damage*". Predecessors of hail research used ice cannons, threw rocks and tried other to methods to simulate hail itself. These methods were labour and resource intensive. For simplicity sake, we opted to simulate hail damage and to irrigate the trial area (Lethbridge) to best simulate hailstorm conditions. We modeled our hail damage on the mechanical damage caused by whipping a dog chain across the crop foliage. Then we mechanized this method by attaching a series of chains to a rotating drum that was mounted on a front-end loader and was driven over the plots at a controlled height and speed through hydraulics (Appendix II, Figure 1). InnoTech added golf balls to the end of their chains to mimic larger hail stones (Appendix II, Figure 2). InnoTech and SARDA opted to attach the drum to a motorized high clearance unit (Appendix II, Figure 3) rather than front end loader. We confirmed with local agronomists and AFSC adjusters that the mechanical damage closely resembled that of actual hail stones. Equipment specifications used for each damage level and timing are in Appendix I, Figure 2.

Study sites

We planted trials over the 2016-2018 growing seasons at Farming Smarter (FS - Lethbridge, AB), InnoTech (IT - Vegreville, AB) and SARDA (SD - Falher, AB) for a total of 9 site years (Appendix I, Figure 3). The data set was analyzed using SAS proc Mixed. In 2017, the SARDA site received a real hailstorm before the final hail timing. The data was analyzed but was ultimately discarded because no yield differences were seen between the damage levels or timings. Some errors and inconsistency also caused us to drop SARDA and InnoTech in 2016 from the combined yield analysis.

Soil Background

The Lethbridge trial site is in the dark brown soil zone. The soil is generally classified as clay-loam. The pH generally ranges between 7.9 and 8.2, EC approximately 0.55, OM between 2.7 and 4.2%. There tends to be optimum Potassium (>600 lbs/ac) and Sulfur (>50 lbs/ac) already in the soil and generally limiting background N (<100 lbs/ac) and Phosphorus (<30 lbs/ac).

The Vegreville site is in the in the black soil zone. The soil is generally classified as silt-loam. The pH generally ranges between 5.6 and 6.5, EC ranges between 0.28 and 0.59, OM between 6.0 and 9.9%. There tends to be optimum Potassium (>500 lbs/ac), Sulfur (>30 lbs/ac) and Phosphorus (>49 lbs/ac) already in the soil and generally limiting background N (<53 lbs/ac), however in 2018 the background N was optimum (214 lbs/ac).

The Falher site is in the in the in the dark grey soil zone. The pH generally ranges between 5.6 and 6.7, OM between 2.2 and 4.3%. There tends to be moderate Potassium (>220 lbs/ac) already in the soil and generally limiting background N (< 11 lbs/ac), Sulfur (< 20 lbs/ac) and Phosphorus (<31 lbs/ac).

Cultural Information

The land used in this trial has been in continuous cropping with minimal tillage. Lethbridge sites were planted into barley (2016) and canola (2017, 2018). Vegreville sites were planted on chem fallow. Falher sites were planted into canola stubble.

Seeding, fertilizing and spraying

The trials were seeded using a custom build, zero-till air seeders. Farming smarter is equipped with side banding Pillar Laser Disc/Hoe openers on 9.5" row spacing for a total plot area of 11.58 m^2. InnoTech is equipped with Acra-Plant double disc opener, with mid-row (same opener) on 9.8" row spacing for fertilizer for a total plot area of 9.6 m^2. SARDA is equipped with a Seed Master side band knife opener with 5 shanks and 11" row spacing for a total plot area of 7.51m^2. Crops were seeded perpendicular to the direction of simulated hail damage At Farming Smarter and SARDA, Plots were seeded parallel to damage at InnoTech. CDC Go was sown at 300 seeds/m^2 throughout years and locations. Nitrogen (46-0-0) was side banded and Phosphorus was put in the seed row (11-52-0) at recommended rates for achieving an 80bu/ac crop.

The nutrient recovery product used was Alpine G22 @ 3L/ac + Boron and the fungicide was Prosaro @320 mL/ac. They were applied with calibrated, 2-meter hand booms at label rates and water volumes using 11001 or 11002 nozzles and C02 propellant. Appendix II, Figure 5-8 shows the seeding, spraying, biomass and harvesting operations. Appendix I, Table 1 lists the operational dates. Crops were sprayed on average 3 days after hail damage (Appendix I, Table 2). Incrop application for Farming Smarter, Innotech and SARDA are listed on Appendix I, Tables 3-5.

Harvesting

Plots were harvested using Wintersteiger plot combines with a 1.5m straight cut header. Grain samples were collected and weighed using calibrated on-board balance, moisture sensor and test weight chamber.

Data collection

In order to quantify how hail damage is manifested in a wheat crop we collected the following parameters

- Pictures of uniformity and damage levels (UAV and plot)
- Plant density counts for uniformity and density (plants/m2)
- greenseeker NDVI reading of crop health (1 week after damage)
- Hail damage ratings to verify damage level and determine payout (done by AFSC)
- Disease ratings (if diseases were present)
- Days to flowering and maturity (if differences are seen)
- Plant heights (before and after hail damage)
- biomass for crop robustness (1 week after damage, at maturity)
- Maturity variability assessment for uniformity (where applicable)
- Yield for profitability (kg/ha and bu/ac)
- Quality for economic impact (TKW, moisture, protein, grading)

The goal of collecting this data is to answer *Objective 3. Identify potential management practices to improve crop growth, harvestability and yield after hail damage.*

RESULTS

Plant counts

An average plant stand of 200 plants/m^2 was achieved from a seeding rate 300 seeds/m^2. The plant stand for the trials were uniform across all site years. The average plant counts are shown in Appendix I, figure 4. This gives us confidence any treatment effects are real, and not due to variability within the research sites.

Biomass at 1 week after damage

Crop biomass was measured 1 week after damage to measure actual defoliations from inflicted damage. This was complete by removing 4 quarter meter quadrats and weighing. Biomass was reduced by simulated hail for each level and timing in 7 of 7 site years (Appendix I, Table 6). Crop biomass at the early timing was reduced from 1370 g/m2 for the check to 870 g/m2 and 640 g/m2 for the 33% and 67% damage levels. At the mid timing, crop biomass was reduced from 2010 g/m2 (check) to 1970 g/m2 (33%) and 1830 g/m2 (67%). At the late timing, it was reduced from 3510 g/mw (check) to 2860 g/m2 (33%) and 2650 g/m2 (67%).

The foliar treatments only effected the biomass 1 week after damage for InnoTech 2017 (P=0.011), where it appears the nutrient decreased yield at the 0% damage level but increased it at the 33% damage level (Appendix I, Figure 5). One explanation for the lack of nutrient and fungicide effects on biomass is that they wouldn't have time to increase the biomass in a meaningful way in less than a week after application.

Biomass at harvest

Crop biomass at harvest was reduced by hail for each damage level and timing in 4 of 6 sites years (Appendix I, Table 6). Crop biomass was highest in the undamaged plots (1110 g/m2). In the early damaged timings, it was reduced to 1020 g/m2 (33%) and 980 g/m2 (67%). At the mid timings it was reduced to 885 g/m2 (33%) and 810 g/m2 (67%). In the late timings it was reduced to 870 g/m2 (33%) and 640 g/m2 (67%).

The foliar treatments only influenced the biomass before harvest at Farming Smarter 2016 (P=0.02). For this year, the fungicide application increased biomass at harvest (Appendix I, Table 6).

NDVI at 1 week after damage

The NDVI baseline for the check was different for each damage timing as the growth stage was different, but regardless of timing, the NDVI was reduced as damage levels increased (Appendix I, Figure 7). For early timings, NDVI dropped from 0.65 (check) to 0.57 (33%) and 0.53 (66%). At mid timing it dropped from 0.73 (check) to 0.69 (33%) and 0.67 (67%). At late timing it dropped from 0.65 (check) to 0.61 (33%) and 0.58 (67%). On average, foliar application of nutrient and fungicide did not exhibit significant effect on NDVI (Appendix I, Table 6). A possible reason for the absence of nutrient and fungicide effects on NDVI is that the foliar application did not influence the photosynthetic activity of the crop in a detectable limit a week after application.

Height before damage

Height before damage was taken as a benchmark for analyzing the effect of hail damage on crops. Plant height differed between timing as the growth stage was different. Average plant height before damage was 28 cm at tiller, whereas at flag and flower was 79 cm and 88 cm, respectively (Appendix I, Figure 8).

Height after damage

Plant height after damage was significantly reduced as hail damage level increased (Appendix I, Figure 9). The decrease of average plant height after hail damage was detected for each timing and increased with hail intensity.

Yield

The undamaged check plots yielded 74-81 bu/ac (Appendix I, Figure 10). The undamaged fungicide yielded on average 1 bu/ac higher than the check and 2 bu/ac higher than the undamaged nutrient. The highest yield was 81 bu/ac for the undamaged fungicide at flag leaf-heading which is consistent with the recommended timing for application. The lowest yielding undamaged treatment was the nutrient applied after heading.

Yield loss at the early damage timing was minimal, but increased as the season progressed (Appendix I, Figure 11). At the early damage timing, 33% and 67% simulated hail damage resulted in yield loss of 3% (76 bu/ac) and 6% (73 bu/ac) respectively. At the flag-heading timing the yield loss for 33% and 67% damage was 34% (53 bu/ac) and 43% (46 bu/ac) respectively. At the flowering timing the yield loss for 33% and 67% damage was 39% (47 bu/ac) and 58% (32 bu/ac) respectively.

The SARDA 2017 data was excluded because of a natural hailstorm.

DISCUSSION

The timing of hail damage had the largest impact on yield, followed by the damage level, and then the application of recovery products.

Timing

Early hail damage during vegetative growth had minimal impact on yield, but mid and late hail damage lowered the yield to a much greater degree (Appendix I, Tables 7 and 8/Figure 10 and 11). Early hail timings also had higher percentage of mature plants at harvest (Appendix I, Figure 12)

Timing had the greatest effect on wheat yield. Early hail timings yielded nearly the same as the checks. Not only does the crop has sufficient growing degree days to reach maturity but it is clearly less sensitive to permanent damage once the reproductive stage has commenced. However, contrary to many anecdotal infield experiences, the data showed negligible statistically valid treatment effects to hail recovery products applied at any hail damage timing.

Damage levels

The damage severity of hail significantly reduced wheat yield in all site years (P<0.0001), except for SARDA 2017 (Appendix I, Table 8). Yield loss did not correlate strongly to damage intensity which was surprising.

Damage x Timing

In all site years wheat yield was reduced as the damage level was increased and as the days after seeding were increased (Appendix I, Table 8/Figure 11). This is not a surprising result however what is surprising is how quickly the crop moves past a stage where any significant yield is possible. A new study might be warranted to chart the change in yield potential with the timing of a hail event. This could be achieved by conducting frequent simulated damage say every three days from the vegetative to flowering timing. This would provide a good understanding of a yield potential as impacts by the timing of damage. This would help determine whether any further investment in crop inputs is warranted.

Later damage timing resulted in the higher wheat yield losses. This is because at the earlier stages, such as tillering, the plant still has a substantial amount of growing season left to recover. Even a 100% defoliation at a very early growth stage would have a smaller effect than a lower damage level at a later growth stage. For this reason, when a crop is hail damaged very early in the season, the AFSC adjusters choose to defer any payments until the crop can be evaluated again later. Any determinations they make for payment are based on a formula that gives the estimated yield loss based on a % of the defoliation. These formulas are adjusted as the crop goes through vegetative growth. In contrast to this, any defoliation at reproductive timing is instead evaluated by head loss at a 1:1 payment. This is because if you have 50% broken stems or fallen heads you have approximately 50% loss in yield. Our yields at the late timing reflect a 33% and 67% head loss very closely.

Foliar

In the combined analysis we found that foliar applications showed no improvement over the check in average wheat yields (Appendix I, Figure 10). However, in the Lethbridge 2016 site we saw a clear yield response to the foliar treatments (P =0.0297), we also saw a potential response in the InnoTech 2017 (P=0.879), Lethbridge 2017 (P=0.0547) and SARDA 2016 (P=0.0611). Overall averages of all site years showed no increase in yield from the nutrient blends, and a 1.5 bu/ac increase in yield from the foliar fungicides.

Timing x Foliar

There was a small yield increase of a 1.5bu/ac yield with the fungicide application at the flag leaf timing with light damage (Appendix I, Figure 10). No interaction of timing and foliar treatments was observed, except for SARDA 2016 and 2018 (Appendix I, Table 8). This suggests that the nutrients and fungicides were ineffective at helping a crop recover from hail damage at any timing for most of the site years.

There were no significant interactions of damage intensity by foliar applications or timing by damage by foliar (Appendix 1, Table 6) suggesting that the products did not impact yield.

Maturity

One obvious side effect of a hailstorm in a wheat crop is uneven maturity. In 2016 we took ratings on % of the plot that was mature (Appendix I, Figure 12) and found that at harvest time all of the undamaged checks were 100% mature. The 33% early and 67% early plots were also 100% mature. Plots damaged at 33% mid were 87% mature, 67% mid were 85% mature, 33% late were 80% mature and 67% late were 75% mature. This caused issues with grain harvest timing, grain storage and downgrading (Appendix I, Figure 13). Some sites opted to desiccate the crop and others had to dry grain when storing.

Grading

Grading represents an evaluation of a physical condition or features to determine the quality of the grain. A down grade can be a result of growing conditions or environmental stress. Early hail timings did not exhibit difference on the grading after hail damage (Appendix I, Figure 13). However, there was a higher proportion of grade 2 and 3 as damage levels increased (Appendix I, Figure 13). At mid stage, no grains with grading 1 were detected at level damages of 33% and 67%. This result indicates that hail damage causes a downgrading of the seed quality at mid and late stages. However, at early stage no effect of hail damage was observed, possibly because the plants had additional time to recover for damage at later stages.

TKW

TKW decreased as hail damage level increased (Appendix I, Figure 14).

Protein

In three of seven years (In Innotech 2018 and Farming Smarter 2016 and 2018) it was detected that protein content was increased when the wheat was damaged at mid and late stages (Appendix I, Table 6). Protein content of wheat seed at the mid timing increased from 14.5% with no damage to 15.3% and 15.5% for the 33% and 67% damage respectively. Protein at the late timing increased to 15.8% and 16.4% for the 33% and 67% damage respectively. (Appendix I, Figure 15). foliar applications only affected protein in one of seven site years.

Weed Biomass

Another consequence of hail damage is increased weed pressure when crop competition is lowered. In most cases the in crop herbicide was sufficient to stunt the majority of weed growth, but in some years, an increase in weed pressure was noted when collecting harvest timing biomass. On average the weed levels were too low and uneven between the checks to determine any real trends (Appendix I, Figure 16).

Objective 4. Develop a practical method for simulating hail damage.

AFSC adjusters use a private internal formula to calculate how much payable a % damage is for a hail event at specific growth stages.

AFSC rated our damage levels 1 week after each timing to see how accurate we were to our 33% and 67% targets (Appendix I, Figure 17). Despite different growth stages we were able to cause our targeted damage levels by calibrating with practice plots and holding the drum rotation, height and number of passes consistent. AFSC ratings were influenced mostly by timing. Hail damage at mid stage causes AFSC of 40%, whereas at late stage was 67% (Appendix I, Figure 17).

The hail simulator design and use has proven to be a very practical method to study hail damage. Dr. Steve Shirtliff from the University of Saskatchewan is now borrowing the simulator for use in further studies.

CONCLUSIONS AND RECOMMENDATIONS

This project evaluated the response of wheat to hail damage using a practical method for simulating hail damage. The simulation of unpredictable natural events such as hail damage, applied at different plant growth stages allows the evaluation of the effect of this phenomenon under field conditions using appropriate controls, which otherwise might be very difficult to perform under natural hailstorms. This innovative method opens new possibilities to study the influence of climatic factors to crop development. The results shown in the study demonstrate that higher yield losses occur at the flag and flowering stages, whereas yield potential remains good at earlier growth stages with more time to recover and reach maturity. This finding implies that yield potential decreases quickly and drastically depending on the growth stage. Further studies may help understand precisely when and at what levels yield potential drops helping producers make better decisions regarding crop management practices after a hail event. The application of nutrient blends and fungicide did not exhibit effects on recovering wheat growth. Most fungicide products are used to protect yield potential and it may be unreasonable to assume they can help recover lost potential from hail damaged crops. Nevertheless, this project did not focus on multiple products, dual applications or include many biostimulants or growth regulator products. We cannot conclude that all products are the same and may it be useful to test more products. It’s difficult to justify field scale testing with limited results on the small plots however producers and industry representatives tend to trust this type of data in real on farm conditions. There would also be an opportunity to study the spatial extend of hail damage which could lead to spatial management of hail damaged crops. While this project has helped add to a limited knowledge base there is still a rather large gap in knowledge regarding appropriate management practices required for a crop that has been hailed.

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Appendix I

Tables and graphs

Table 1. Dates of operations for Farming Smarter (FS, Lethbridge, AB), InnoTech (IT, Vegreville, AB) and SARDA (SD, Falher, AB).

	2016 FS	2017 FS	2018 FS	2016 IT	2017 IT	2018 IT	2016 SD	2017 SD	2018 SD
Seeding									
Seeding Date	3-May	20-Apr	13-May	11-May	23-May	15-May	12-May	21-May	24-May
Emergence Date	16-May	3-May	25-May	23-May	2-Jun	24-May	na	na	na
Plant Count Date	13-Jun	16-Jun	4-Jun	2-Jun	9-Jun	7-Jun	na	14-Jun	18-Jun
Days to Emergence	13	13	12	12	10	9	na	na	na
Early									
Hail Damage 1	15-Jun	12-Jun	14-Jun	10-Jun	21-Jun	21-Jun	23-Jun	19-Jun	21-Jun
Spray Early	17-Jun	15-Jun	15-Jun	10-Jun	21-Jun	23-Jun	27-Jun	22-Jun	26-Jun
AFSC Early	na	19-Jun	na	17-Jun	29-Jun	28-Jul	na	na	na
NDVI Early	na	21-Jun	na	17-Jun	27-Jun	28-Jun	na	22-Jun	4-Jul
Biomass Early	22-Jun	19-Jun	22-Jun	17-Jun	27-Jun	28-Jun	na	22-Jun	9-Jul
Mid									
Hail Damage 2	29-Jun	26-Jun	29-Jun	12-Jul	13-Jul	5-Jul	11-Jul	7-Jul	18-Jul
Spray Mid	1-Jul	27-Jun	29-Jun	12-Jul	13-Jul	6-Jul	11-Jul	11-Jul	25-Jul
AFSC Mid	na	11-Jul	9-Jul	19-Jul	20-Jul	12-Jul	na	na	na
NDVI Mid	na	6-Jul	na	19-Jul	20-Jul	12-Jul	na	13-Jul	18-Jul
Biomass Mid	8-Jul	6-Jul	na	19-Jul	20-Jul	12-Jul	na	13-Jul	24-Jul
Late									
Hail Damage 3	15-Jul	10-Jul	16-Jul	19-Jul	26-Jul	19-Jul	18-Jul	26-Jul	31-Jul
Spray Late	18-Jul	11-Jul	17-Jul	19-Jul	26-Jul	20-Jul	18-Jul	2-Aug	7-Aug
AFSC Late	na	17-Jul	na	26-Jul	2-Aug	26-Ju	na	na	na
NDVI Late	na	17-Jul	na	26-Jul	2-Aug	26-Jul	na	31-Jul	25-Jul
Biomass Late	22-Jul	17-Jul	27-Jul	26-Jul	2-Aug	26-Jul	na	31-Jul	7-Aug
Harvest									
Biomass Maturity	na	na	na	na	na	na	25-Aug	23-Aug	na
Harvest	26-Sep	8-Sep	26-Sep	16-Sep	29-Sep	27-Sep	13-Sep	25-Sep	2-Oct

Table 2. Average Days to Spray for all site years.

Timing	Avg Days to Spray	SE
Early (tiller)	2.8	0.12
Mid (flag)	3.1	0.17
Late (flower)	2.9	0.17

Table 3 – Incrop applications Farming Smarter

Spray Treatments	2016 FS	2017 FS	2018 FS
Pre-seed Burn off:	Gly	Gly+ Heat	Gly + aim
Date:	16-Apr-16	20-Apr-17	2-May-18
Rate:	1 L/ac	Gly 1 L/ac +28 g/ac Heat	1 L/ac
In-crop Treatment (s):	OcTTain + Achieve	OcTTain +2, 4-D	Octtain +Axial
Date:	3-Jun-16	30-May-17	5-Jun-18
Stage:	4-6 leaf	5 leaf stage	4-6 leaf stage
Rate:	label high	label high	label
Pre-harvest Burn off:	Reglone	Reglone	
Date:	15-Sep-16	23-Aug-17	
Rate:	label high	label low	
Spray notes:	40L/ac using 10001-110 flat fan, C02		

Table 4 – Incrop applications for InnoTech

Spray Treatments	2016 FS	2017 FS	2018 FS
Pre-seed Burn off:	glyphosate	glyphosate	tandem
Date:	9-May-16	21-May-17	
Rate:	360 gai/acre	360 gai/acre	
In-crop Treatment (s):	Refine + Axial Extreme	Refine + Axial Extreme	Refine + Agral 90
Date:	9-Jun-16	12-Jun-17	16-Jun-18
Stage:	3-4 leaf	3-4 leaf	3-4 leaf
Rate:	label	label	Refine at 12g/acre
Pre-harvest Burn off:			
Date:			
Rate:			
Spray notes:	40 L/acre using 110-2 airmix nozzle		

Table 5 – Incrop application for SARDA

Spray Treatments	2016 FS	2017 FS	2018 FS
Pre-seed Burn off:	Express Pro		
Date:	2-May-16		
Rate:	label		
In-crop Treatment (s):	Stellar	Stellar + Axial	Pixaro + Axial
Date:	7-Jun-16	8-Jun-17	21-Jun-18
Stage:	3 leaf	3 leaf	4 leaf
Rate:	label	label	label
Pre-harvest Burn off:	Reglone Ion	Reglone Ion	Reglone Ion
Date:	12-Sep-16	14-Sep-17	21-Sep-18
Rate:			
Spray notes:			

Table 6. – Number of times each factor was Significant at P<0.05. T = Timing, D = Damage, F = Foliar.

Factor	Plant Counts	Yield	Biomass at Harvest	Biomass 1 week	NDVI 1 week	Protein
Timing	2	9	5	7	8	3
Damage	1	8	5	7	6	1
T*D	1	8	4	0	5	0
Foliar	0	1	1	1	1	1
T*F	1	2	1	0	2	0
D*F	0	0	0	1	0	0
T*D*F	1	0	0	0	0	0
Site Years Data	8	9	6	7	8	7

Table 7. Combined analysis of wheat yield for site years. IT16 excluded because of missing treatment. SD16 excluded because of skewness/kurtosis. SD 17 excluded because yield showed no response to damage or timings.

Factor	LocYr	D	T	D*T	F	D*F	T*F	D*T*F	Skewness	Kurtosis
Yield	6	0.000	0.000	0.000	0.608	0.862	0.532	0.166	-0.1	2.7

Table 8. Analysis of Variance for yield at all site years. FS = Farming Smarter, IT = InnoTech, SD = SARDA. Grey cells are significantly different at 95%.

LocYr	Damage	Timing	D*T	Foliar	D*F	T*F	D*T*F	Skewness	Kurtosis
FS16	0.000	0.000	0.000	0.030	0.485	0.186	0.421	0.1	-0.5
FS17	0.000	0.000	0.000	0.055	0.714	0.316	0.297	-0.4	0.9
FS18	0.006	0.015	0.017	0.511	1.000	0.925	0.639	0.2	0.0
IT16	0.000	0.000	0.000	0.419	0.416	0.118	0.683	-0.6	2.1
IT17	0.000	0.000	0.000	0.088	0.328	0.234	0.102	-0.3	-0.6
IT18	0.000	0.009	0.000	0.853	0.988	0.602	0.801	-0.4	0.8
SD16	0.000	0.000	0.000	0.057	0.108	0.000	0.098	1.8	7.1
SD17	0.367	0.752	0.259	0.960	0.962	0.227	0.520	-0.2	-0.5
SD18	0.000	0.000	0.000	0.290	0.573	0.005	0.946	-0.3	0.2

Table 10. Average of plant counts (P/m²), plant height (cm), NDVI, biomass (g/m²), damage (AFSC), yield (bu/ac), TKW and protein content of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Averages calculated from combined values from all locations and years (N = 9).

	P/m²	cm pre	cm post	NDVI	g/ m² 1wk	g/ m² crop	g/ m² weed	AFSC dam	AFSC pay	bu/ac	TKW	prot
Early (tiller)	**200**	**28**	**30**	**0.5852**	**962**	**1030**	**79**	**22**	**20**	**76**	**43.2**	**14.3**
Early 0	**202**	**28**	**40**	**0.6515**	**1374**	**1088**	**66**			**78**	**42.7**	**14.4**
Check	202	27	41	0.6618	1374	1073	66			76	42.9	14.5
Fungicide	204	28	43	0.6503	1383	1123	55			80	42.6	14.4
Nutrient	201	27	36	0.6410	1365	1067	77			78	42.7	14.5
Early 33	**199**	**28**	**28**	**0.5729**	**873**	**1020**	**89**	**32**	**17**	**75**	**41.4**	**14.3**
Check	198	29	28	0.5806	921	1023	136	31	17	75	40.6	14.3
Fungicide	197	28	29	0.5662	847	1074	58	34	19	75	42.0	14.3
Nutrient	202	**28**	28	0.5709	845	962	71	32	16	77	41.5	14.2
Early 67	**198**	**28**	**25**	**0.5305**	**640**	**982**	**84**	**58**	**22**	**74**	**45.4**	**14.3**
Check	200	29	25	0.5555	732	1001	68	61	22	75	53.0	14.2
Fungicide	200	28	25	0.5255	566	1007	71	58	22	76	41.7	14.5
Nutrient	193	28	25	0.5072	607	937	112	56	22	71	41.4	14.3
Mid (flag)	**204**	**79**	**75**	**0.6968**	**1939**	**937**	**57**	**23**	**49**	**60**	**41.6**	**15.1**
Mid 0	**201**	**83**	**83**	**0.7269**	**2010**	**1113**	**60**			**79**	**43.0**	**14.5**
Check	197	84	85	0.7244	2146	1077	66			78	42.5	14.4
Fungicide	202	82	83	0.7263	1915	1130	43			80	43.1	14.5
Nutrient	205	83	83	0.7296	1954	1131	70			78	43.2	14.5
Mid 33	**209**	**76**	**73**	**0.6920**	**1974**	**886**	**63**	**39**	**35**	**53**	**41.6**	**15.3**
Check	207	79	74	0.6821	1826	859	63	37	35	51	41.3	15.2
Fungicide	211	76	73	0.6978	2024	916	48	40	35	56	42.2	15.3
Nutrient	209	75	71	0.6965	2117	881	77	41	35	53	41.2	15.2
Mid 67	**202**	**78**	**69**	**0.6695**	**1830**	**810**	**48**	**65**	**65**	**46**	**40.1**	**15.5**
Check	198	78	71	0.6679	1808	799	75	62	64	46	39.6	15.4
Fungicide	204	78	69	0.6720	1835	798	39	68	63	46	40.2	15.6
Nutrient	204	78	69	0.6684	1853	835	28	64	67	47	40.5	15.6
Late (flower)	**205**	**89**	**85**	**0.6104**	**2993**	**877**	**53**	**29**	**56**	**52**	**41.1**	**15.6**
Late 0	**205**	**88**	**87**	**0.6481**	**3512**	**1122**	**27**		**56**	**77**	**43.0**	**14.6**
Check	206	88	87	0.6448	3469	1069	24			78	43.0	14.6
Fungicide	201	87	87	0.6502	3379	1105	28			78	43.0	14.7
Nutrient	208	88	88	0.6496	3674	1191	31			74	42.9	14.6
Late 33	**209**	**89**	**85**	**0.6058**	**2863**	**872**	**55**	**47**	**45**	**47**	**40.7**	**15.8**
Check	215	89	85	0.5983	2808	884	45	45	38	48	40.6	15.8
Fungicide	205	89	85	0.6184	3034	865	13	49	36	49	40.0	15.9
Nutrient	208	89	85	0.6015	2758	867	108	48	64	45	41.5	15.8
Late 67	**200**	**89**	**82**	**0.5809**	**2654**	**636**	**76**	**71**	**67**	**31**	**39.5**	**16.4**
Check	197	89	81	0.5865	2692	636	51	68	69	32	39.8	16.4
Fungicide	199	89	83	0.5775	2686	626	65	69	64	32	39.9	16.5
Nutrient	204	90	83	0.5784	2582	646	114	75	67	28	38.7	16.3

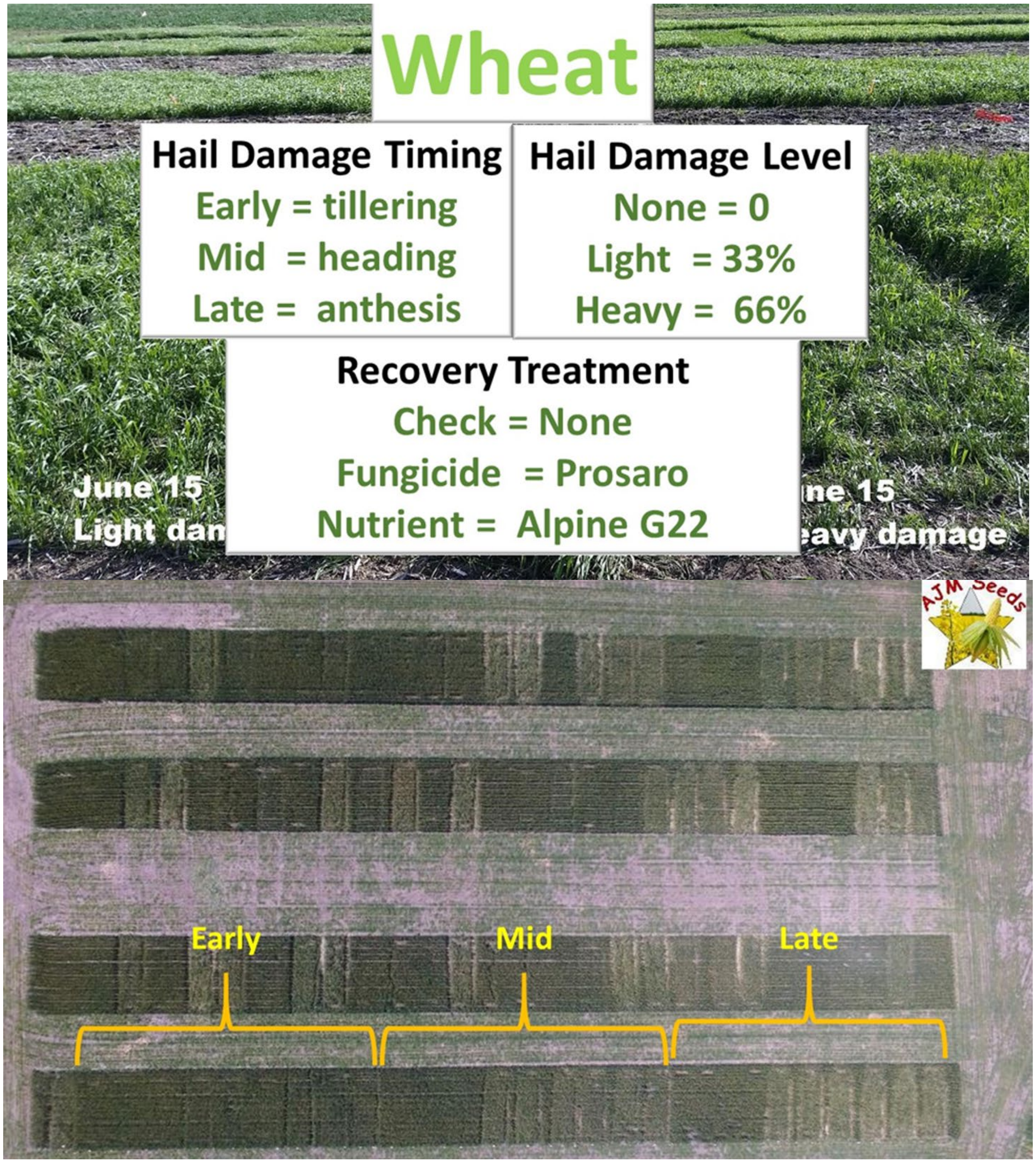


Figure 1. Experimental design of hail damage simulation on wheat in Alberta during 2016, 2017 and 2018.

At bolting (Early):

% Damage	Direction	RPM	Chains	Speed
67%	4 passes	2300	on ground	A1
33%	2 passes	2300	on ground	A1

At heading (Mid):

% Damage	Direction	RPM	Chains	Speed

67%	1 pass	2300	on ground	A1
33%	1 pass	2300	on ground	A3

At flowering (Late):

% Damage	Direction	RPM	Chains	Speed
67%	1 pass	2300	on ground	A1
33%	1 pass	2300	on ground	A3

Figure 2. Hail simulator specifications.

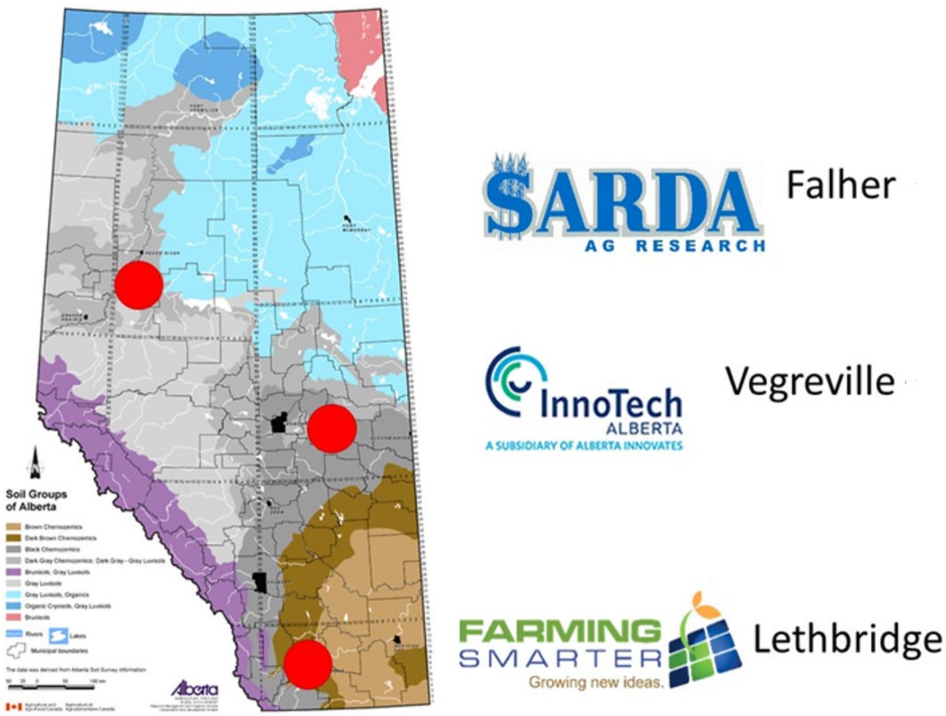


Figure 3. Location of experimental wheat fields used for hail damage simulation in Alberta during 2016, 2017 and 2018.

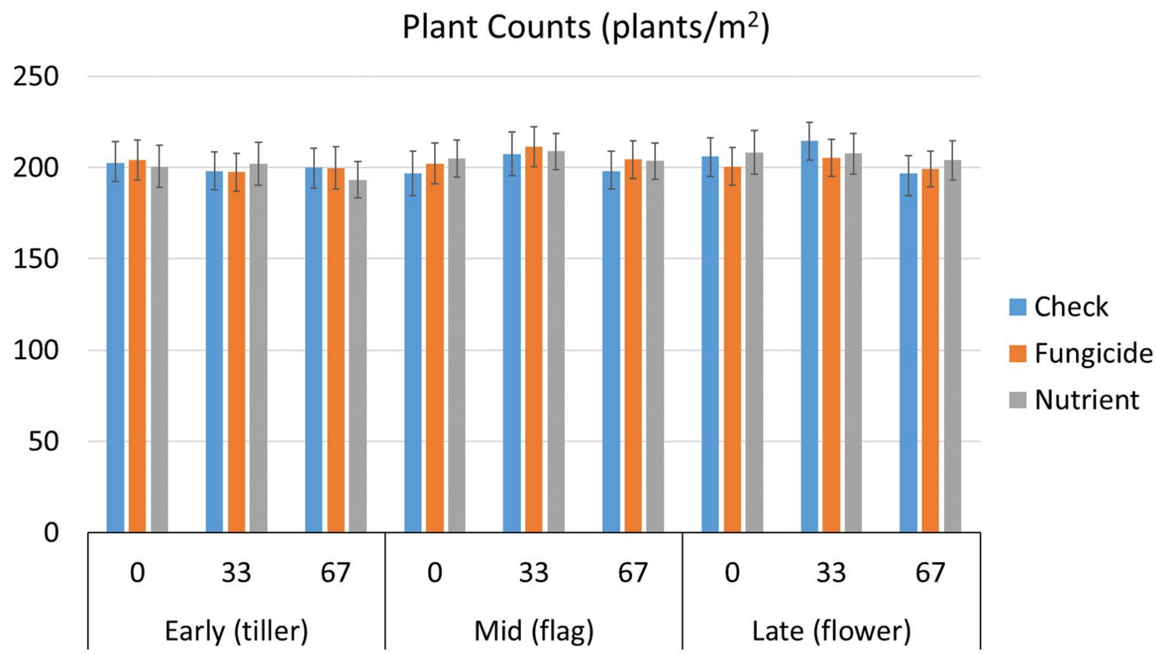


Figure 4. Plant counts of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

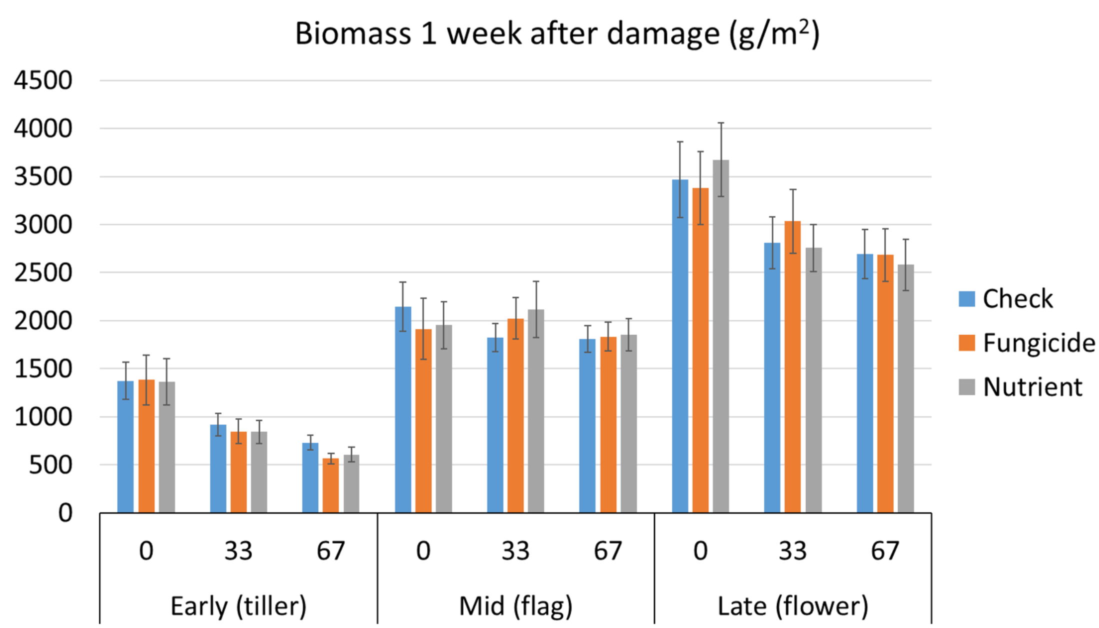


Figure 5. Biomass 1 week after damage hail damage of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

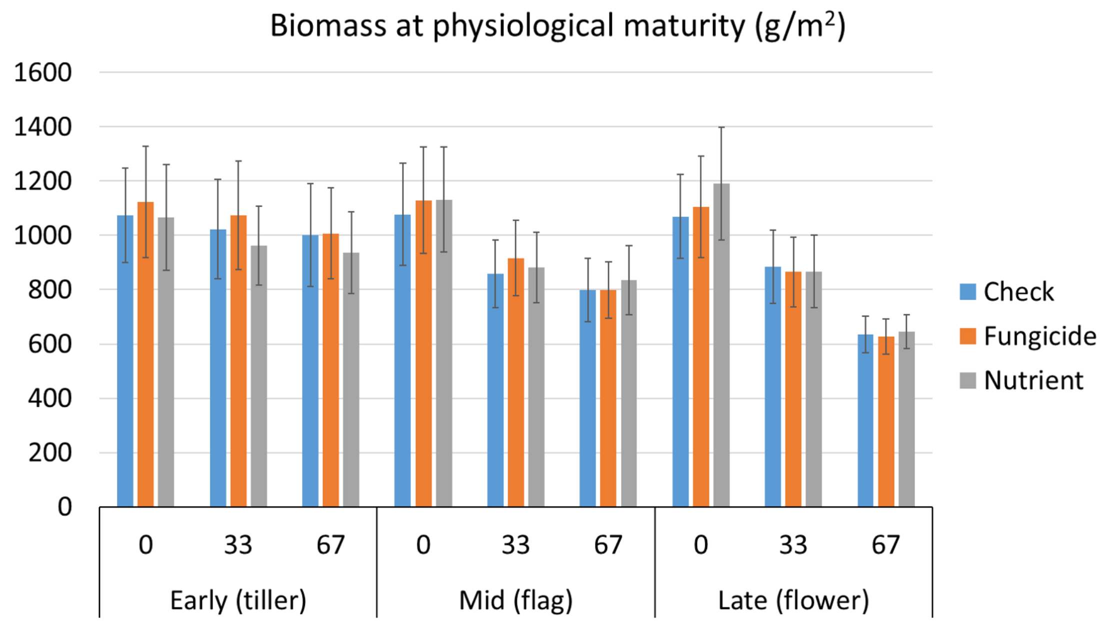


Figure 6. Biomass at maturity of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

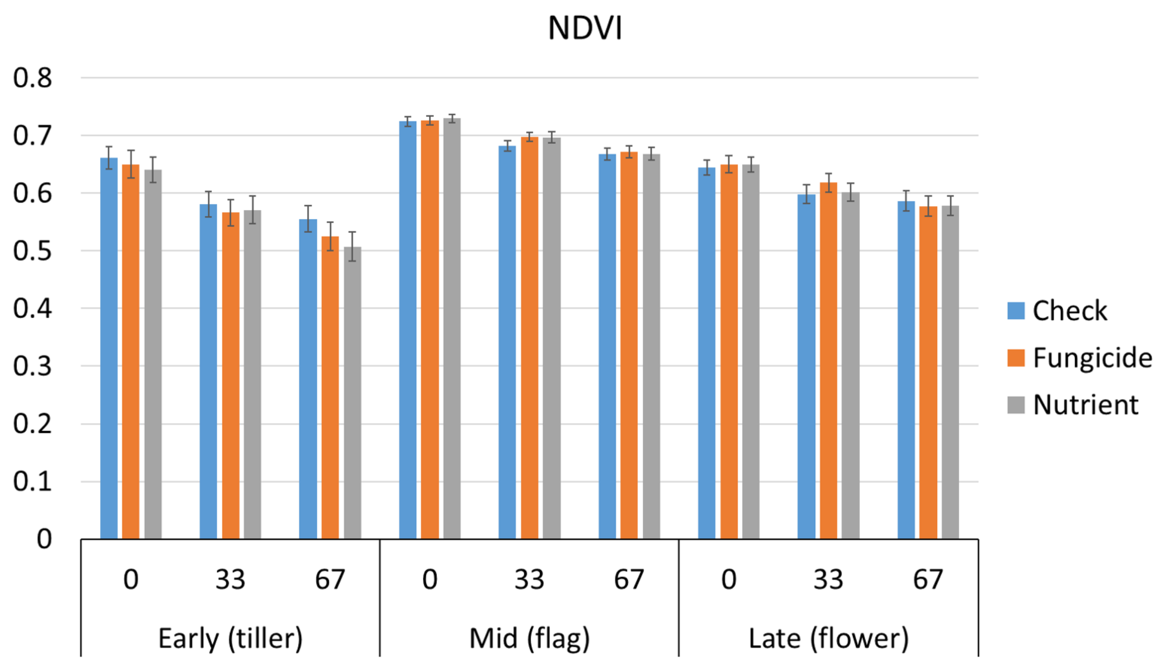


Figure 7. NDVI of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

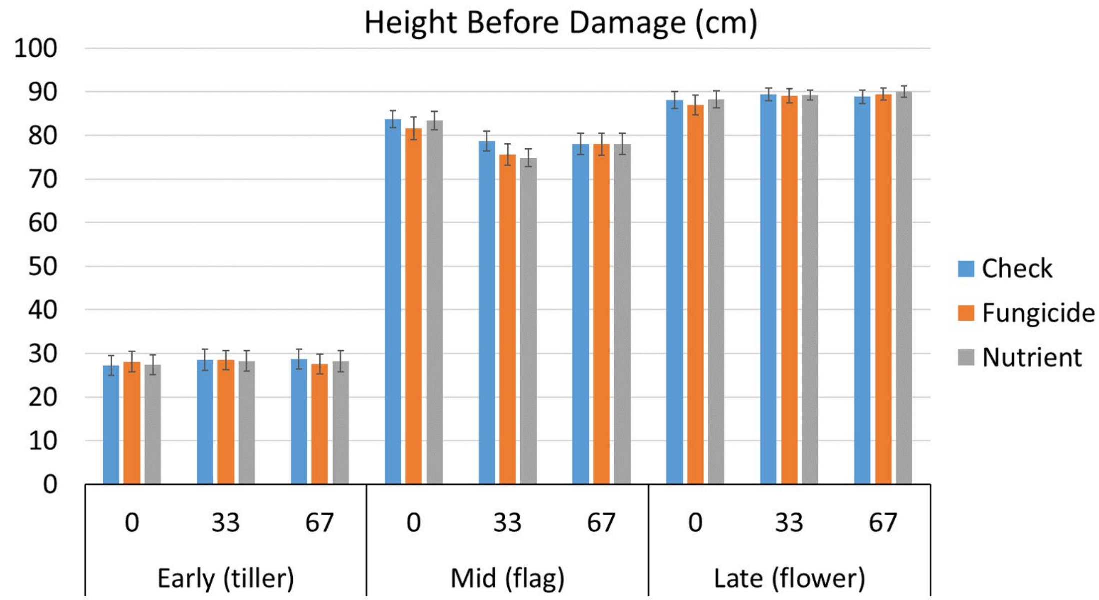


Figure 8. Plant height before hail damage of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were further exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

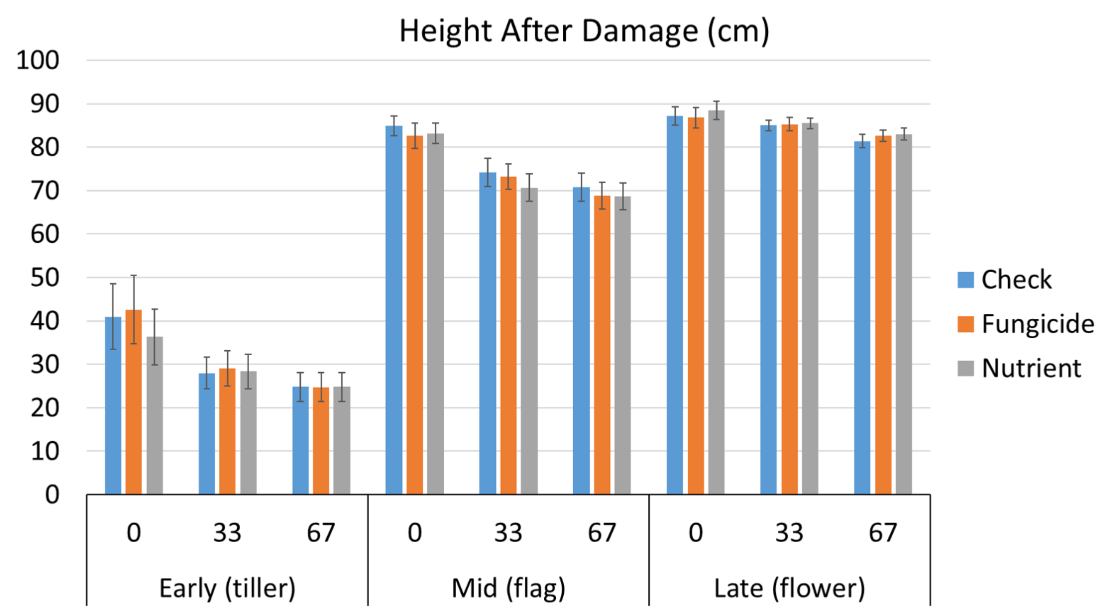


Figure 9. Plant height after hail damage of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were further exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

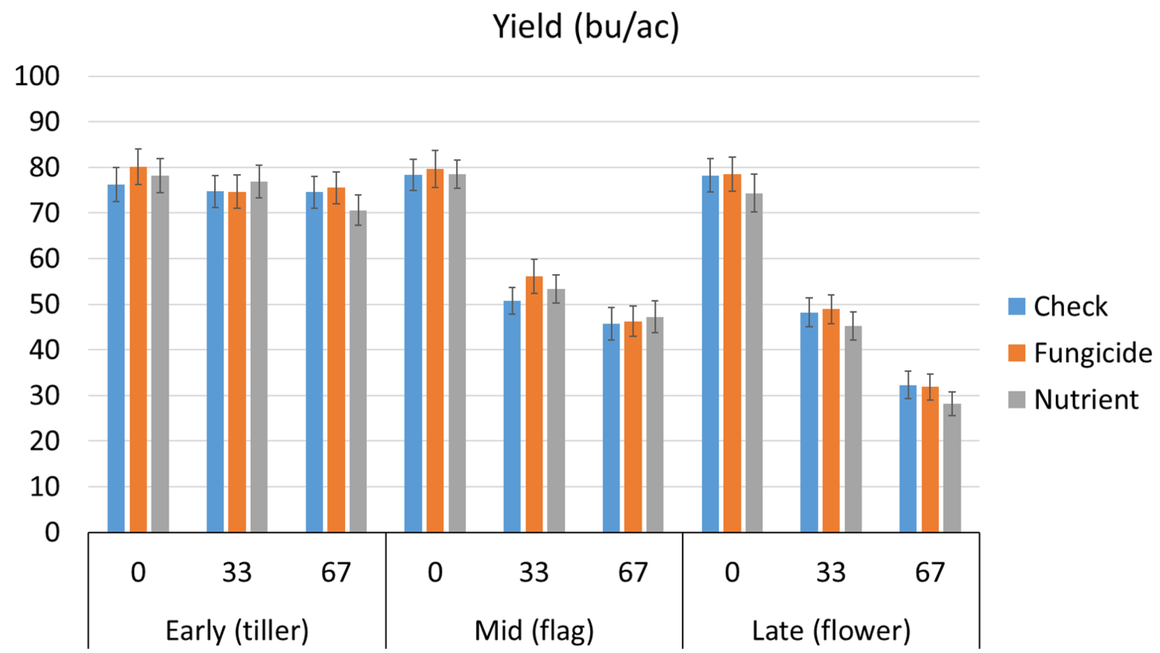


Figure 10. Yield of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

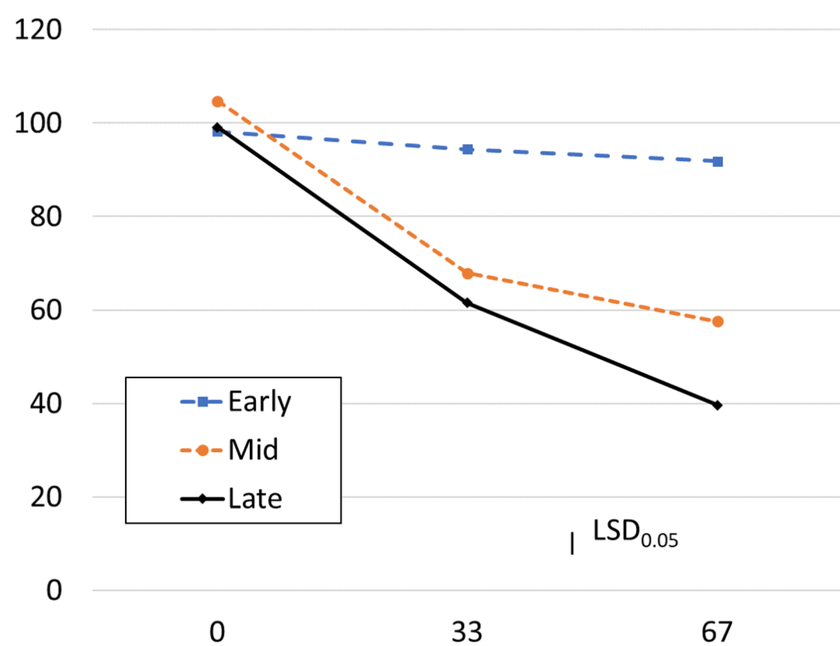


Figure 11. Percent of yield for wheat at different damage levels and timings. N = 6.

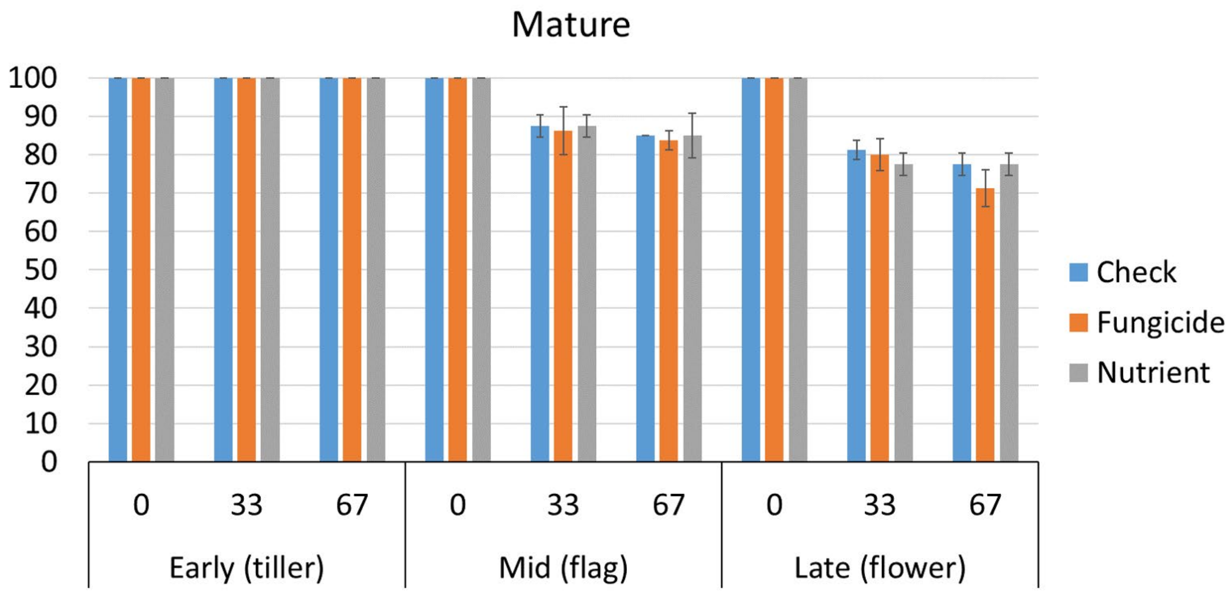


Figure 12. Maturity percentage of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

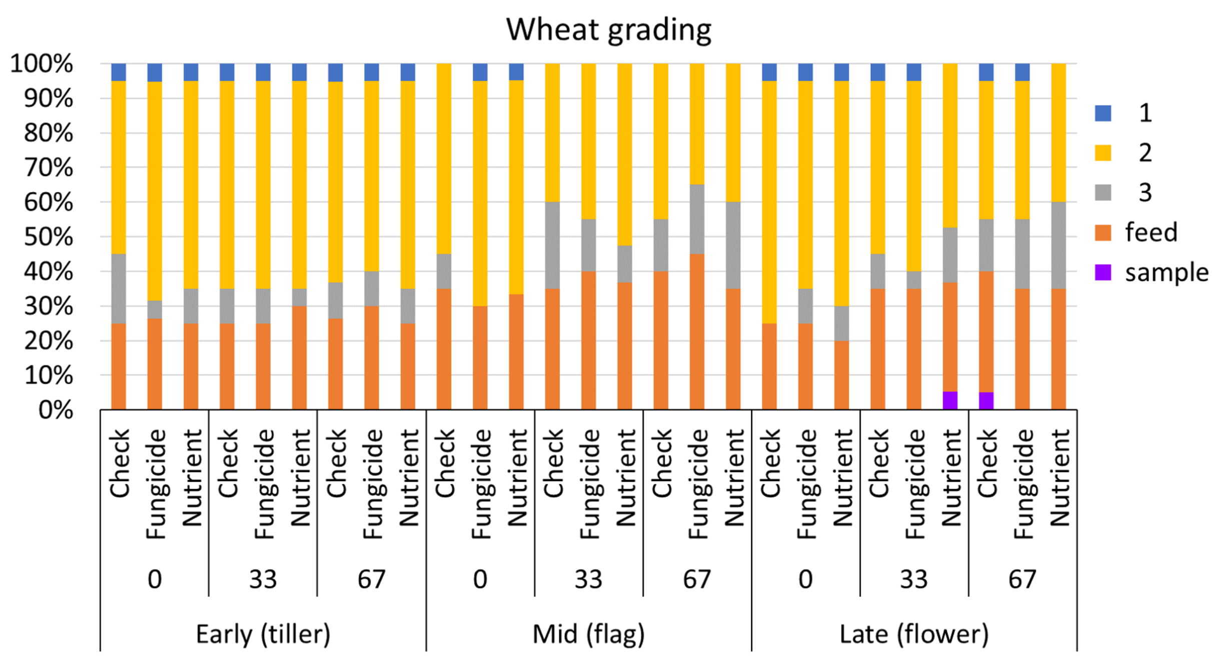


Figure 13. Wheat grading at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient).

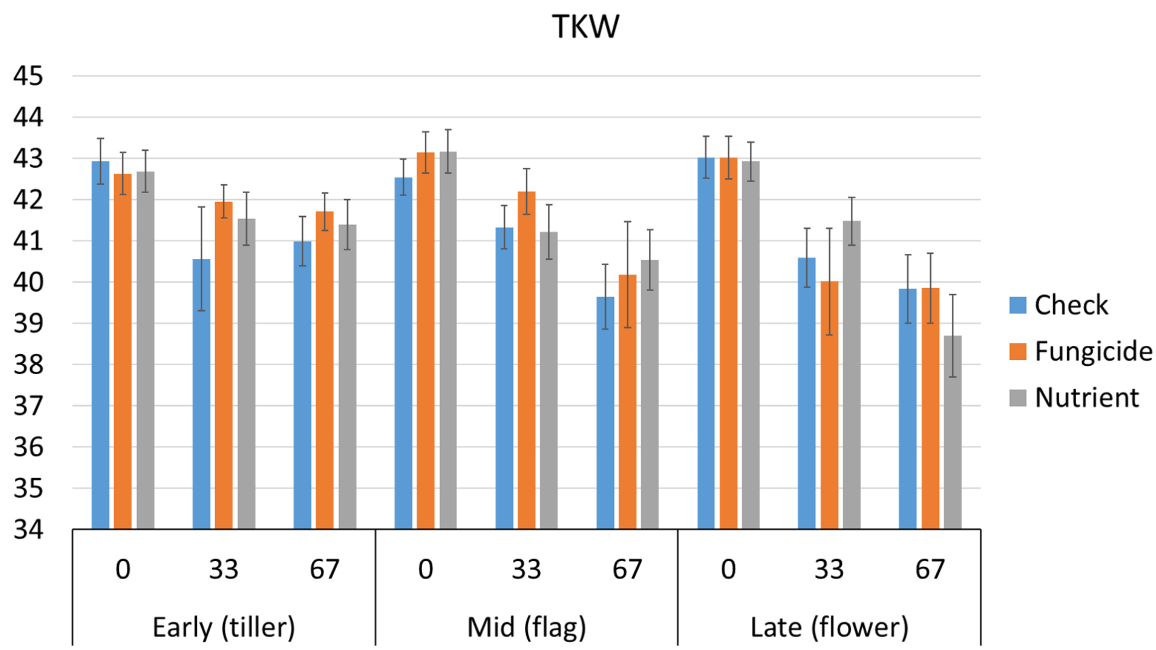


Figure 14. TKW of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

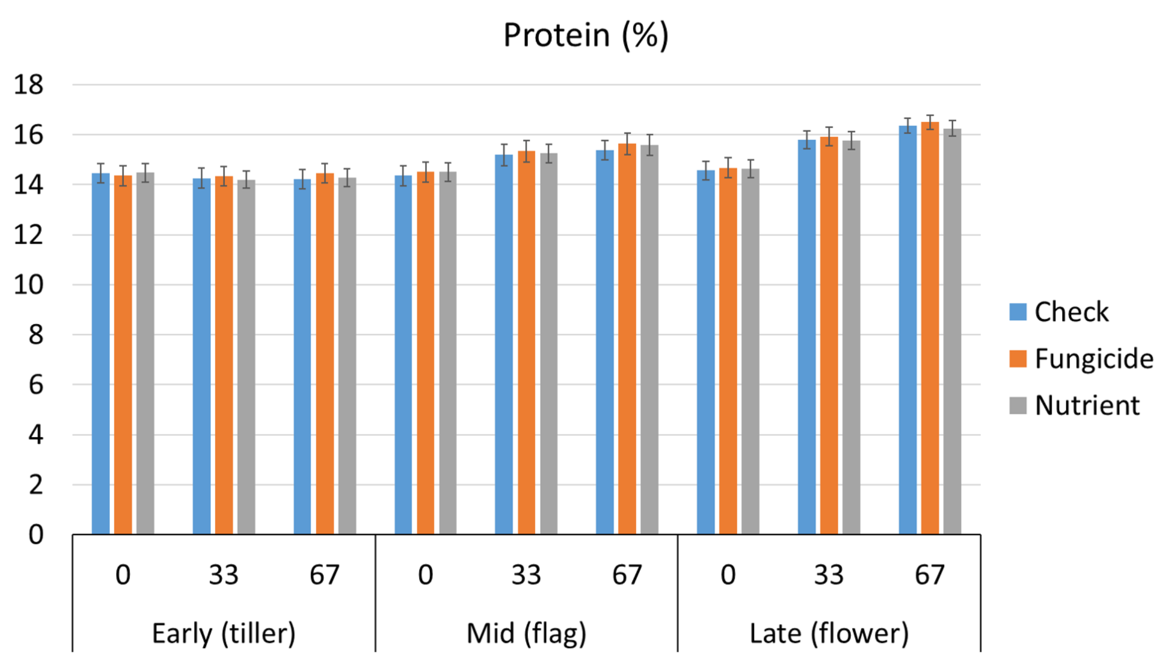


Figure 15. Protein content of wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

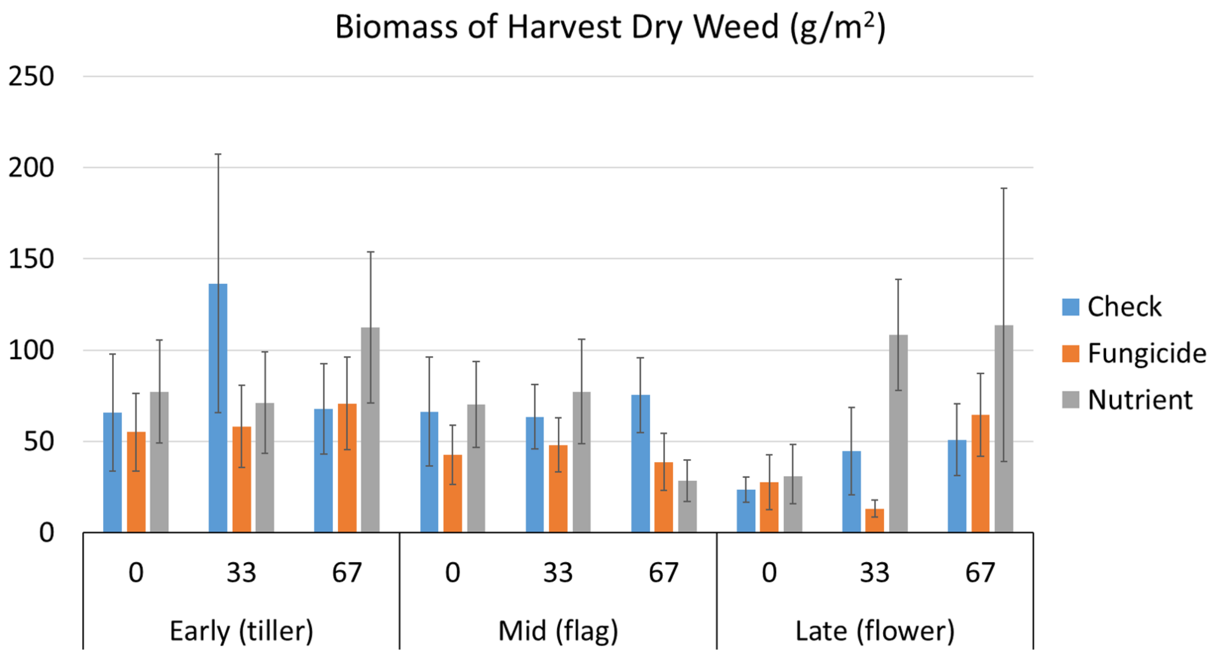


Figure 16. Biomass of harvest dry weed grown in wheat fields at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

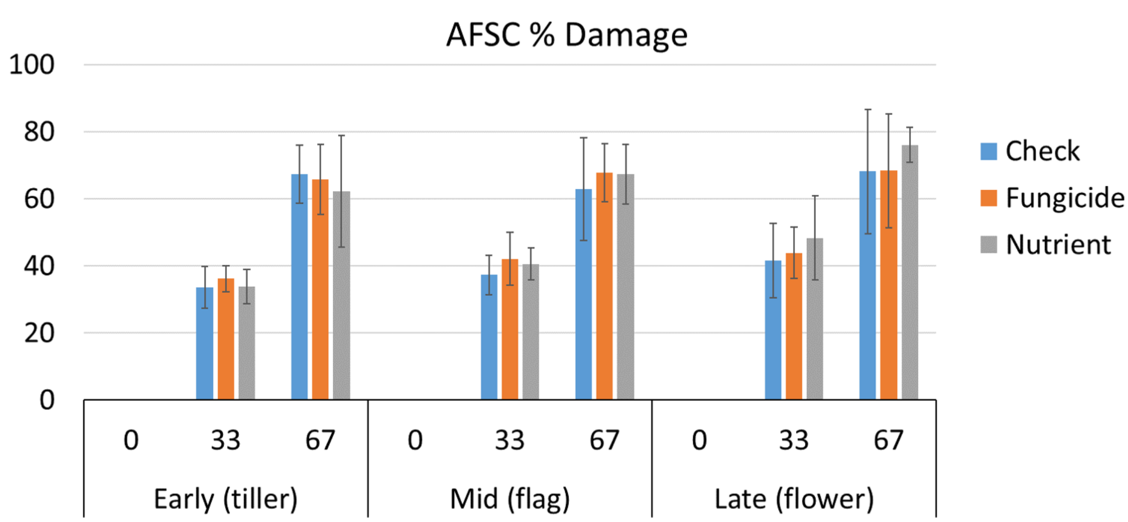


Figure 17. Percentage of damage (Defoliation) determined by AFSC 1 week after rating on wheat grown at Lethbridge, Vegrevile and Falher during 2016, 2017 and 2018. Plants were exposed to hail at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard deviation.

Appendix II

Photographs and UAV shots

Figure 1. Hail simulator with shorter chains attached to a rotating drum that was mounted on a front-end loader and controlled by hydraulics.

Figure 2. Hail simulator with golf balls to the end of their chains to mimic larger hail stones causing mechanical damage to the crop foliage.

Figure 3. Innotech hail simulator.

Figure 4. AFSC Booth at InnoTech field day

Figure 5. Seeding Wheat

Figure 6. Preparing to spray the plots

Figure 7. Collecting wheat Biomass

Figure 8. Harvesting Wheat

Appendix III

Knowledge and Technology transfer activities

a) Scientific publications (*e.g.*, scientific journals); attach copies of any publications as an appendix to this final report

- Ongoing

b) Industry-oriented publications (*e.g.*, agribusiness trade press, popular press, etc.); attach copies of any publications as an appendix to this final report

- Timing of hail more important than damage, Jan 3, 2019. Western Producer. https://www.farmingsmarter.com/wp-content/files/2019/01/WP-Timing-of-hail-more-important-than-damage.pdf
- WheatStalk: Researching crop recovery from hail damage, August 30, 2017, Rural Roots Canada - http://www.ruralrootscanada.com/wheatstalk-researching-crop-recovery-from-hail-damage/
- Managing your hail damage, March 28, 2017, Grainews - https://www.farmingsmarter.com/wp-content/files/2012/10/GN-Managing-Your-Hail-Damage.pdf
- Learning in the field at Farming Smarter, Farming Smarter Magazine, Spring 2017, page 10 - https://issuu.com/fbcpublishing/docs/170301003255-494701e6c3c64202b1a4a0d4bfeb0de0/10 Distribution: 10,000 addresses
- Do hail recovery products really work, Farming Smarter Magazine, Fall 2016, page 10 - https://issuu.com/fbcpublishing/docs/161101141617-2af47b6afd664cd3ad27f3b35f5cdb9b/10 Distribution: 10,000 addresses
- Hail simulator helps determine crop recovery expectations, July 7, 2016, Western Producer - http://www.farmingsmarter.com/wp-content/files/2012/10/WP-Hail-simulator-helps-determine-crop-recovery-expectations-07-16.pdf
- DIY hail, March 2016, Top Crop Manager - http://www.farmingsmarter.com/wp-content/files/2012/10/TCM-DIY-hail-03-16.pdf

c) Scientific presentations (*e.g.*, posters, talks, seminars, workshops, etc.); attach copies of any presentations as an appendix to this final report

d) Industry-oriented presentations (*e.g.*, posters, talks, seminars, workshops, etc.); attach copies of any presentations as an appendix to this final report

- Farming Smarter Conference December 12 & 13, 2018 (282 attendees)
- Farming Smarter Conference December 5 & 6, 2017 (202 attendees)
- WheatStalk July 20, 2017 (72 attendees)
- Cypress Field Day July 6, 2017 (38 attendees)
- Stamp Seeds Workshop, Enchant, December 16, 2016 (52 attendees)
- South Country Co-op Training webinar, December 14, 2016 (60 attendees)
- Farming Smarter Conference, Medicine Hat, December 6 & 7, 2016 (220 attendees)
- Alberta Barley and Wheat Region 1 Meeting, November 22, 2016 (35 attendees)
- Disease Plot Hop, Farming Smarter Lethbridge field site, July 28, 2016 (36 attendees)

- Alberta Wheat Day, Farming Smarter field site, Auch, AAFC Fairfield site, July 21, 2016 (42 attendees)
- South Country Co-op training day, Farming Smarter Lethbridge field site, July 19, 2016 (61 attendees)
- Farming Smarter AGM February 25, 2016 (65 attendees)
- FarmTech tradeshow (1,800 attendees)

e) Media activities (*e.g.*, radio, television, internet, etc.)

- Farming Smarter Conference December 12 & 13, 2018 – not yet posted
- Farming Smarter Conference December 5 & 6, 2017 - https://youtu.be/SJ1Cbo_Ho0o
- WheatStalk July 20, 2017 - https://youtu.be/86l16lDbsDs
- Cypress Field Day July 6, 2017 - https://youtu.be/60MTX831qrg
- Farming Smarter Conference, Medicine Hat, December 6 & 7, 2016 - https://youtu.be/Akd7Ycs8f4g
- Plot hop season ends on a high note for Farming Smarter – July 28, 2016 http://www.farmingsmarter.com/plot-hop-season-ends-high-note-farming-smarter/
- Disease Plot Hop, Farming Smarter Lethbridge field site, July 28, 2016 - https://youtu.be/62ThjBQDv-o
- Alberta Wheat Day, Farming Smarter field site, Auch, AAFC Fairfield site, July 21, 2016 - https://youtu.be/Hm5yAcvHmOY
- Farming Smarter AGM, February 25, 2016 - https://youtu.be/nHVEE1cU6Fc
- Farming Smarter hail simulator at FarmTech - https://youtu.be/qg9VAm5ni8E
- Farming Smarter introduces its unique hail simulator - https://youtu.be/w6C1V_Qx3ak

f) Any commercialisation activities or patents

- none

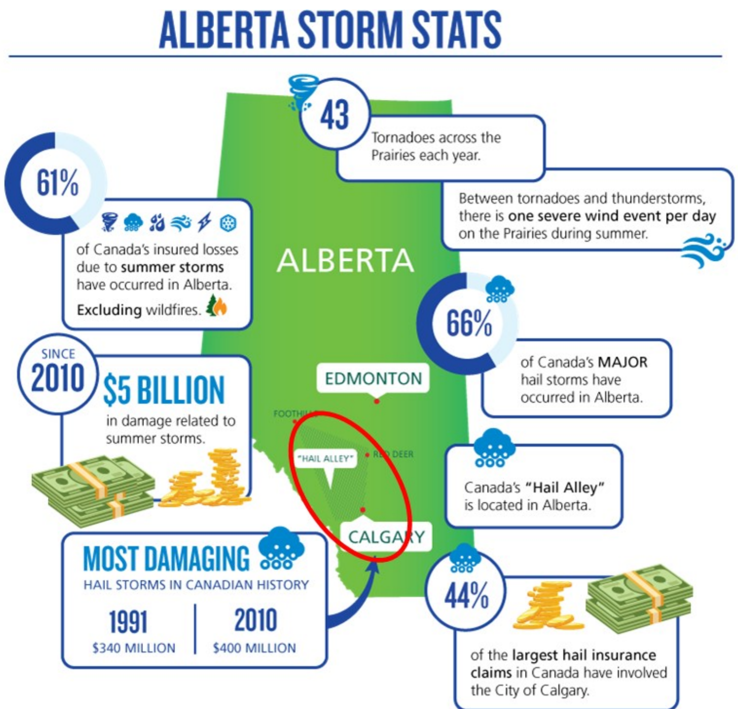
Farming Smarter Conference December 12 & 13, 2018 (282 attendees)

FARMING SMARTER
Growing new ideas.

A Hail of Story

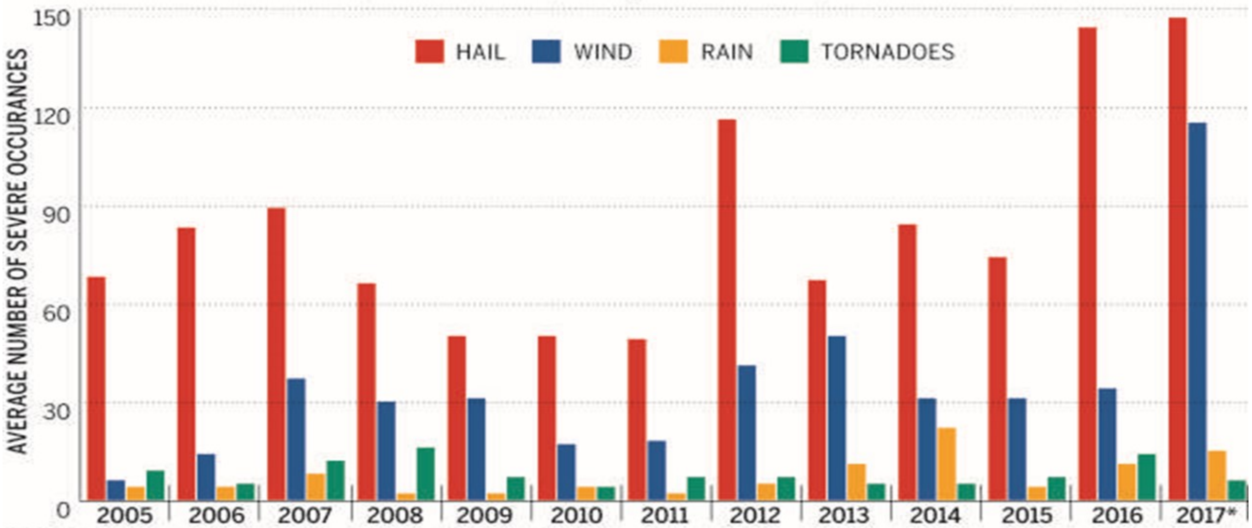
#FSC18

December 12,13
Lethbridge Exhibition Park
Ken Coles, M.Sc., P.Ag., CCA


ALBERTA STORM STATS
43
Tornadoes across the Prairies each year.
Between tornadoes and thunderstorms, there is one severe wind event per day on the Prairies during summer.
61%
of Canada's insured losses due to summer storms have occurred in Alberta. Excluding wildfires.
ALBERTA
66%
of Canada's MAJOR hail storms have occurred in Alberta.
SINCE 2010
$5 BILLION
in damage related to summer storms.
EDMONTON
"HAIL ALLEY"
Canada's "Hail Alley" is located in Alberta.
CALGARY
MOST DAMAGING
HAIL STORMS IN CANADIAN HISTORY
1991
$340 MILLION
2010
$400 MILLION
44%
of the largest hail insurance claims in Canada have involved the City of Calgary.

SEVERE WEATHER

Average numbers of severe hail, wind, rain and tornadoes. Severe hail is defined as any hail 2 cm (nickel size) or larger. Severe rain is defined as 50 mm or more in an hour. Severe wind is defined as sustained wind speeds of 70 km/h or gusts to 90 km/h.



*Numbers are preliminary and may be subject to change

SOURCE: ENVIRONMENT AND CLIMATE CHANGE CANADA

POSTMEDIA NEWS

AFSC Annual Crops Hail Endorsement – subsidized premiums

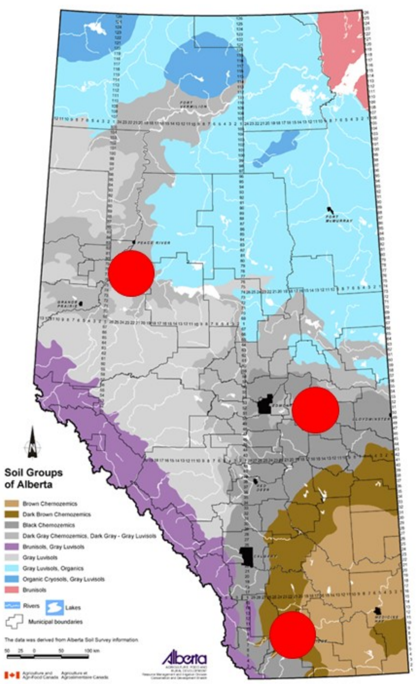
Year	Overall Cause of Loss = Hail	Contracts	Acres	Liability	Claims	Loss-premium ratio
2017	43%	10,251	13.1 million	$4 billion	$161 million	59.2%
2016	78%	10,679	13.5 million	$4.1 billion	$307 million	113%
2015	50%	10,481	13.3 million	$3.6 billion	$206 million	95.2%

AFSC Annual Crops Straight Hail – 100% producer funded premiums

Year	Cause of Loss = Hail	Contracts	Acres	Liability	Claims	Loss-premium ratio
2017	43%	3180	3.3 million	$485 million	$15 million	34.3%
2016	78%	3768	3.9 million	$550 million	$51 million	111.8%
2015	50%	3757	3.8 million	$546 million	$32 million	72.2%


LARGEST HAILSTONE EVER


HAIL
PROTECTOR
© Hail Protector/Solent News



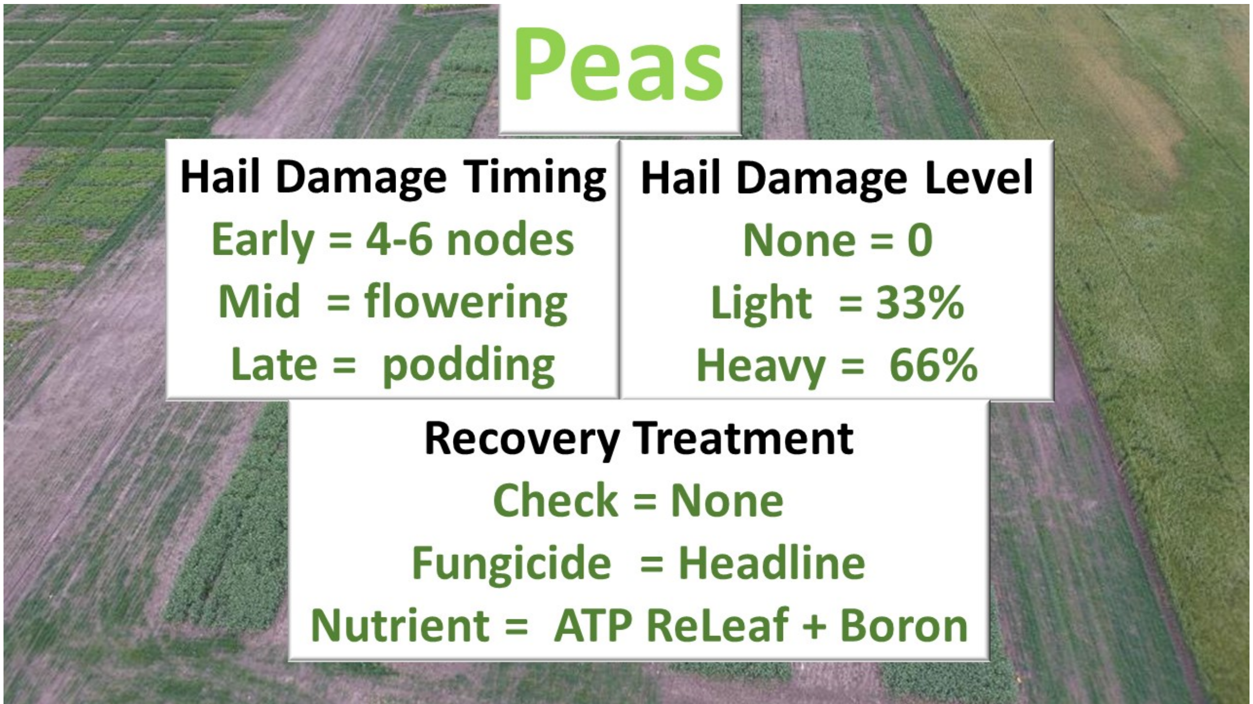
3 year study @ 3 locations

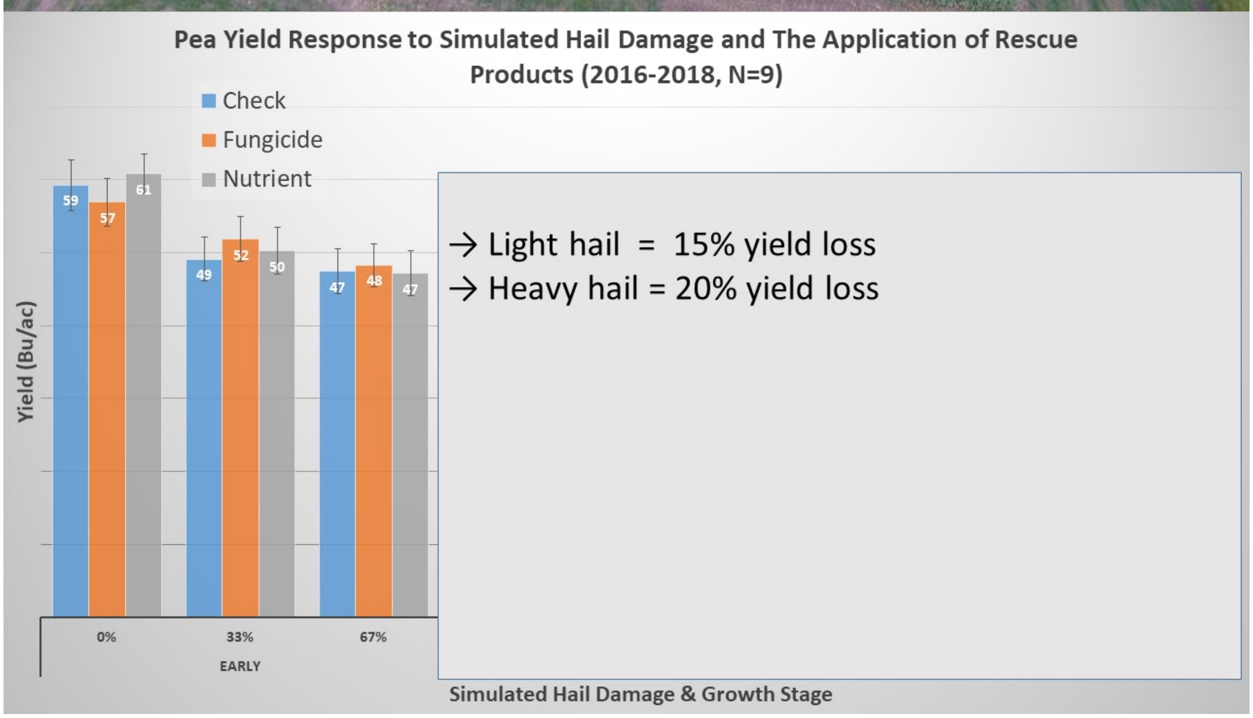
SARDA AG RESEARCH — Falher – Vance Yaremko, Darcy Boisevert

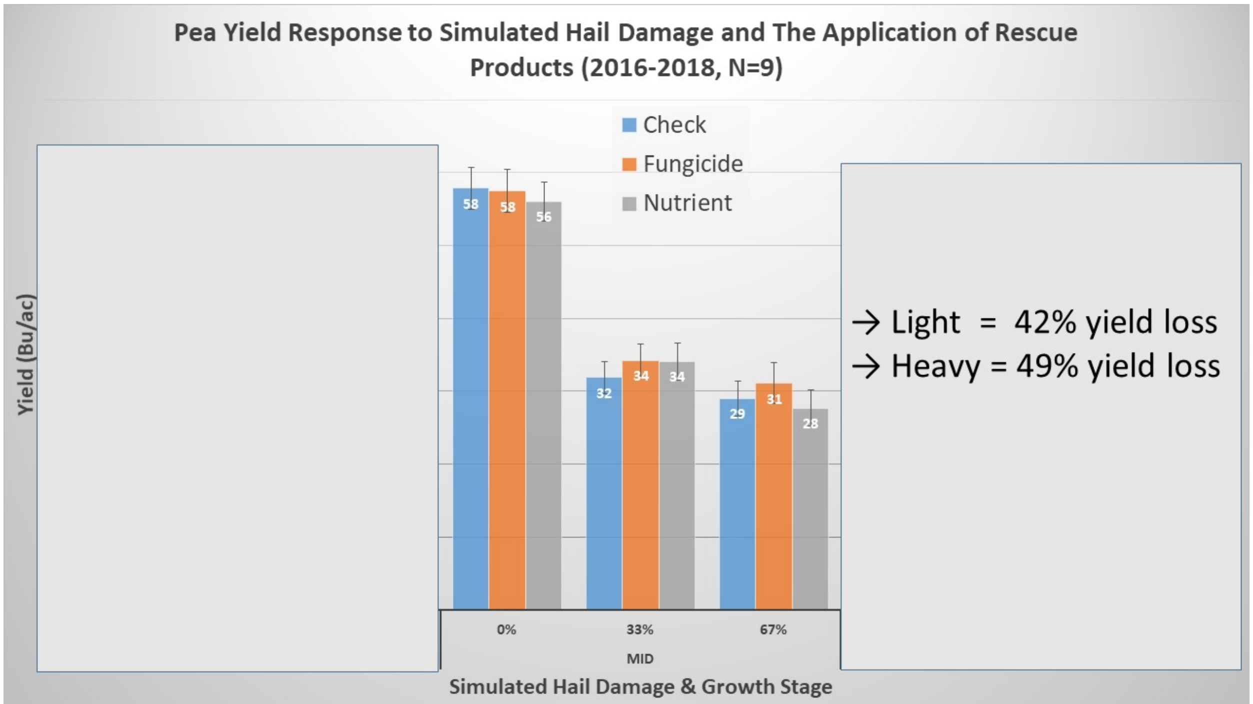
InnoTech ALBERTA, A SUBSIDIARY OF ALBERTA INNOVATES — Vegreville – Ralph Lange, Rod Werezuk

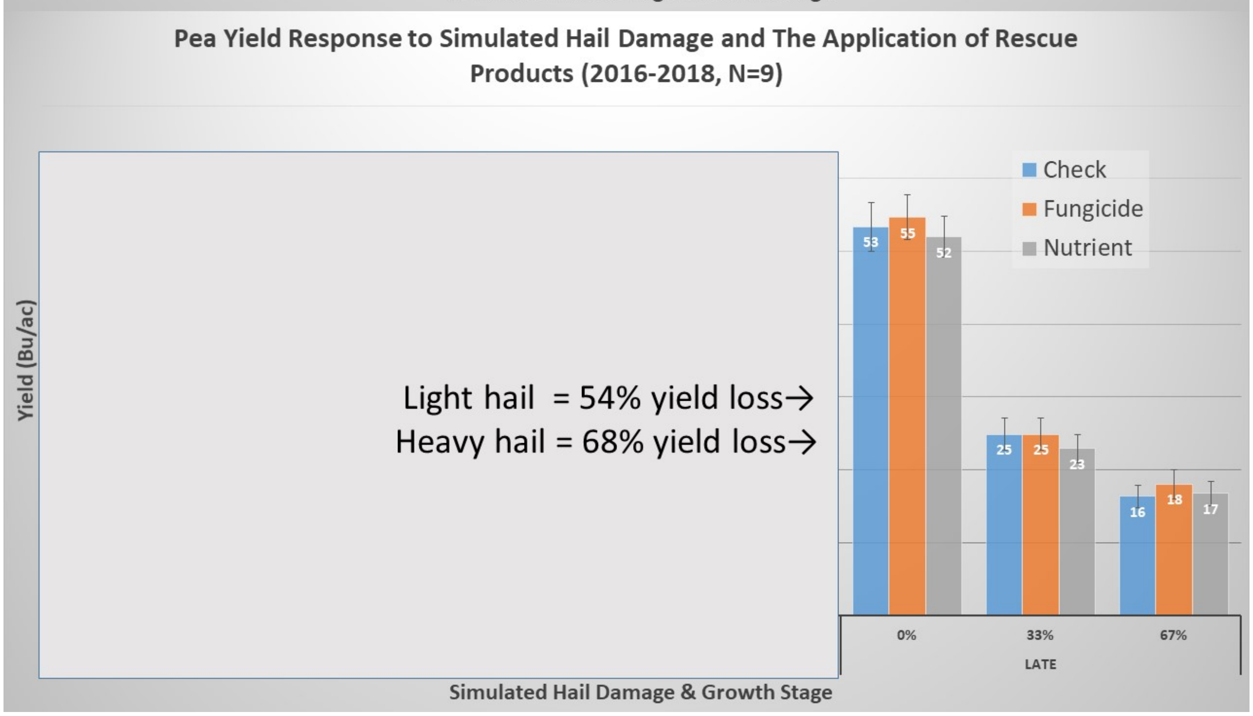
FARMING SMARTER, Growing new ideas. — Lethbridge – Ken Coles, Mike Gretzinger

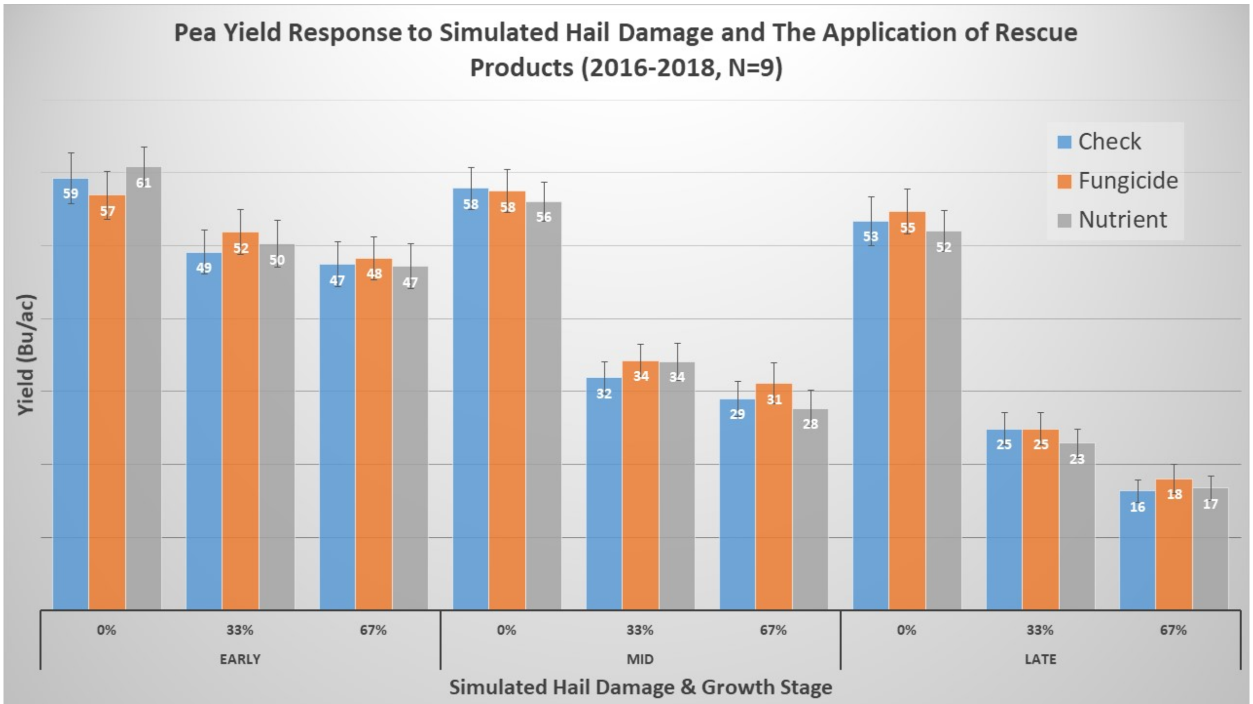

ALBERTA PULSE
GROWERS

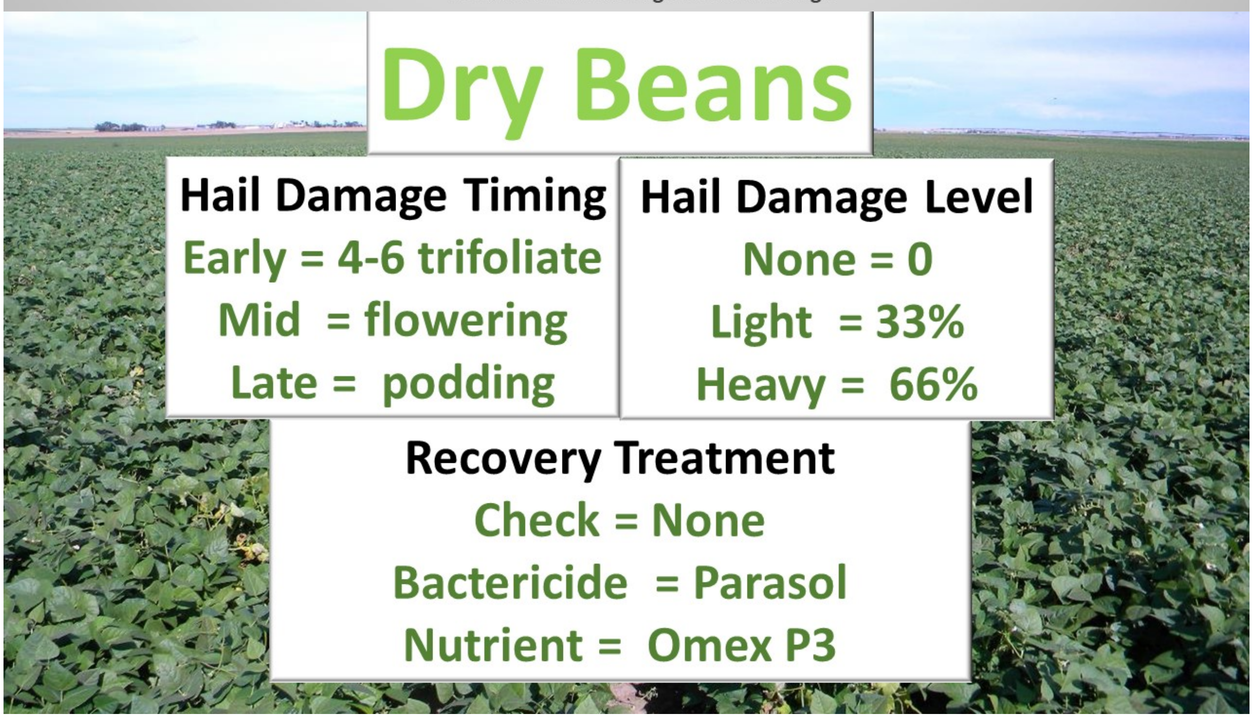

Peas
Hail Damage Timing
Early = 4-6 nodes
Mid = flowering
Late = podding
Hail Damage Level
None = 0
Light = 33%
Heavy = 66%
Recovery Treatment
Check = None
Fungicide = Headline
Nutrient = ATP ReLeaf + Boron

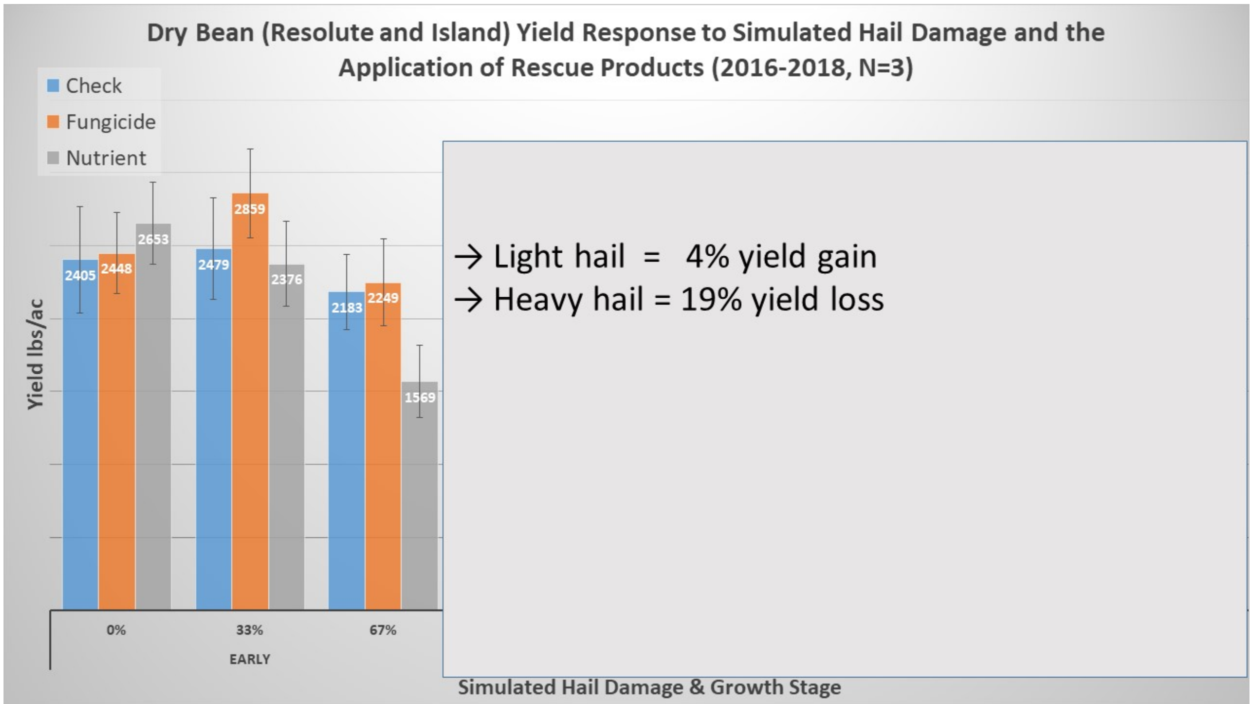

Pea Yield Response to Simulated Hail Damage and The Application of Rescue Products (2016-2018, N=9)
Check
Fungicide
Nutrient
Yield (Bu/ac)
59
57
61
49
52
50
47
48
47
0%
33%
67%
EARLY
→ Light hail = 15% yield loss
→ Heavy hail = 20% yield loss
Simulated Hail Damage & Growth Stage

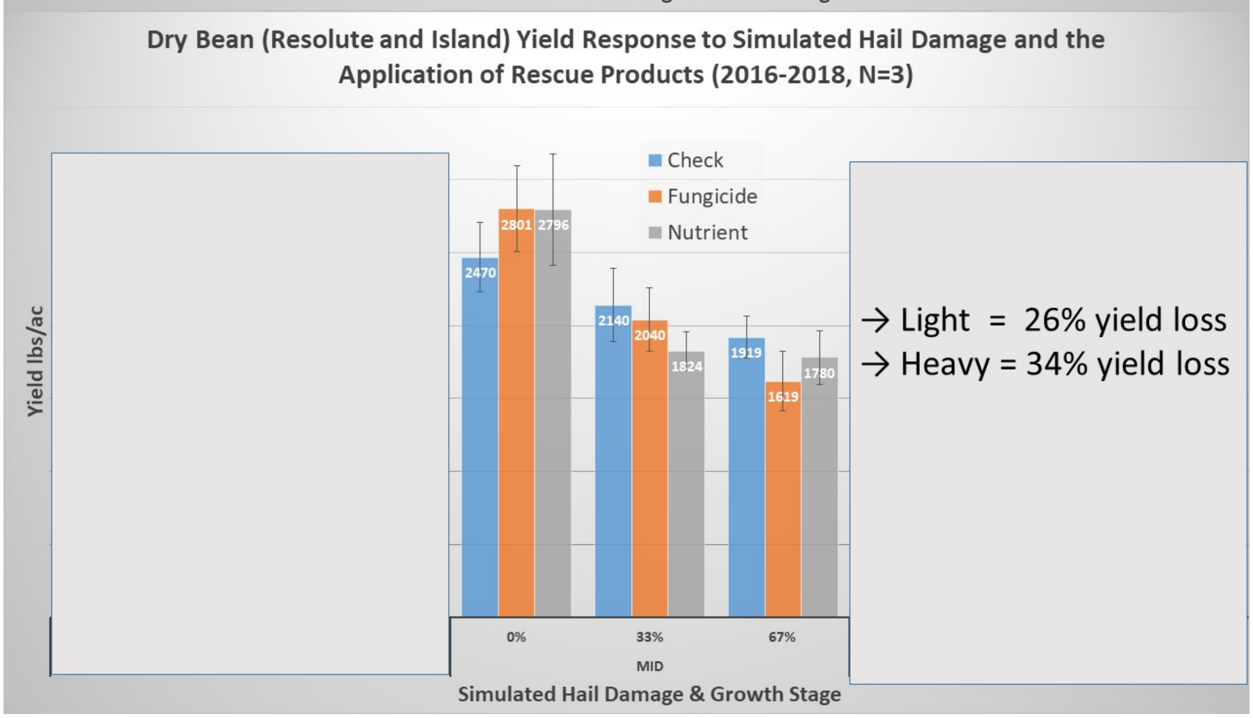

Pea Yield Response to Simulated Hail Damage and The Application of Rescue Products (2016-2018, N=9)
Check
Fungicide
Nutrient
Yield (Bu/ac)
58
58
56
32
34
34
29
31
28
0%
33%
67%
MID
Simulated Hail Damage & Growth Stage
→ Light = 42% yield loss
→ Heavy = 49% yield loss

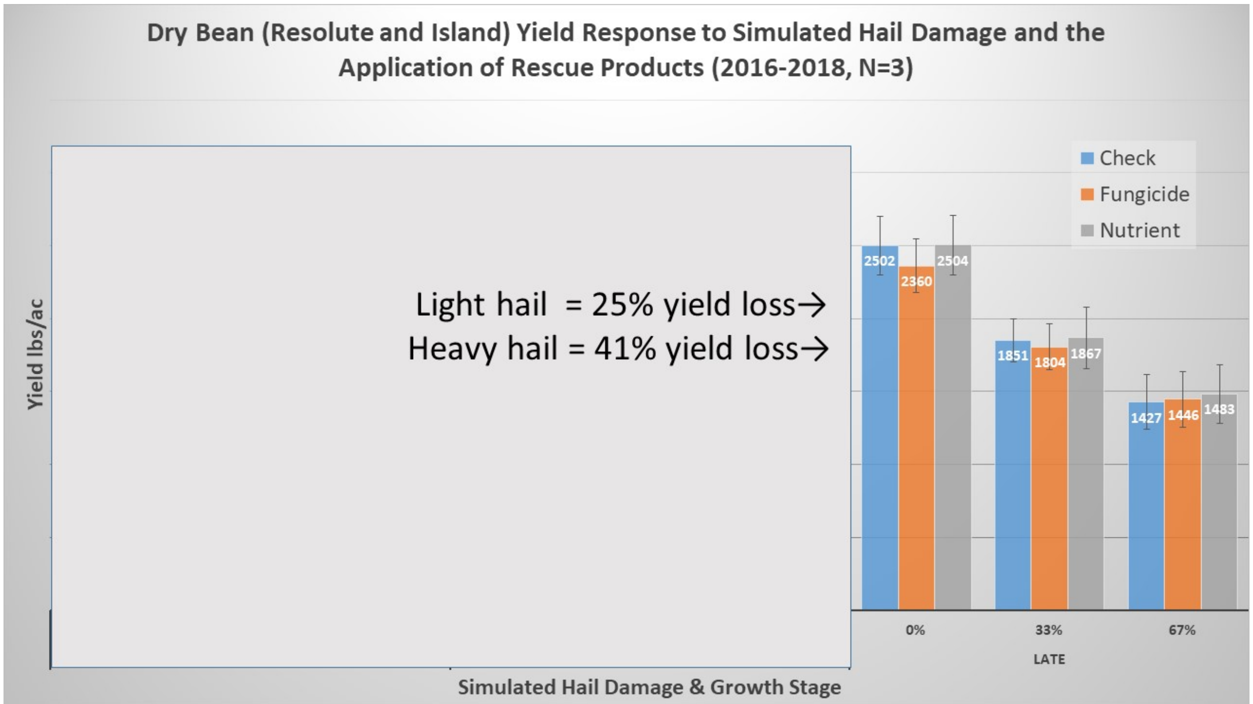

Pea Yield Response to Simulated Hail Damage and The Application of Rescue Products (2016-2018, N=9)
Check
Fungicide
Nutrient
Yield (Bu/ac)
Light hail = 54% yield loss→
Heavy hail = 68% yield loss→
53
55
52
25
25
23
16
18
17
0%
33%
67%
LATE
Simulated Hail Damage & Growth Stage


Pea Yield Response to Simulated Hail Damage and The Application of Rescue Products (2016-2018, N=9)
Check
Fungicide
Nutrient
Yield (Bu/ac)
59 57 61
49 52 50
47 48 47
58 58 56
32 34 34
29 31 28
53 55 52
25 25 23
16 18 17
0% 33% 67%
EARLY
0% 33% 67%
MID
0% 33% 67%
LATE
Simulated Hail Damage & Growth Stage

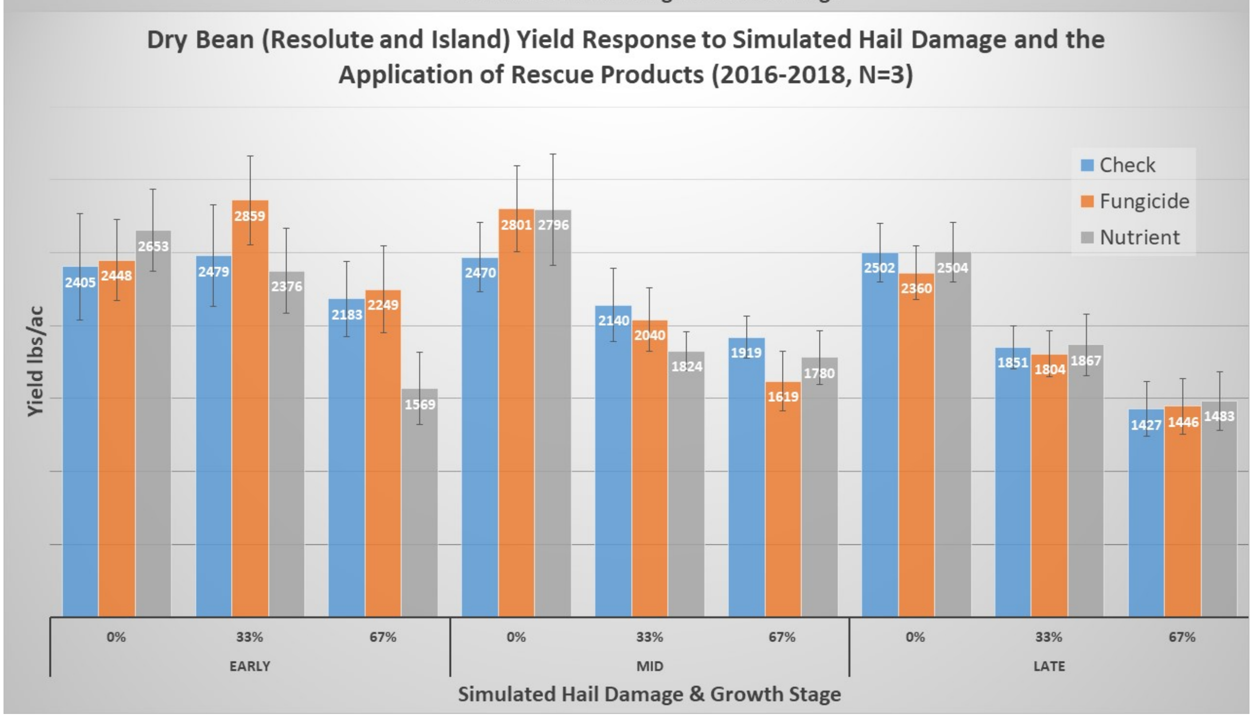

Dry Beans
Hail Damage Timing
Early = 4-6 trifoliate
Mid = flowering
Late = podding
Hail Damage Level
None = 0
Light = 33%
Heavy = 66%
Recovery Treatment
Check = None
Bactericide = Parasol
Nutrient = Omex P3


Dry Bean (Resolute and Island) Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=3)
Check
Fungicide
Nutrient
Yield lbs/ac
2405
2448
2653
2479
2859
2376
2183
2249
1569
0%
33%
67%
EARLY
→ Light hail = 4% yield gain
→ Heavy hail = 19% yield loss
Simulated Hail Damage & Growth Stage

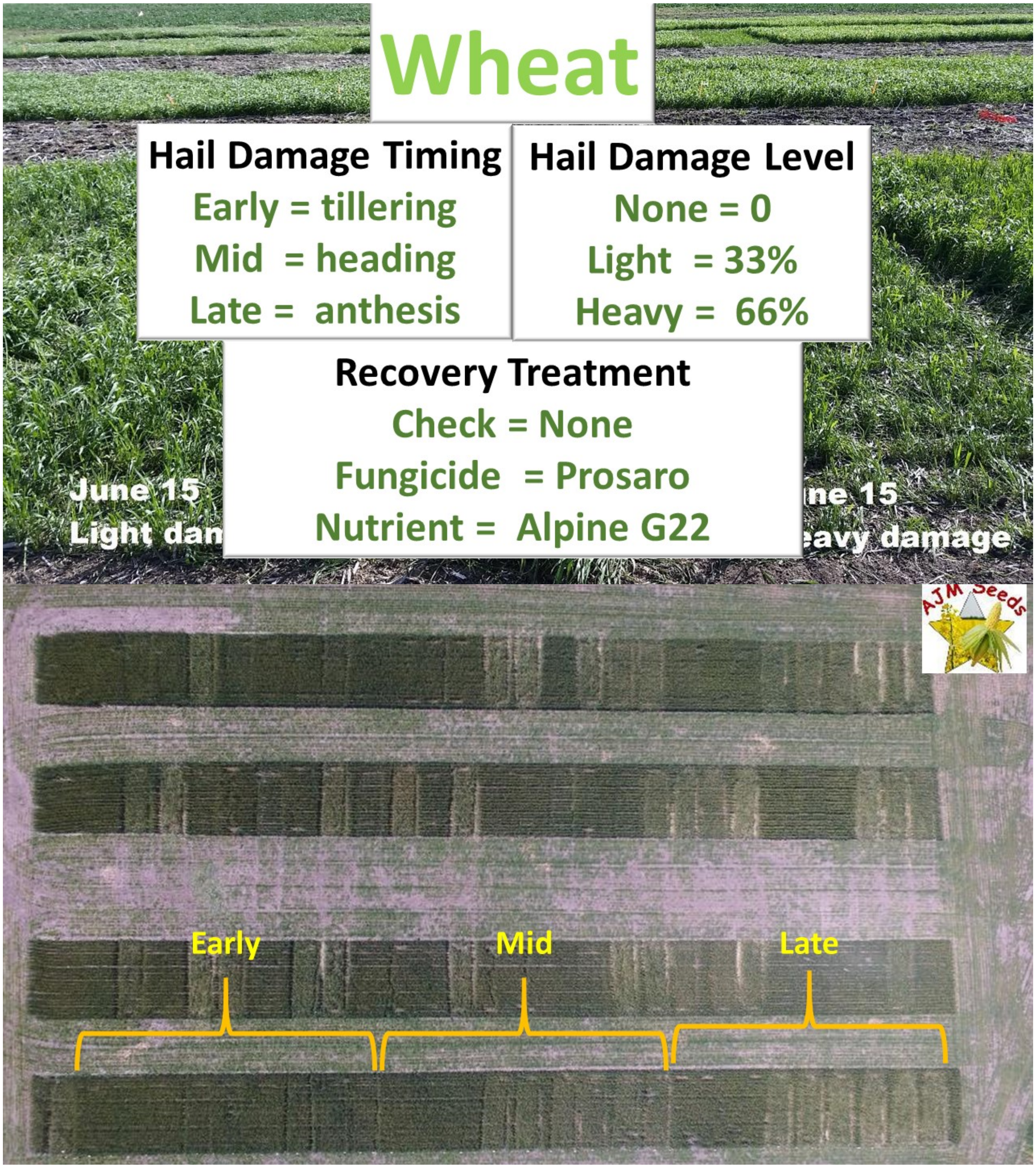

Dry Bean (Resolute and Island) Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=3)
Check
Fungicide
Nutrient
Yield lbs/ac
2470
2801
2796
2140
2040
1824
1919
1619
1780
0%
33%
67%
MID
→ Light = 26% yield loss
→ Heavy = 34% yield loss
Simulated Hail Damage & Growth Stage

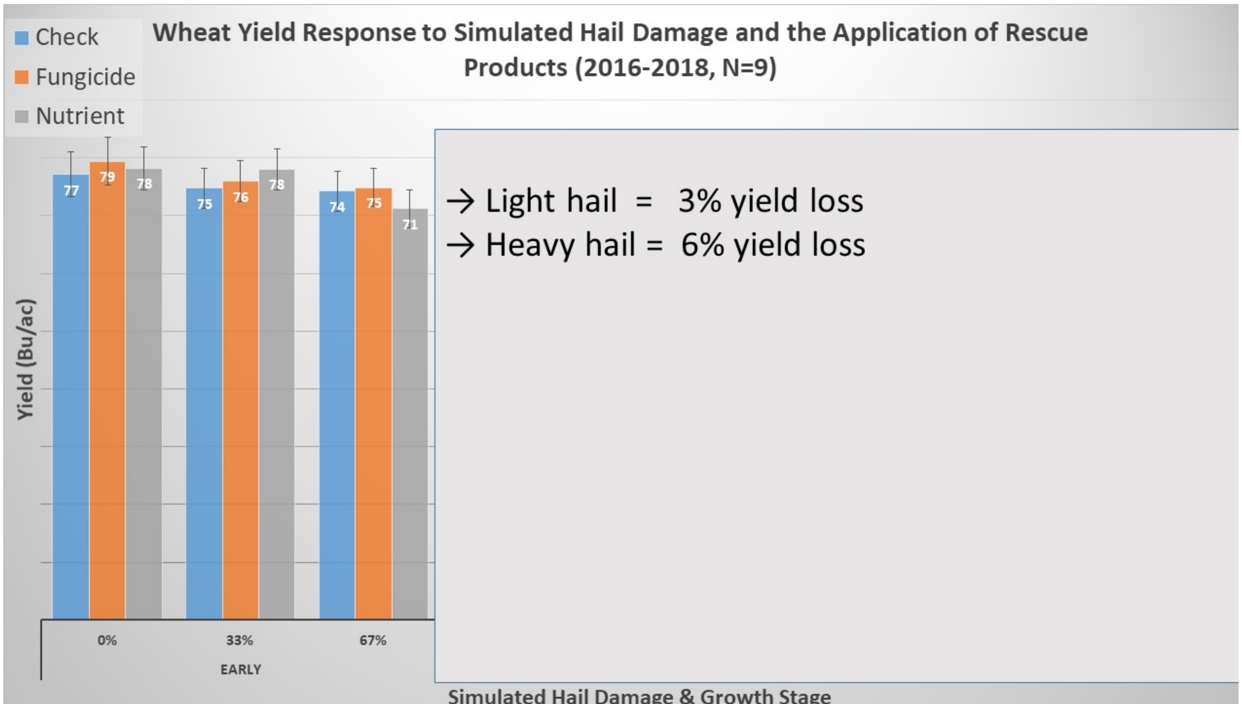


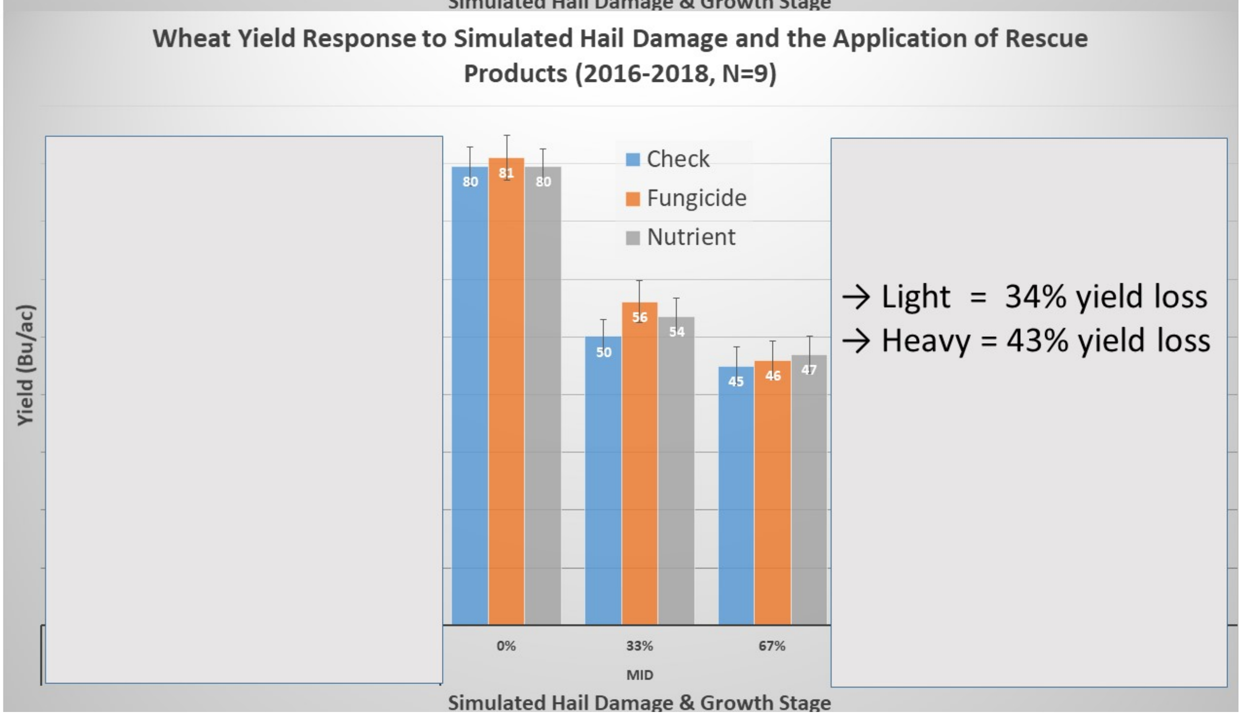
Dry Bean (Resolute and Island) Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=3)
Check
Fungicide
Nutrient
Light hail = 25% yield loss→
Heavy hail = 41% yield loss→
Yield lbs/ac
2502
2360
2504
1851
1804
1867
1427
1446
1483
0%
33%
67%
LATE
Simulated Hail Damage & Growth Stage

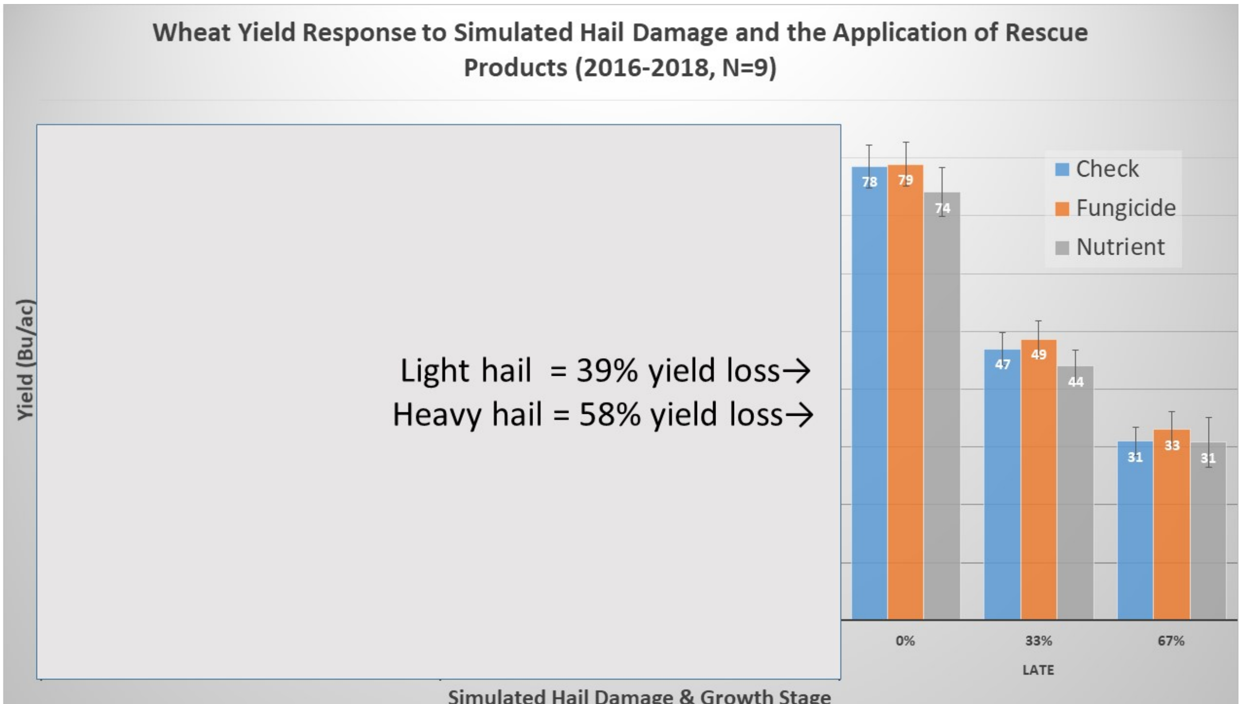


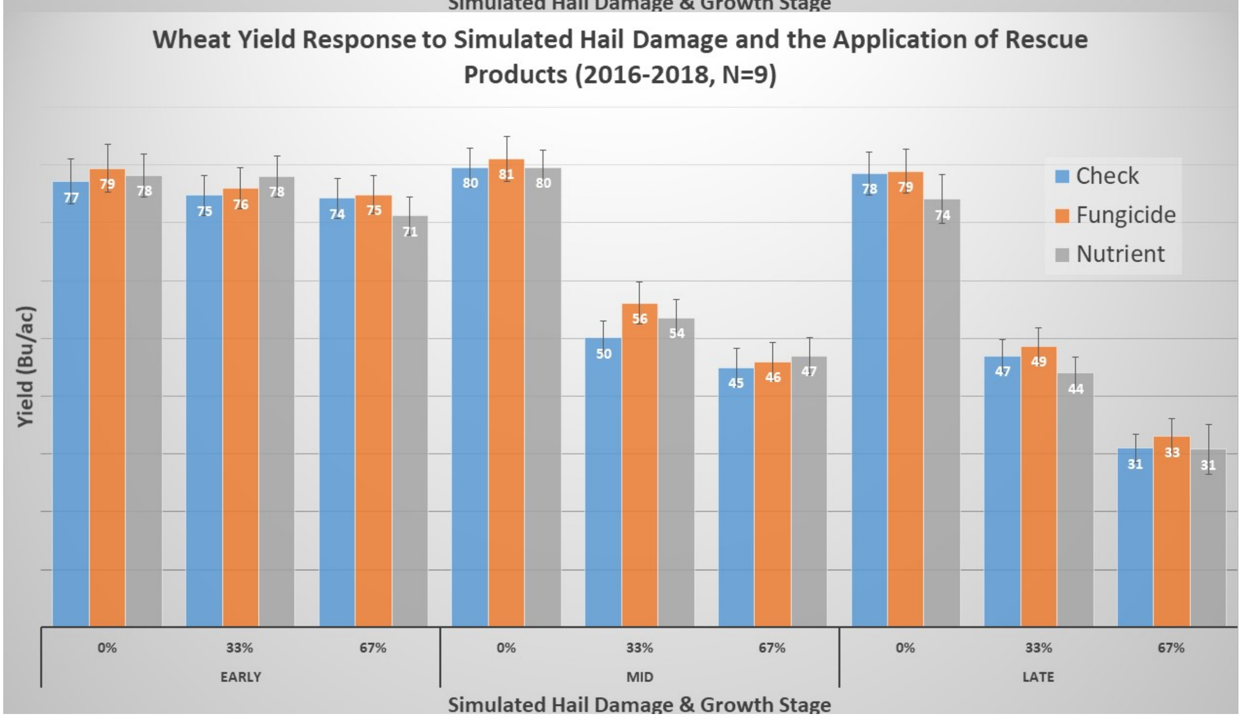
Dry Bean (Resolute and Island) Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=3)
Check
Fungicide
Nutrient
Yield lbs/ac
2405
2448
2653
2479
2859
2376
2183
2249
1569
2470
2801
2796
2140
2040
1824
1919
1619
1780
2502
2360
2504
1851
1804
1867
1427
1446
1483
0%
33%
67%
EARLY
0%
33%
67%
MID
0%
33%
67%
LATE
Simulated Hail Damage & Growth Stage

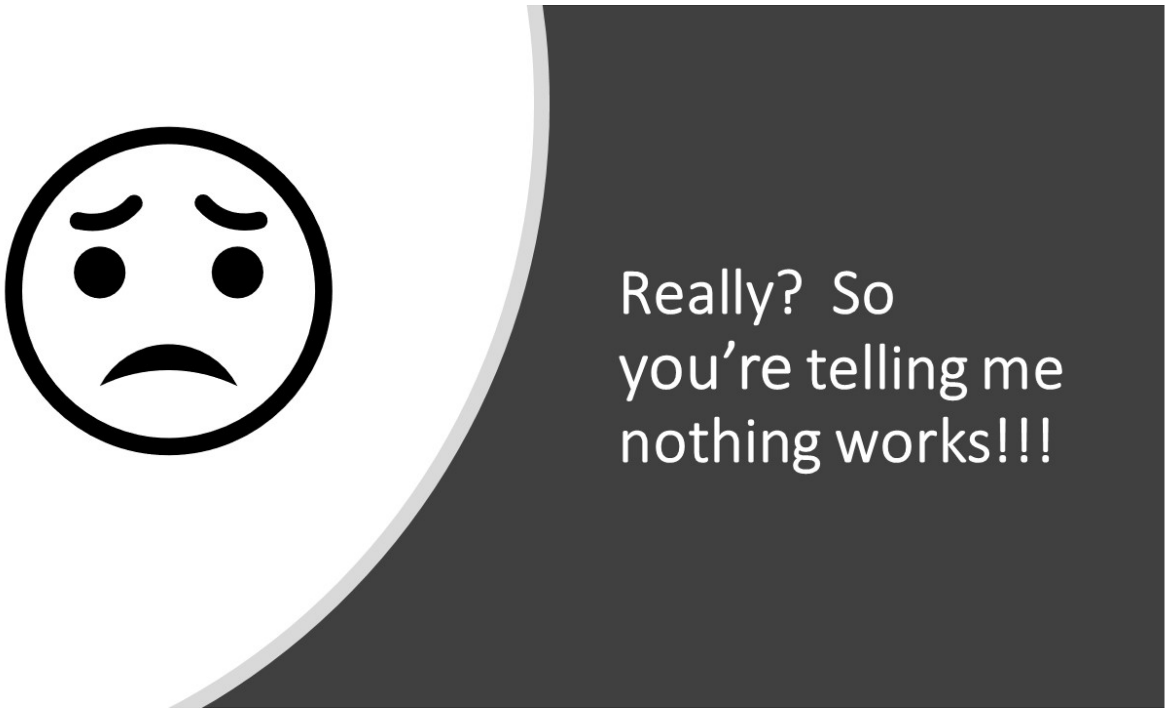

Wheat
Hail Damage Timing
Early = tillering
Mid = heading
Late = anthesis
Hail Damage Level
None = 0
Light = 33%
Heavy = 66%
Recovery Treatment
Check = None
Fungicide = Prosaro
Nutrient = Alpine G22
June 15
Light dam
ne 15
eavy damage
AJM Seeds
Early
Mid
Late


Wheat Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=9)
Check
Fungicide
Nutrient
Yield (Bu/ac)
77
79
78
75
76
78
74
75
71
0%
33%
67%
EARLY
→ Light hail = 3% yield loss
→ Heavy hail = 6% yield loss
Simulated Hail Damage & Growth Stage

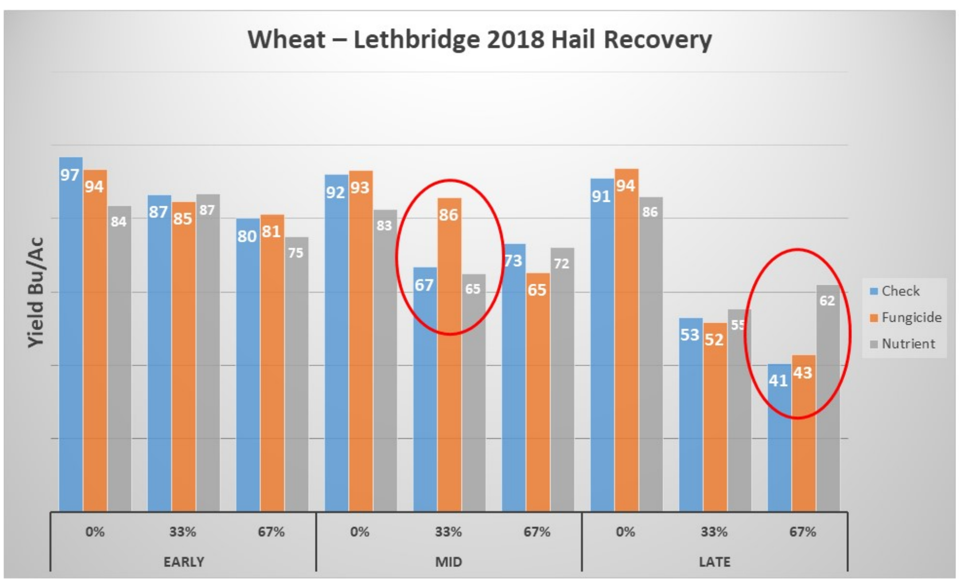

Wheat Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=9)
Yield (Bu/ac)
80
81
80
Check
Fungicide
Nutrient
50
56
54
45
46
47
0%
33%
67%
MID
→ Light = 34% yield loss
→ Heavy = 43% yield loss
Simulated Hail Damage & Growth Stage


Wheat Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=9)
Light hail = 39% yield loss→
Heavy hail = 58% yield loss→
Check
Fungicide
Nutrient
78
79
74
47
49
44
31
33
31
0%
33%
67%
LATE
Yield (Bu/ac)
Simulated Hail Damage & Growth Stage

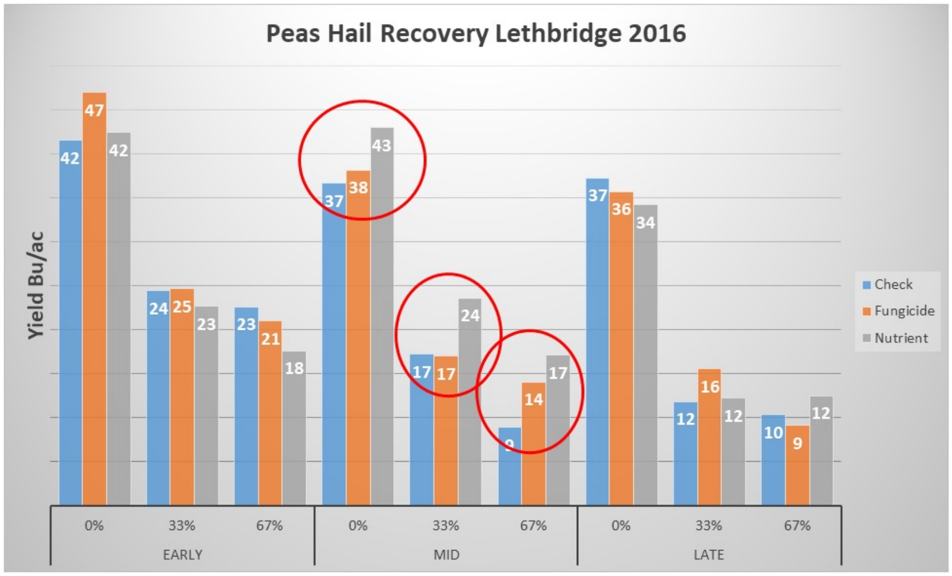

Wheat Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=9)
Check
Fungicide
Nutrient
77
79
78
75
76
78
74
75
71
80
81
80
50
56
54
45
46
47
78
79
74
47
49
44
31
33
31
0%
33%
67%
EARLY
MID
LATE
Yield (Bu/ac)
Simulated Hail Damage & Growth Stage

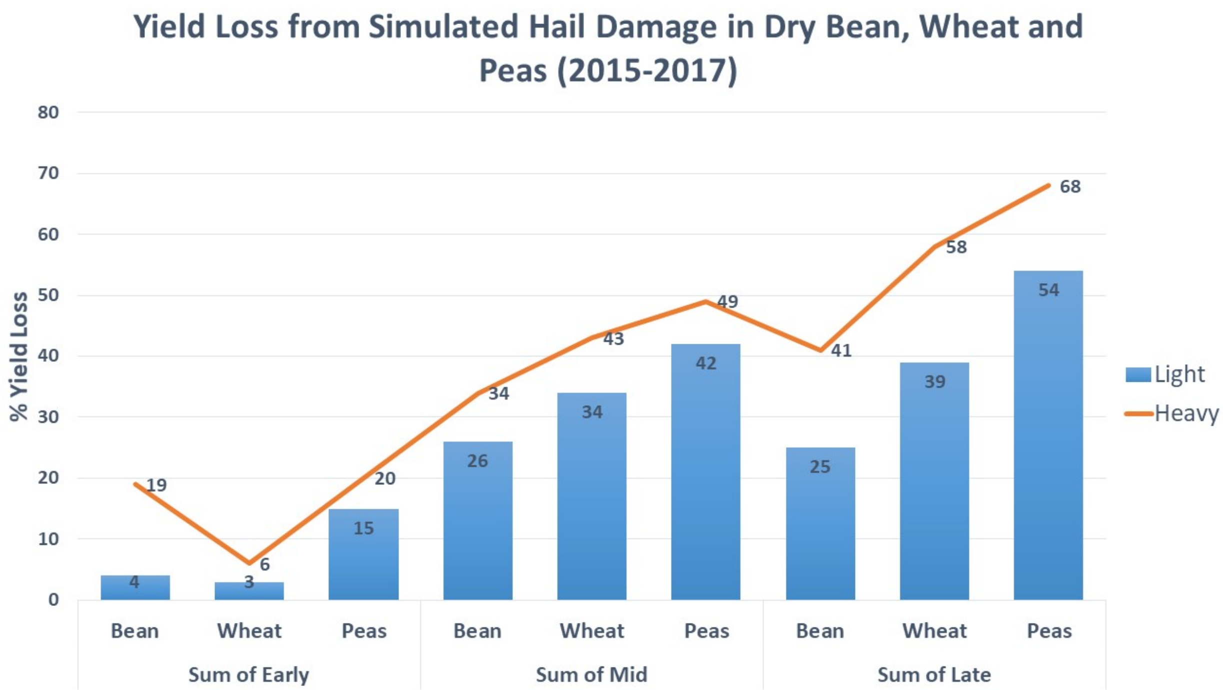


Well….. we did see a response 1 in 9 years in wheat



And also 1 of 9 years in Peas






Minimal response to rescue products
Growth stage is the largest factor affecting yield loss
Peas are most sensitive to yield loss from simulated hail
Wheat is very tolerant to damage at the tillering stage
Late nutrient application may help weeds more than crops
Hail insurance is good ☺
ALBERTA PULSE GROWERS
Alberta Wheat COMMISSION
Unique Financial Services
AFSC
INSURANCE • LENDING • INCOME STABILIZATION

Thanks!

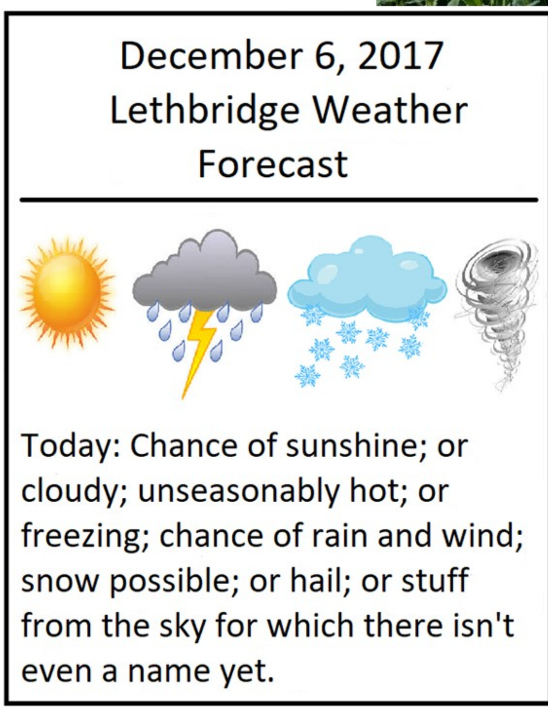
Farming Smarter Conference December 5 & 6, 2017 (202 attendees)

FARMING SMARTER
Growing new ideas.

Chasing Hail

#FSC17

December 6
Lethbridge Exhibition Park
Jamie Puchinger, B.Sc., CCA




KIRCHNER

Hail Sucks!

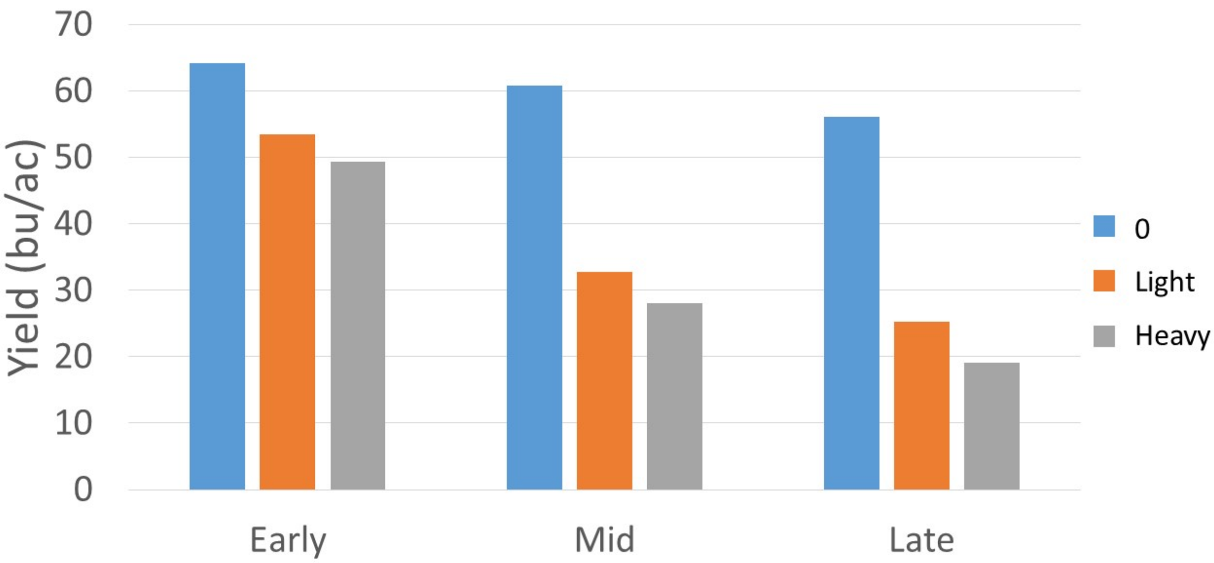
Things to Learn:

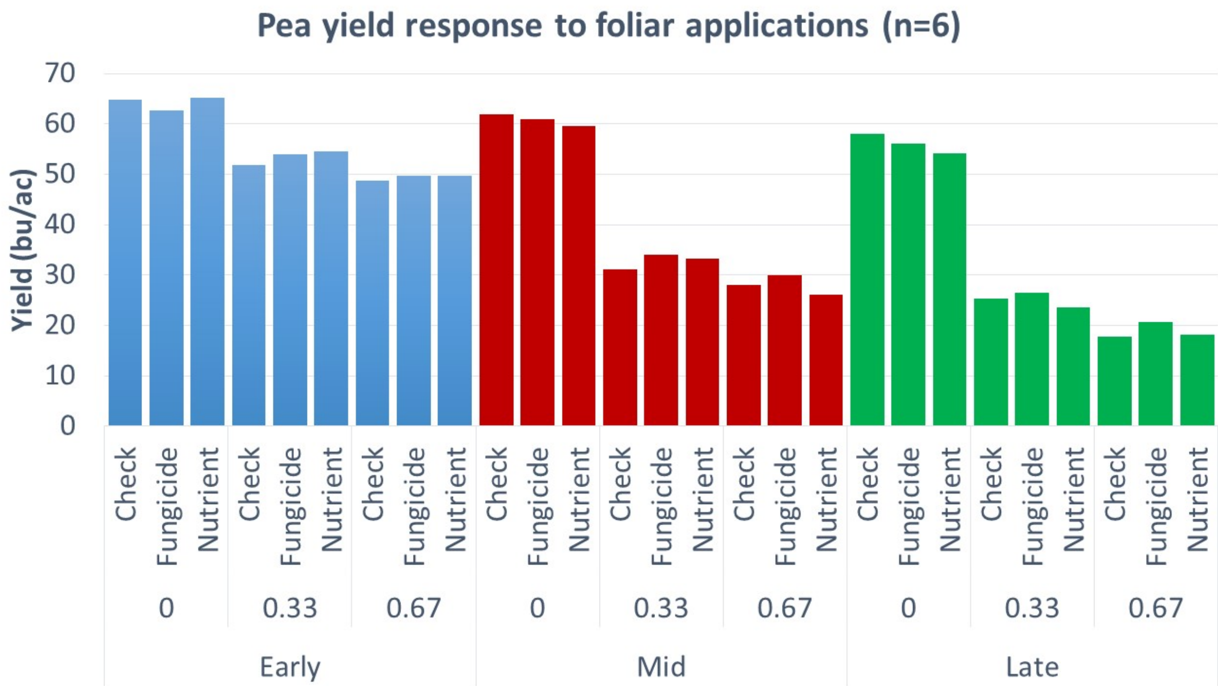
1. **Timing of Hail - Crop Stage and Recovery Period**
   a. Peas: 4-6 nodes, flowering, podding
   b. Dry Beans: 4-6 trifoliate, flowering, podding
   c. Wheat: tillering, heading, flowering

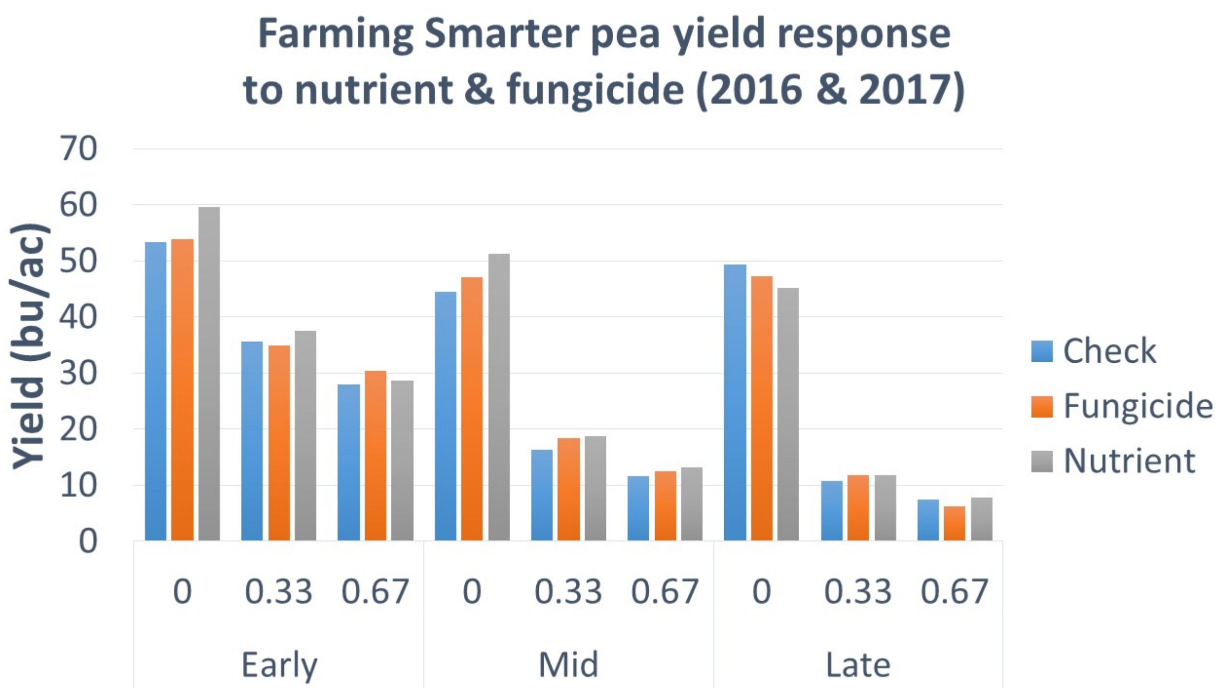
2. **Damage Level: None, Light (33%), Heavy (66%)**

3. **Recovery Treatments:**
   a. Peas: None, Hail Claim (ATP ReLeaf + Boron), Fungicide (Headline)
   b. Dry Beans: None, Hail Claim (Omex P3), Bacteriacide (Parasol)
   c. Wheat: None, Hail Claim (Alpine G22), Fungicide (Prosaro)

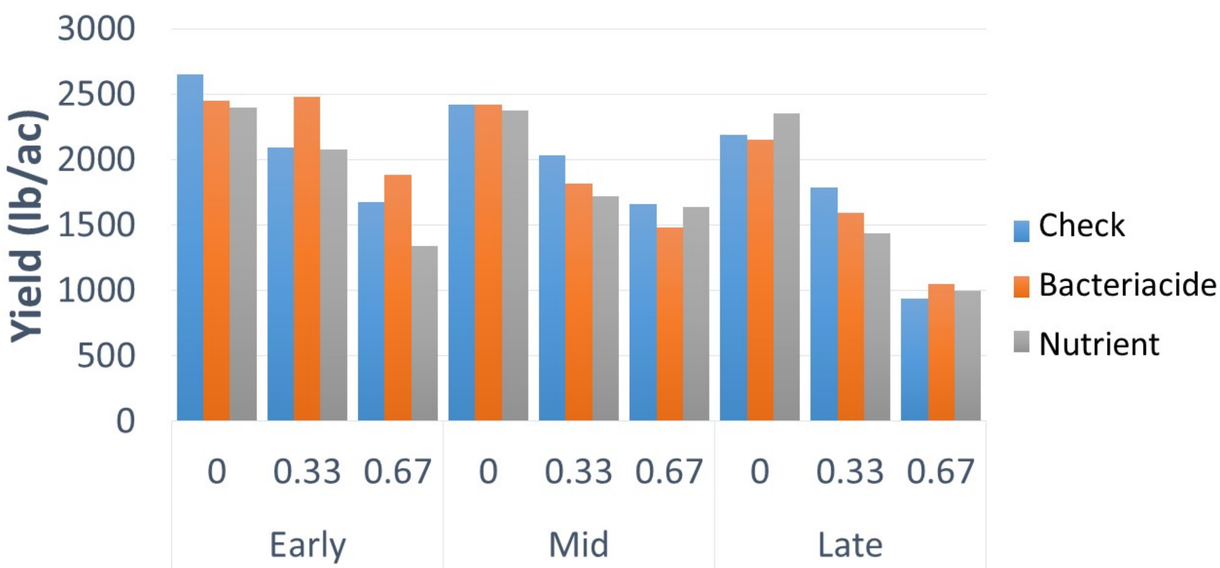
Pea yields with simulated hail damage 2016 & 2017
average from FS, SARDA & Innotech (bu/ac)

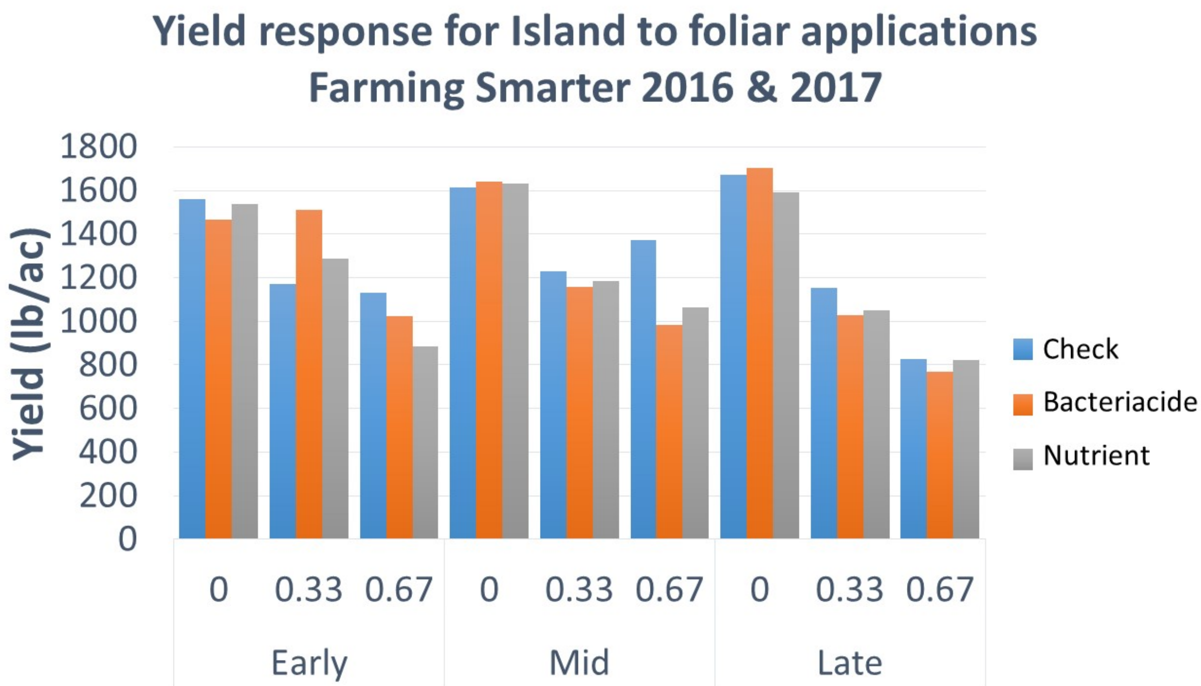



Pea yield response to foliar applications (n=6)
Yield (bu/ac)
70
60
50
40
30
20
10
0
Check
Fungicide
Nutrient
0
0.33
0.67
Early
Mid
Late

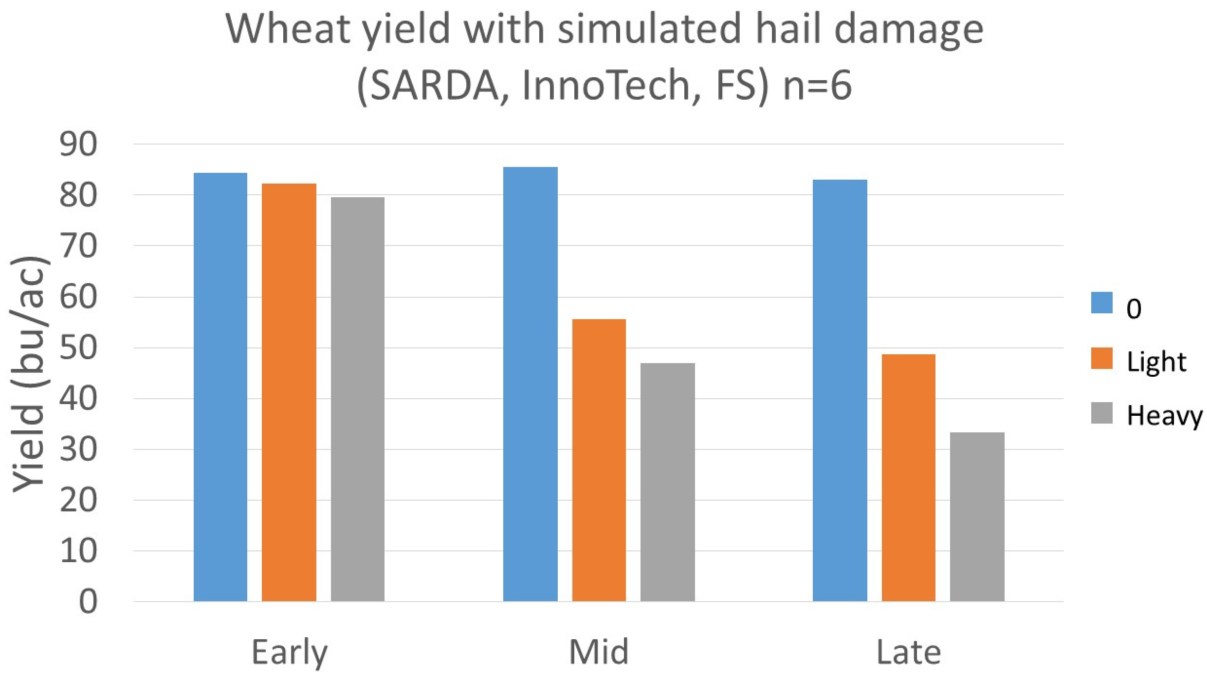

Farming Smarter pea yield response to nutrient & fungicide (2016 & 2017)
Yield (bu/ac)
70
60
50
40
30
20
10
0
0
0.33
0.67
Early
Mid
Late
Check
Fungicide
Nutrient

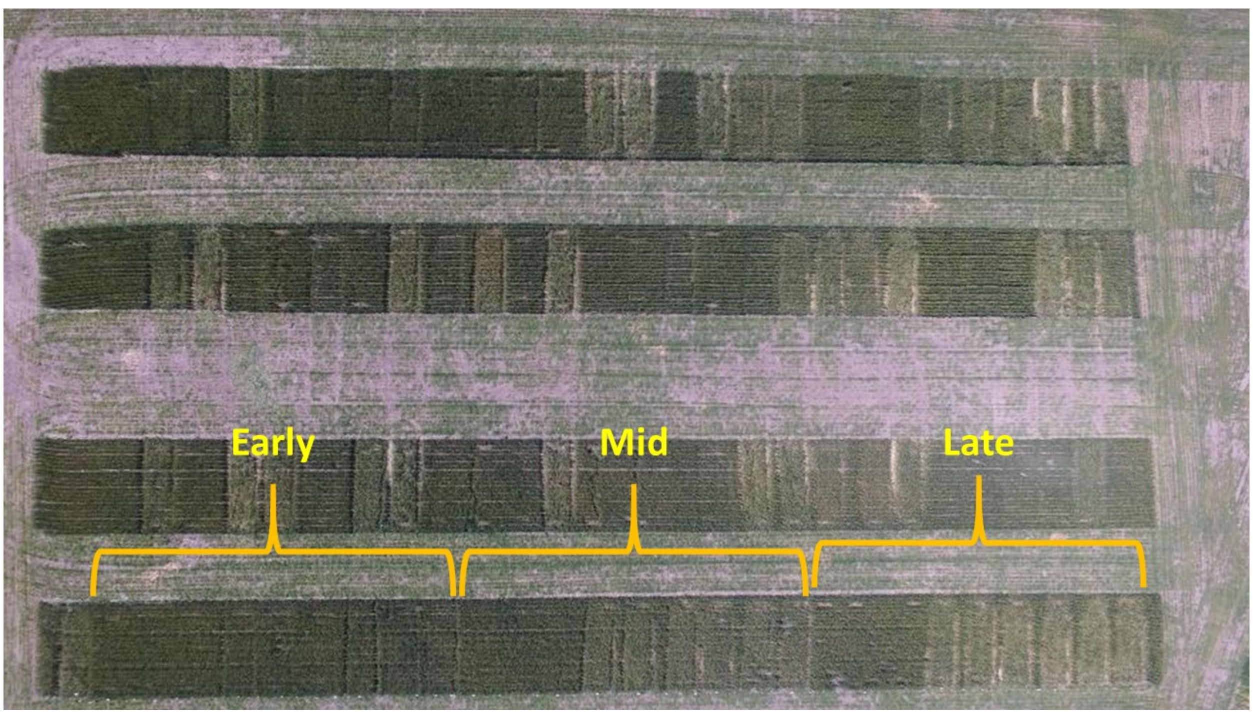
Yields response for Resolute to foliar applications
Farming Smarter 2016 & 2017

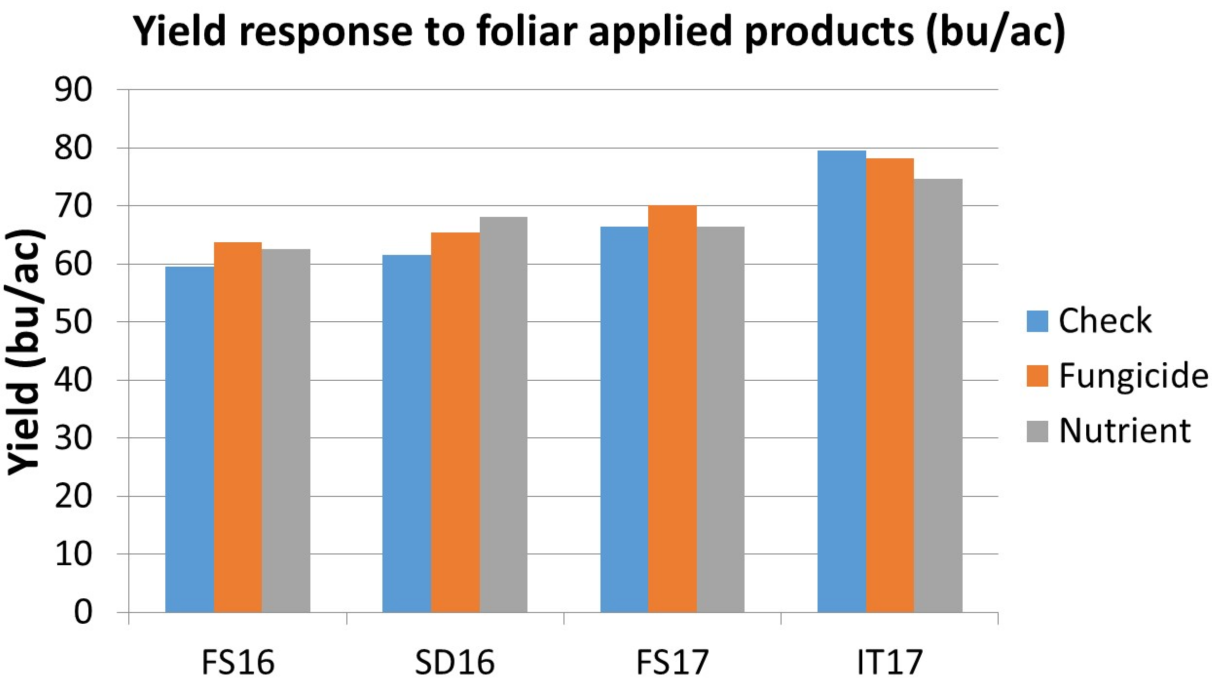



Yield response for Island to foliar applications
Farming Smarter 2016 & 2017
Yield (lb/ac)
1800
1600
1400
1200
1000
800
600
400
200
0
0
0.33
0.67
0
0.33
0.67
0
0.33
0.67
Early
Mid
Late
Check
Bacteriacide
Nutrient


Alberta Wheat
COMMISSION
Hail Recovery Project
June 15
Light damage
June 15
Heavy damage


Wheat yield with simulated hail damage
(SARDA, InnoTech, FS) n=6
Yield (bu/ac)
90
80
70
60
50
40
30
20
10
0
Early
Mid
Late
0
Light
Heavy


Early
Mid
Late



Growth stage is the largest factor in yield

Peas are more sensitive than canola

Wheat has ability to sustain yields with early season damage

Foliar applications may benefit wheat following hail damage

Management practices should remain consistent

You cant protect your crops from hail

http://www.ruralrootscanada.com/wheatstalk-researching-crop-recovery-from-hail-damage/

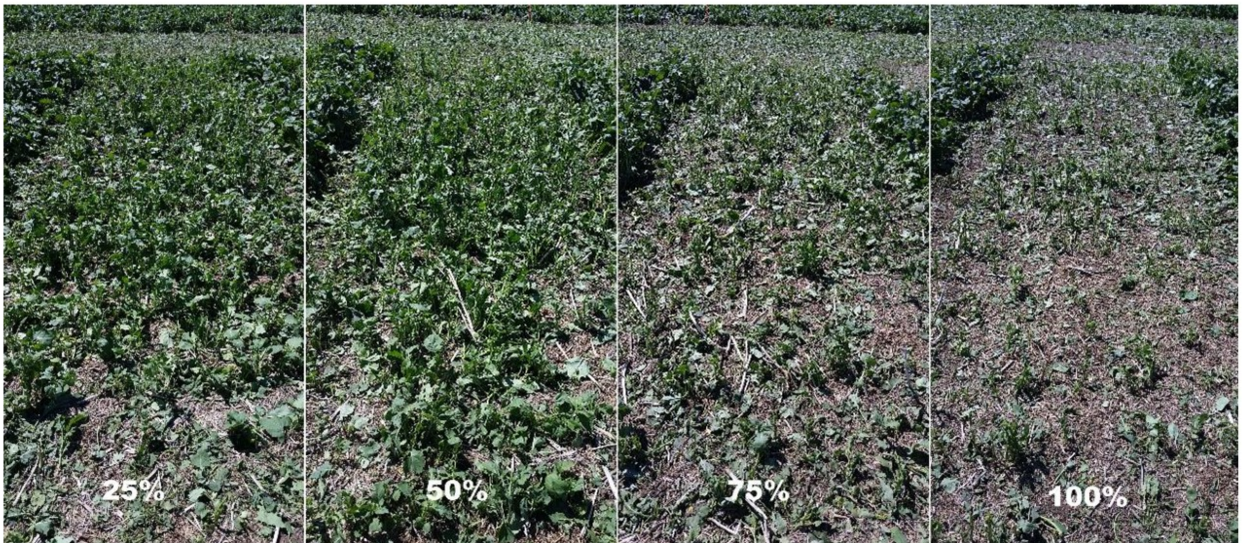
Farming Smarter Conference, Medicine Hat, December 6 & 7, 2016 (220 attendees)

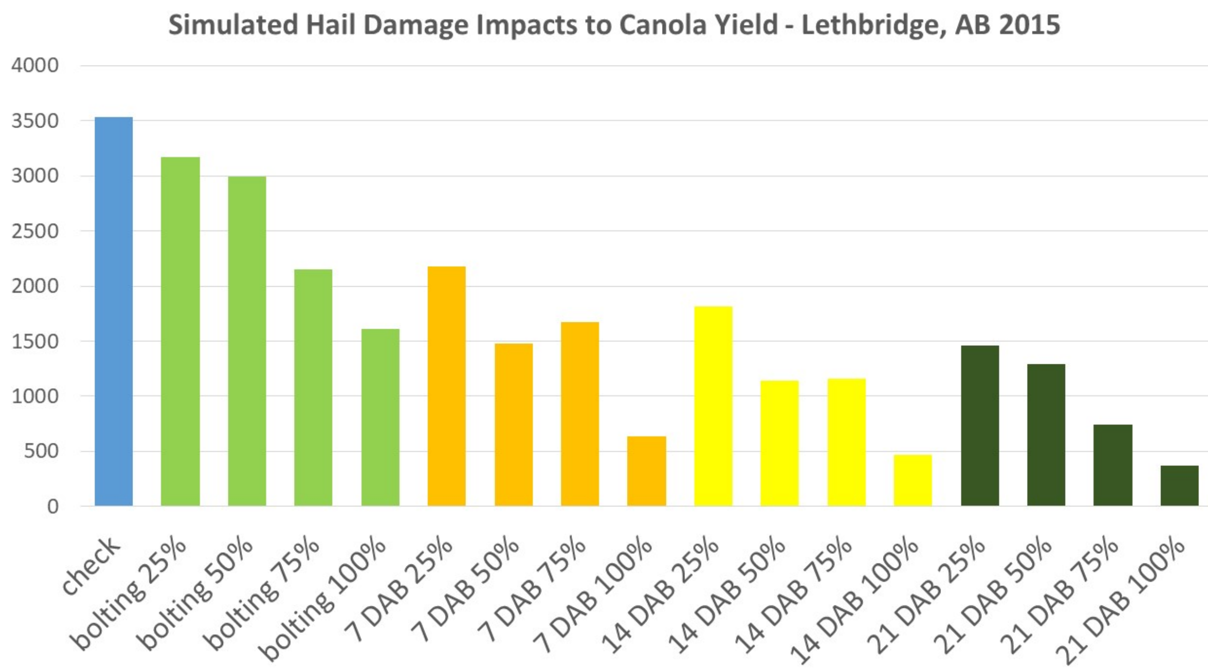
Not a
ual
The Darwin Awards
@AwardsDarwin
Following
Selfie.
RETWEETS
335
LIKES
416
5:14 AM - 2 Dec 2016
17
335
416
ALBERTA PULSE
GROWERS

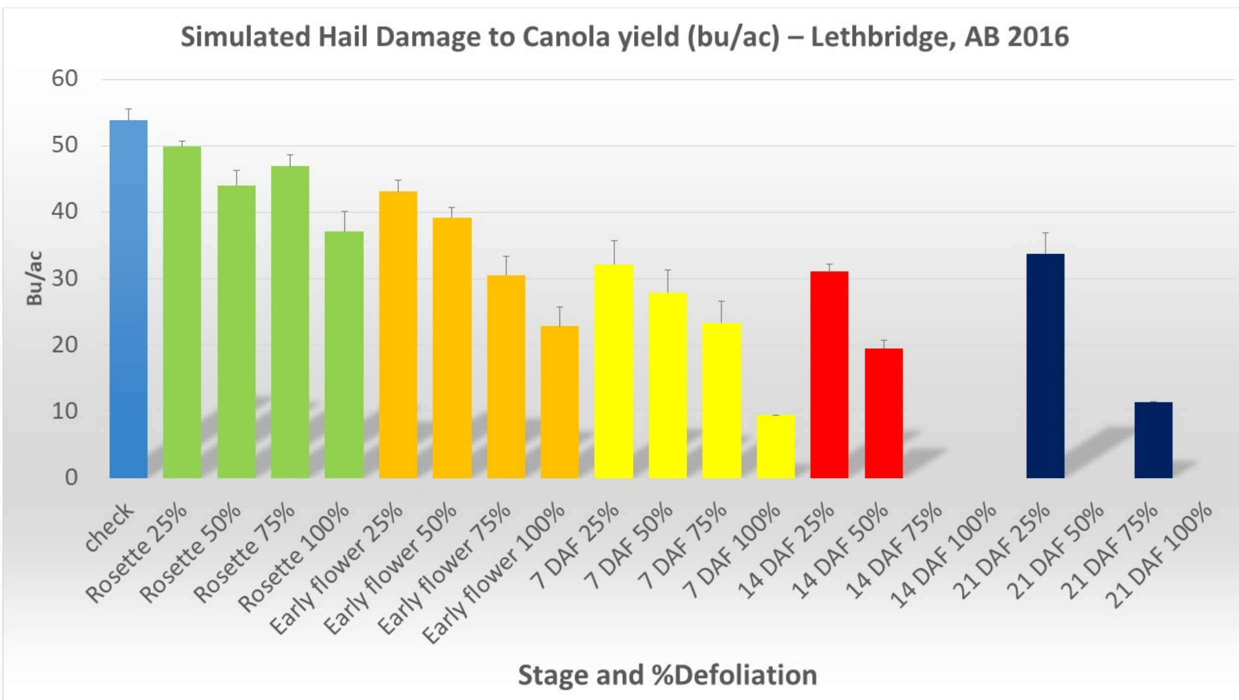

ΚΑΙΚΙΑΣ

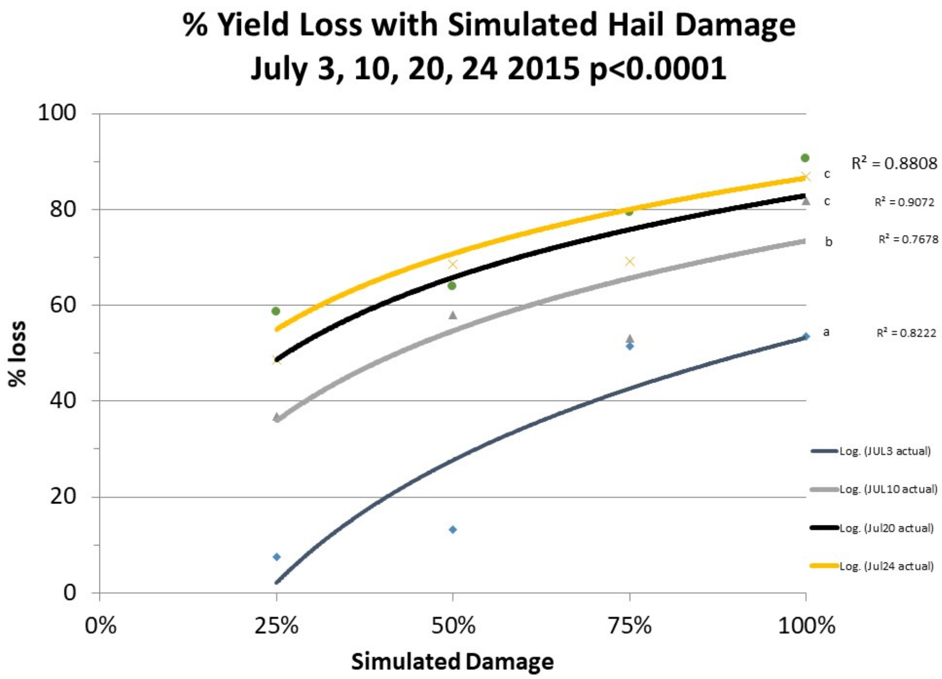
Unique Financial Services
AFSC
INSURANCE • LENDING • INCOME STABILIZATION

Hail Canola Study – 5 Timings & 4 Levels

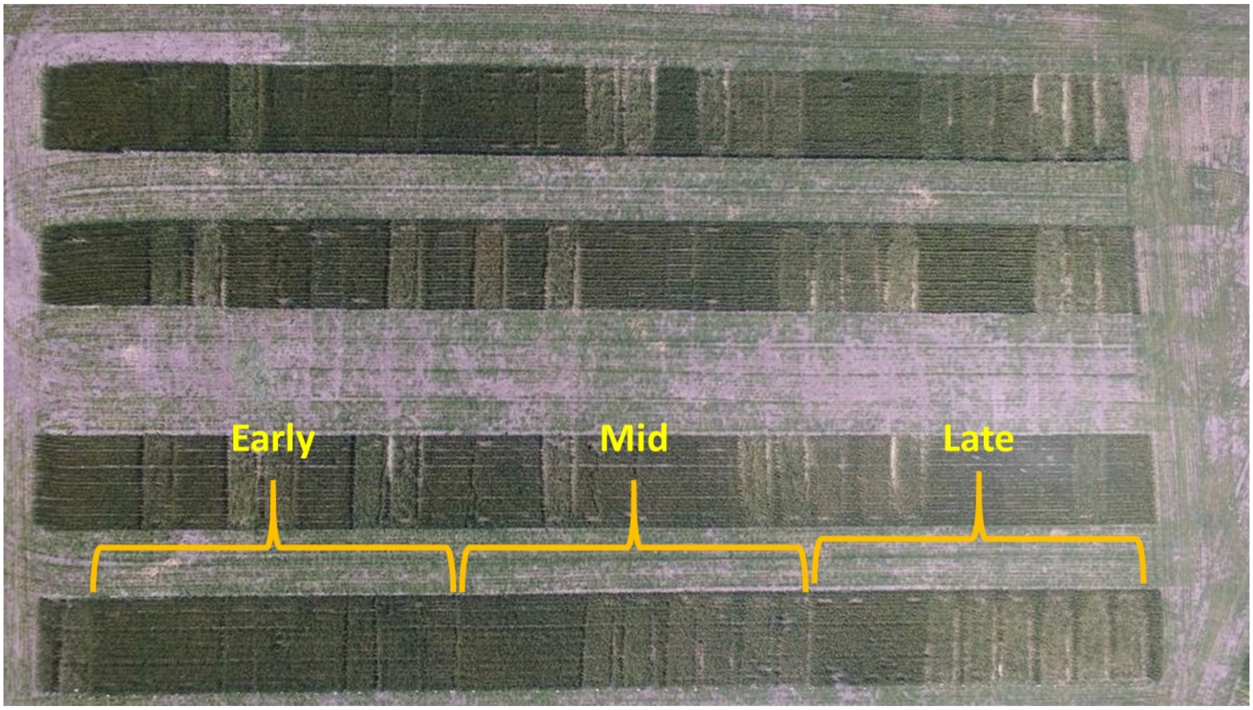


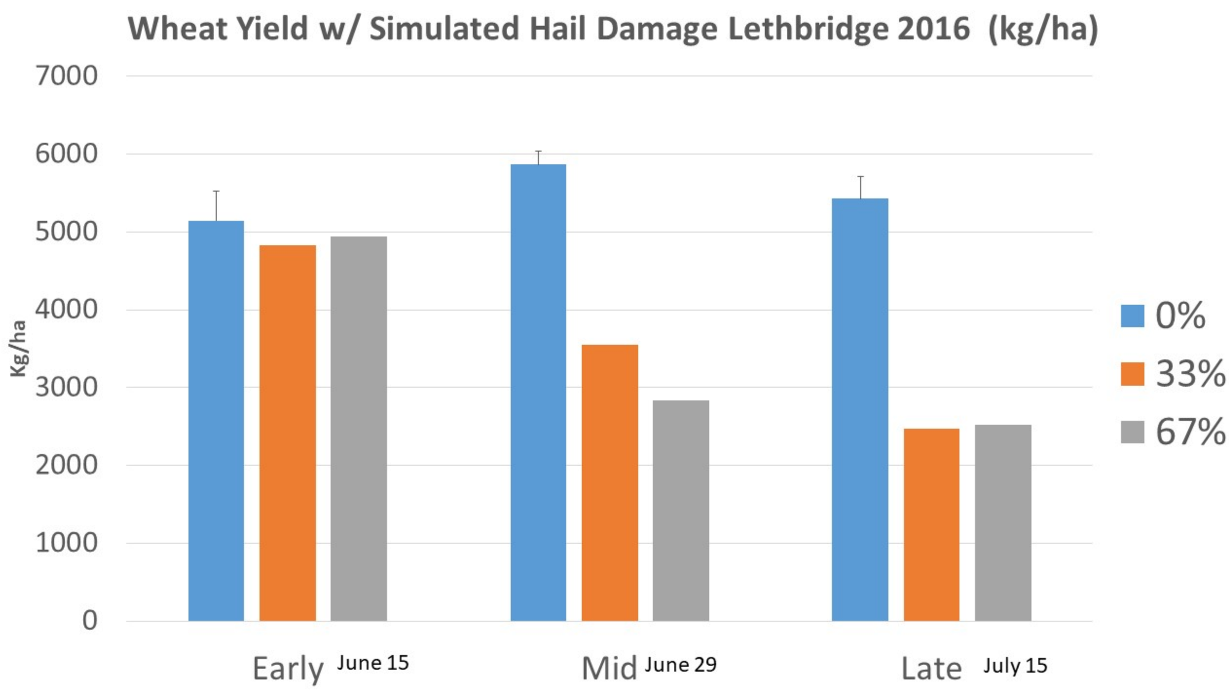

Simulated Hail Damage Impacts to Canola Yield - Lethbridge, AB 2015
4000
3500
3000
2500
2000
1500
1000
500
0
check
bolting 25%
bolting 50%
bolting 75%
bolting 100%
7 DAB 25%
7 DAB 50%
7 DAB 75%
7 DAB 100%
14 DAB 25%
14 DAB 50%
14 DAB 75%
14 DAB 100%
21 DAB 25%
21 DAB 50%
21 DAB 75%
21 DAB 100%

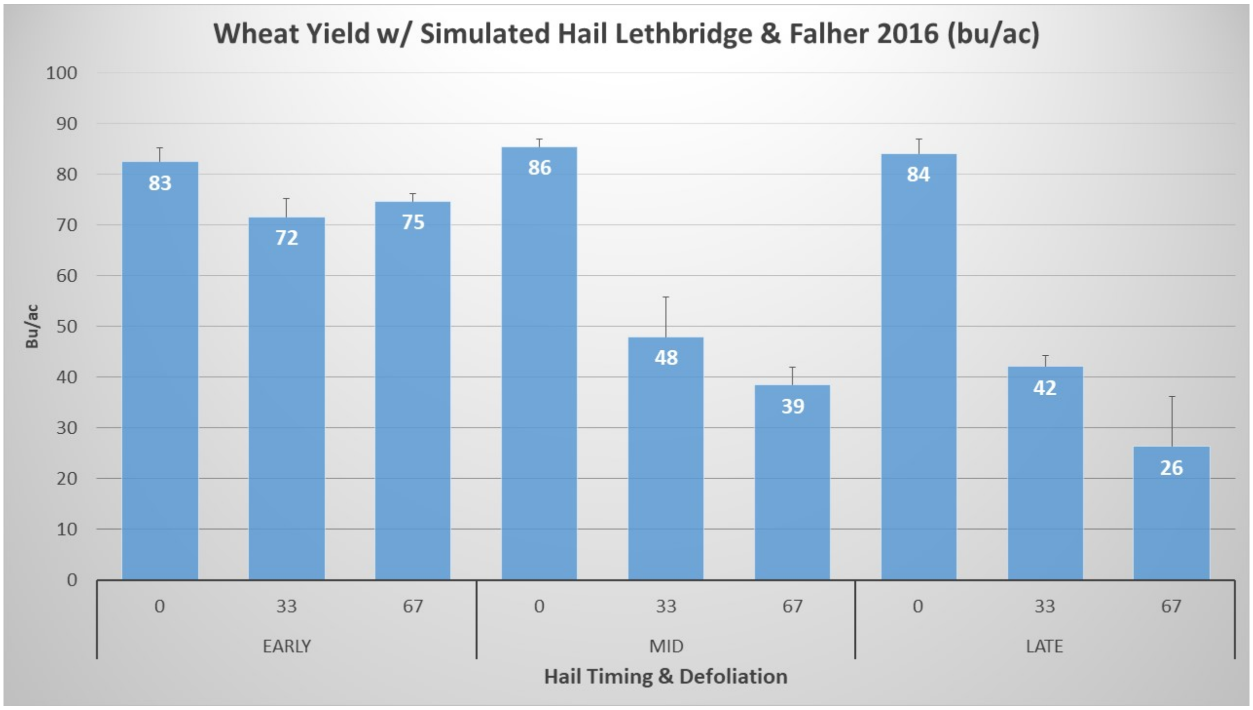

Simulated Hail Damage to Canola yield (bu/ac) – Lethbridge, AB 2016
60
50
40
30
20
10
0
Bu/ac
check
Rosette 25%
Rosette 50%
Rosette 75%
Rosette 100%
Early flower 25%
Early flower 50%
Early flower 75%
Early flower 100%
7 DAF 25%
7 DAF 50%
7 DAF 75%
7 DAF 100%
14 DAF 25%
14 DAF 50%
14 DAF 75%
14 DAF 100%
21 DAF 25%
21 DAF 50%
21 DAF 75%
21 DAF 100%
Stage and %Defoliation

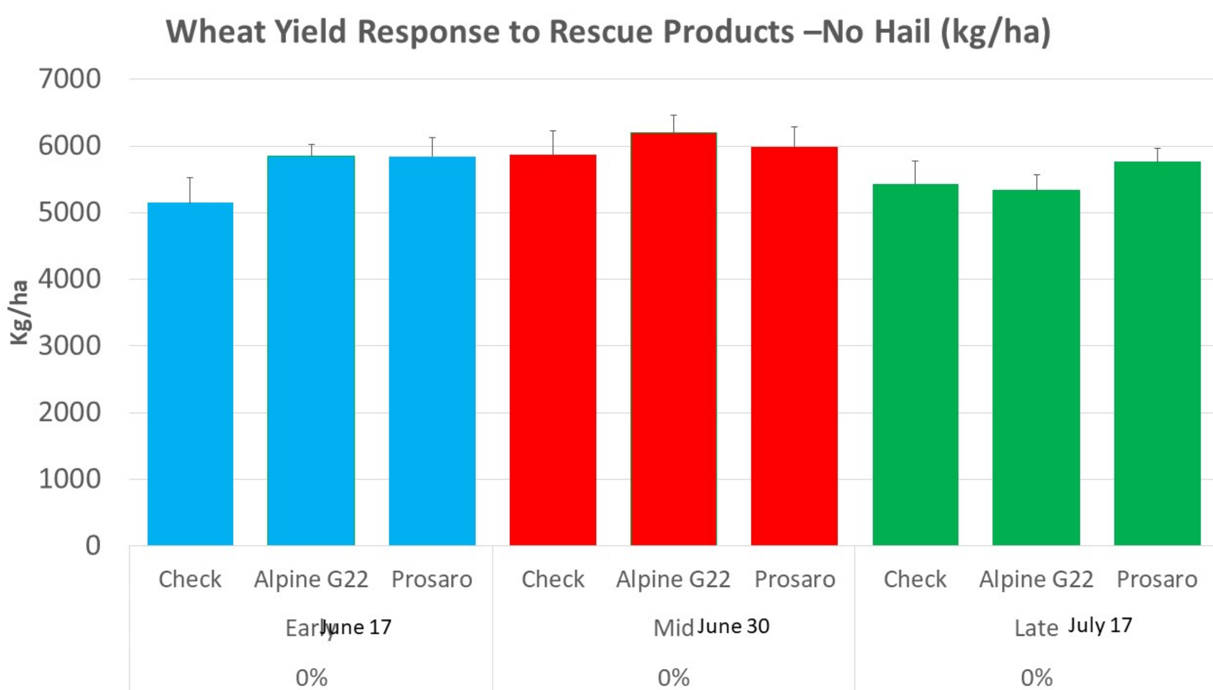

% Yield Loss with Simulated Hail Damage
July 3, 10, 20, 24 2015 p<0.0001
100
80
60
40
20
0
% loss
0%
25%
50%
75%
100%
Simulated Damage
c
c
b
a
R² = 0.8808
R² = 0.9072
R² = 0.7678
R² = 0.8222
Log. (JUL3 actual)
Log. (JUL10 actual)
Log. (Jul20 actual)
Log. (Jul24 actual)

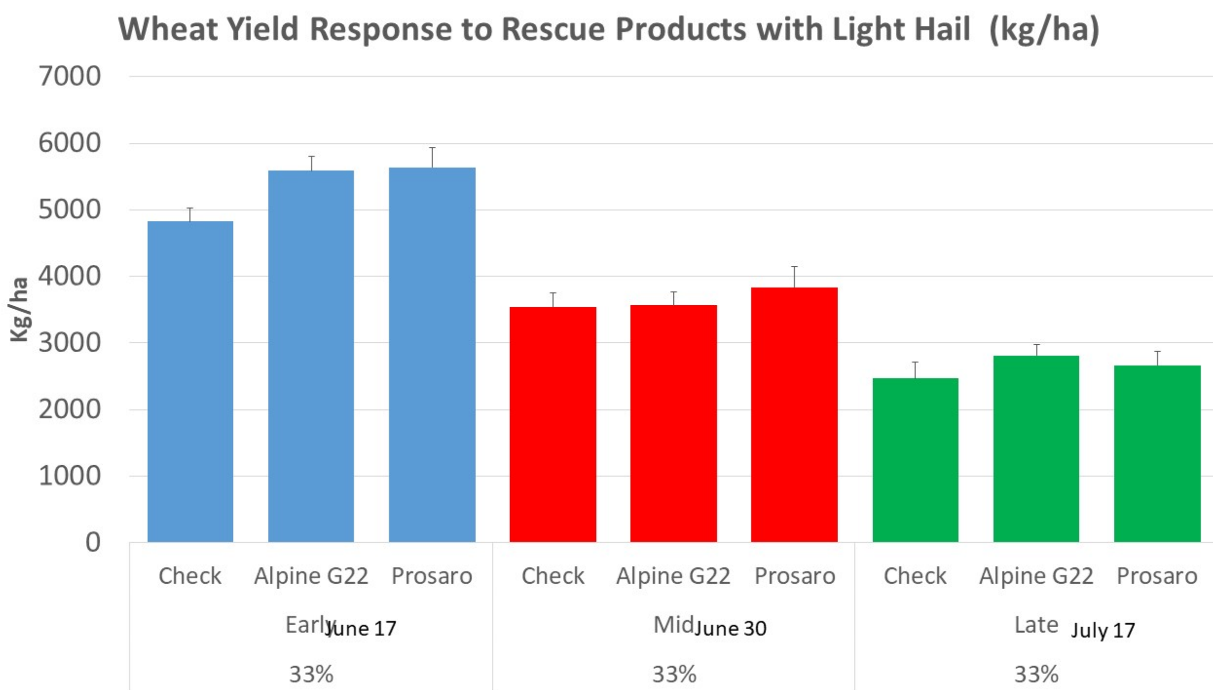

Alberta Wheat
COMMISSION
Hail Recovery Project
June 15
Light damage
June 15
Heavy damage

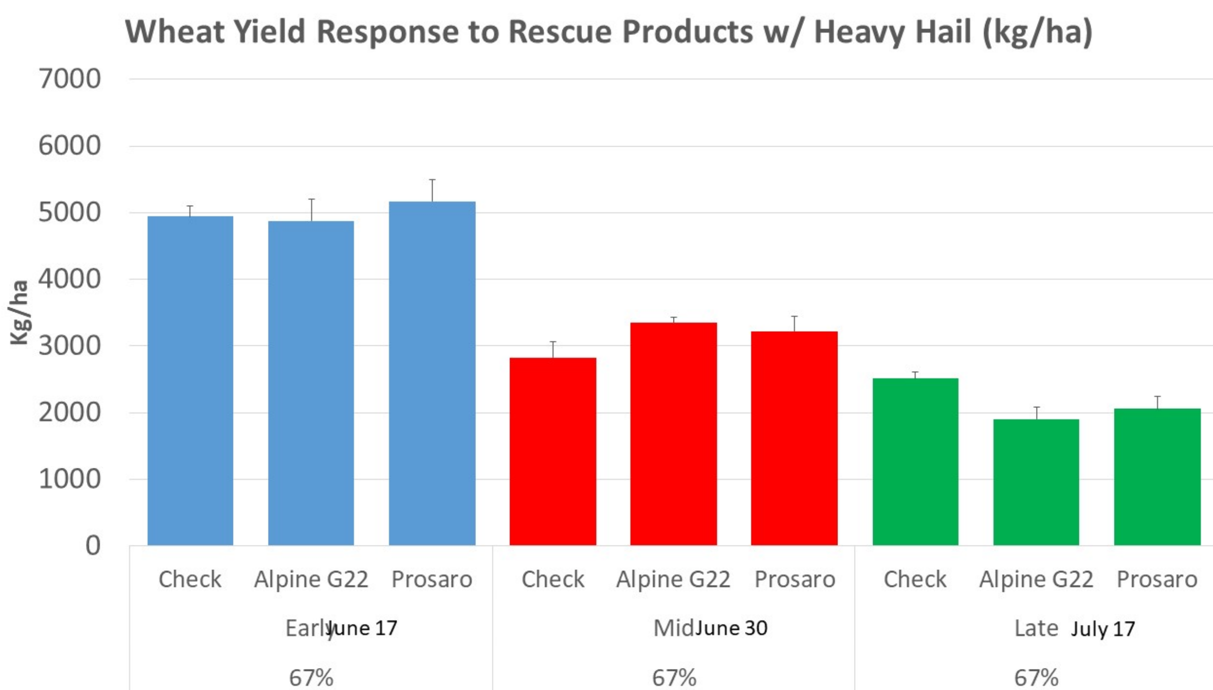

Early
Mid
Late

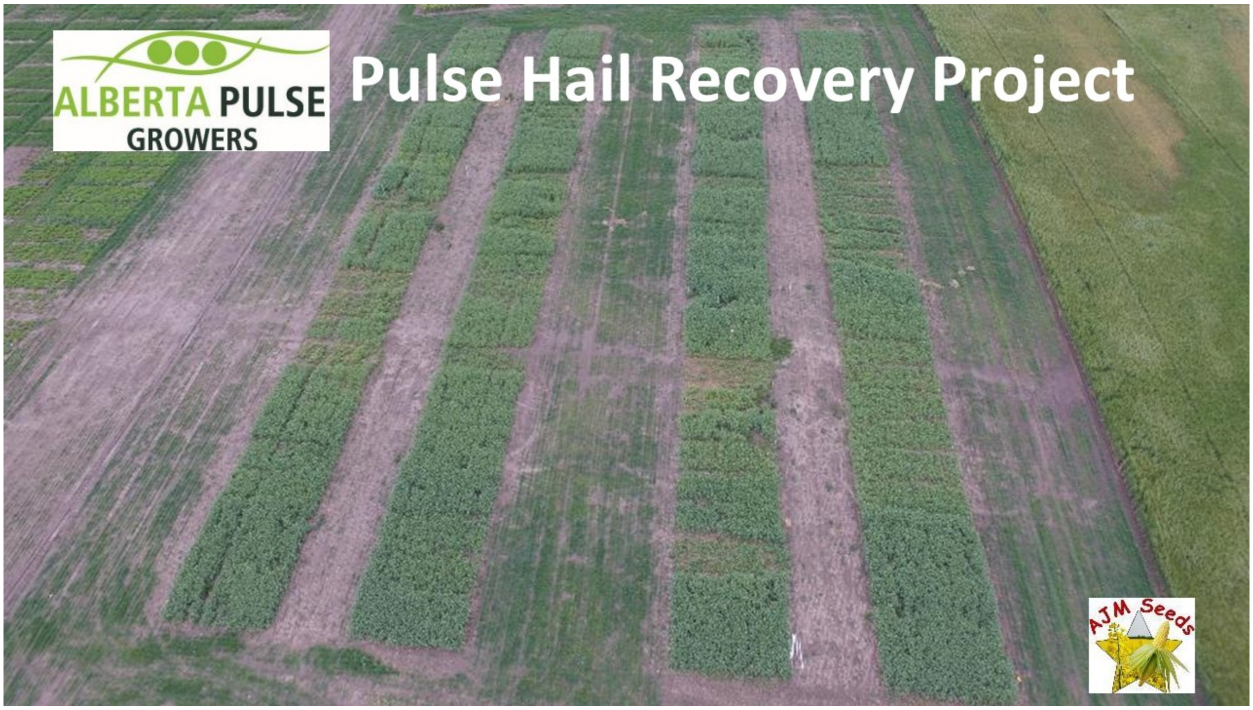

Wheat Yield w/ Simulated Hail Damage Lethbridge 2016 (kg/ha)
7000
6000
5000
4000
3000
2000
1000
0
Kg/ha
0%
33%
67%
Early June 15
Mid June 29
Late July 15

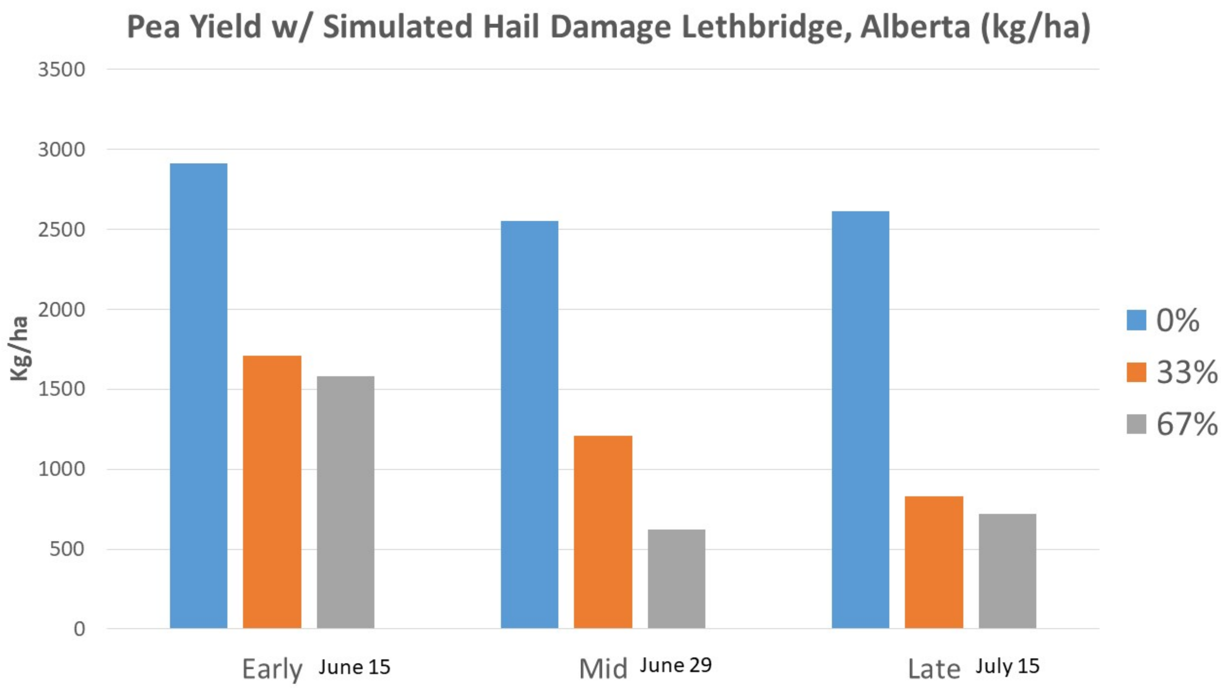

Wheat Yield w/ Simulated Hail Lethbridge & Falher 2016 (bu/ac)
Bu/ac
100
90
80
70
60
50
40
30
20
10
0
83
72
75
86
48
39
84
42
26
0
33
67
0
33
67
0
33
67
EARLY
MID
LATE
Hail Timing & Defoliation

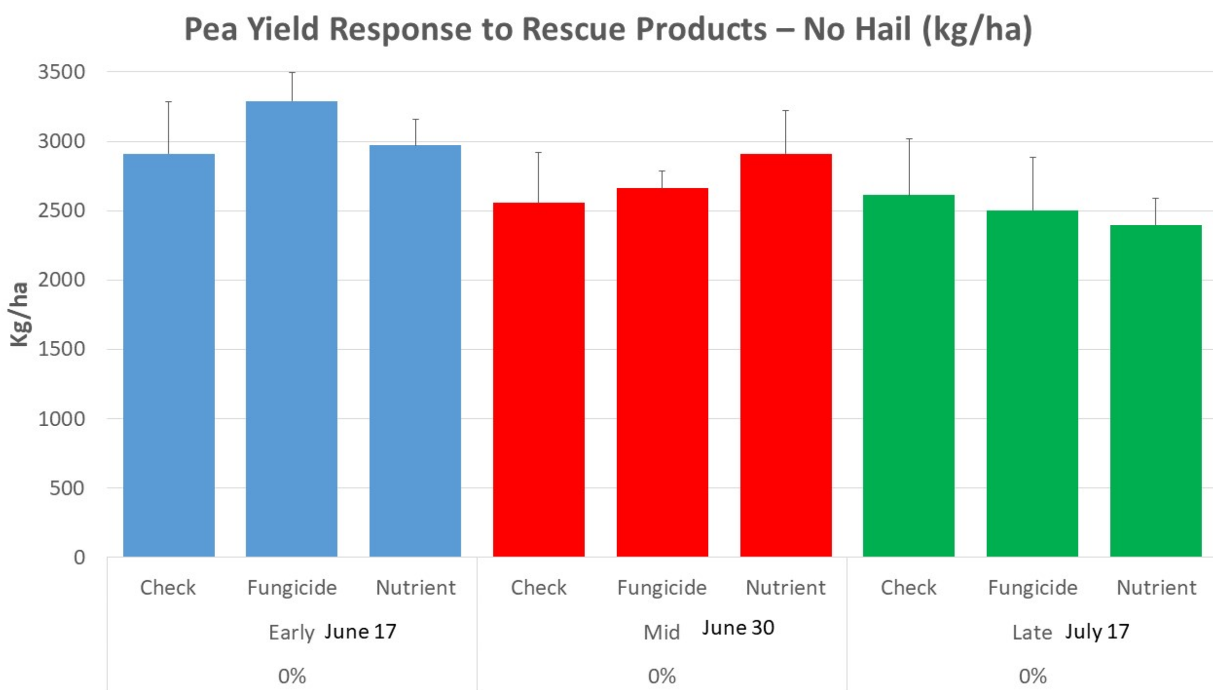

Wheat Yield Response to Rescue Products –No Hail (kg/ha)
Kg/ha
7000
6000
5000
4000
3000
2000
1000
0
Check
Alpine G22
Prosaro
Check
Alpine G22
Prosaro
Check
Alpine G22
Prosaro
Early June 17
Mid June 30
Late July 17
0%
0%
0%

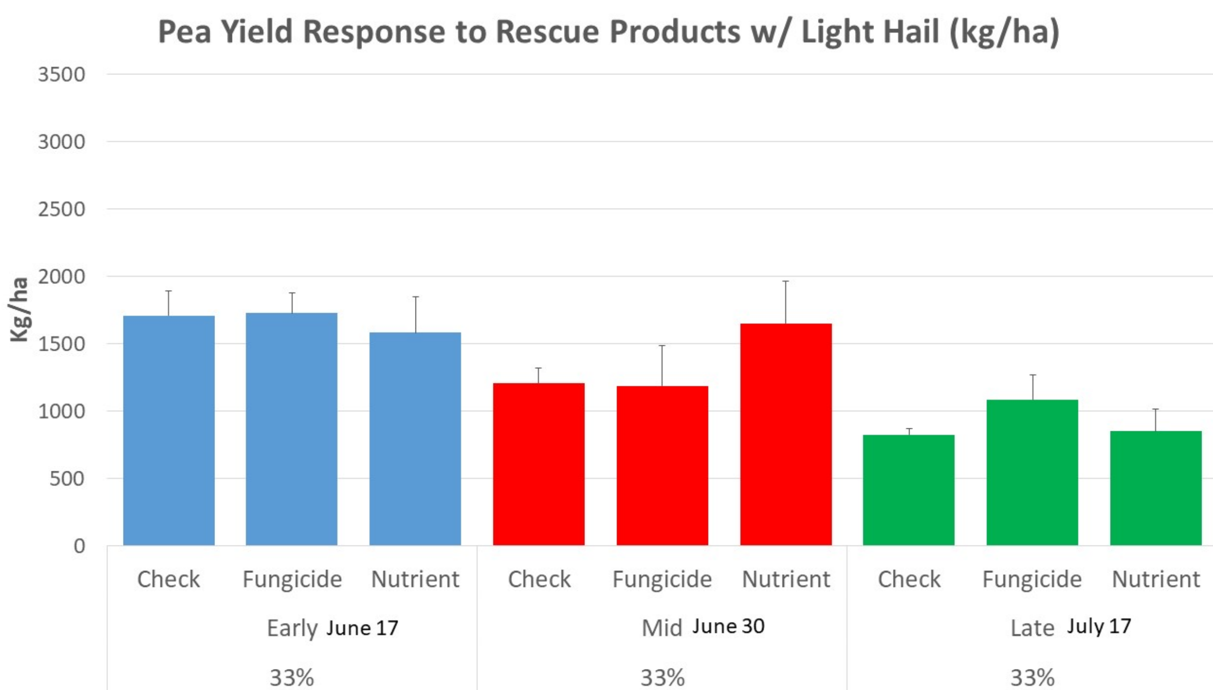

Wheat Yield Response to Rescue Products with Light Hail (kg/ha)
7000
6000
5000
4000
3000
2000
1000
0
Kg/ha
Check
Alpine G22
Prosaro
Check
Alpine G22
Prosaro
Check
Alpine G22
Prosaro
Early June 17
Mid June 30
Late July 17
33%
33%
33%

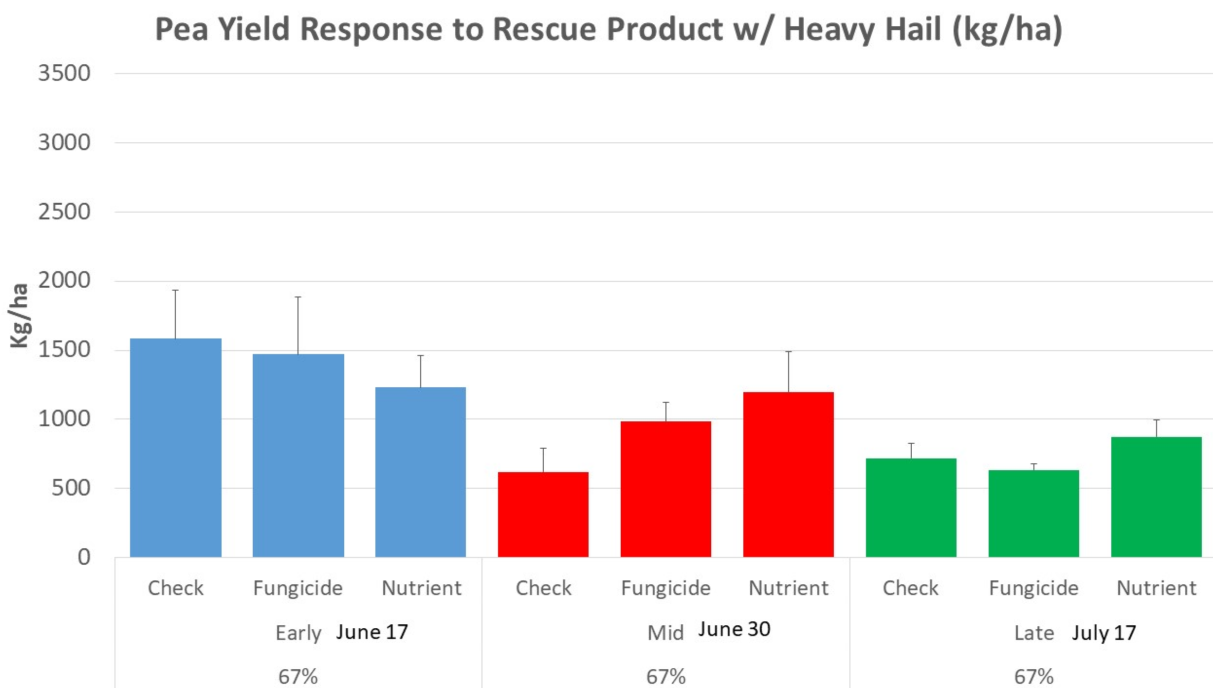

Wheat Yield Response to Rescue Products w/ Heavy Hail (kg/ha)
7000
6000
5000
4000
3000
2000
1000
0
Kg/ha
Check
Alpine G22
Prosaro
Check
Alpine G22
Prosaro
Check
Alpine G22
Prosaro
Early June 17
Mid June 30
Late July 17
67%
67%
67%

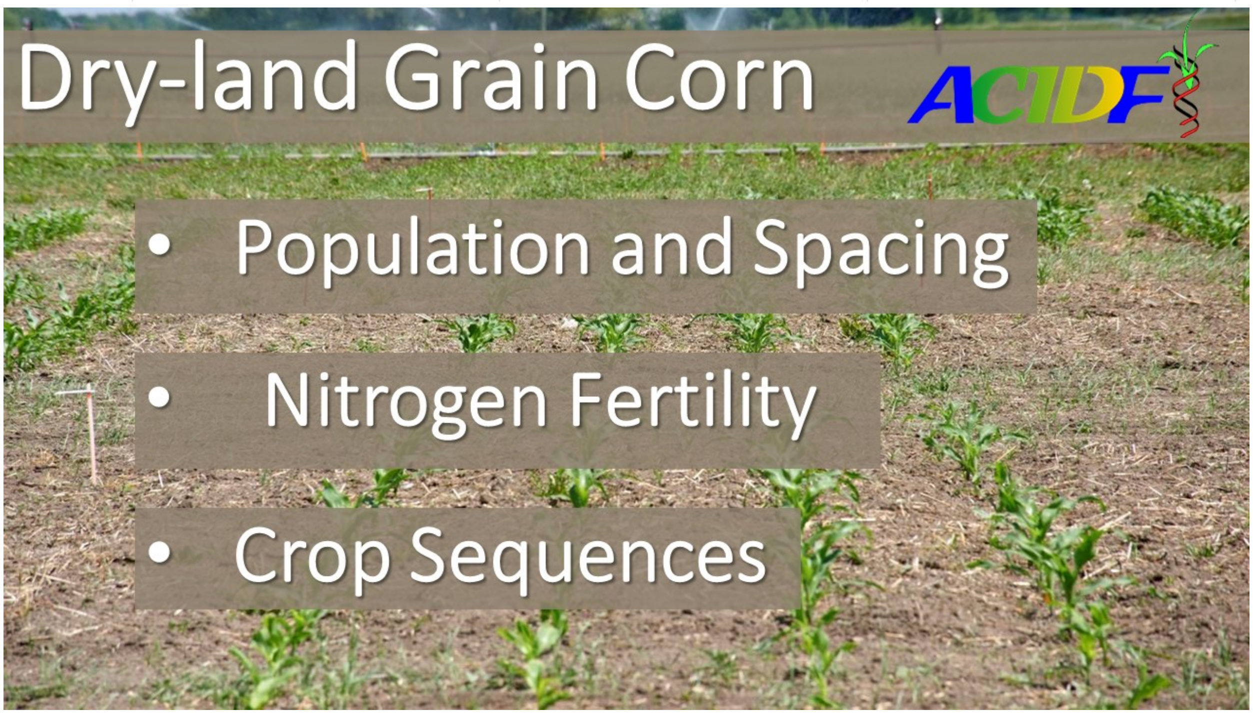

ALBERTA PULSE
GROWERS
Pulse Hail Recovery Project
AJM Seeds


Pea Yield w/ Simulated Hail Damage Lethbridge, Alberta (kg/ha)
Kg/ha
3500
3000
2500
2000
1500
1000
500
0
Early June 15
Mid June 29
Late July 15
0%
33%
67%

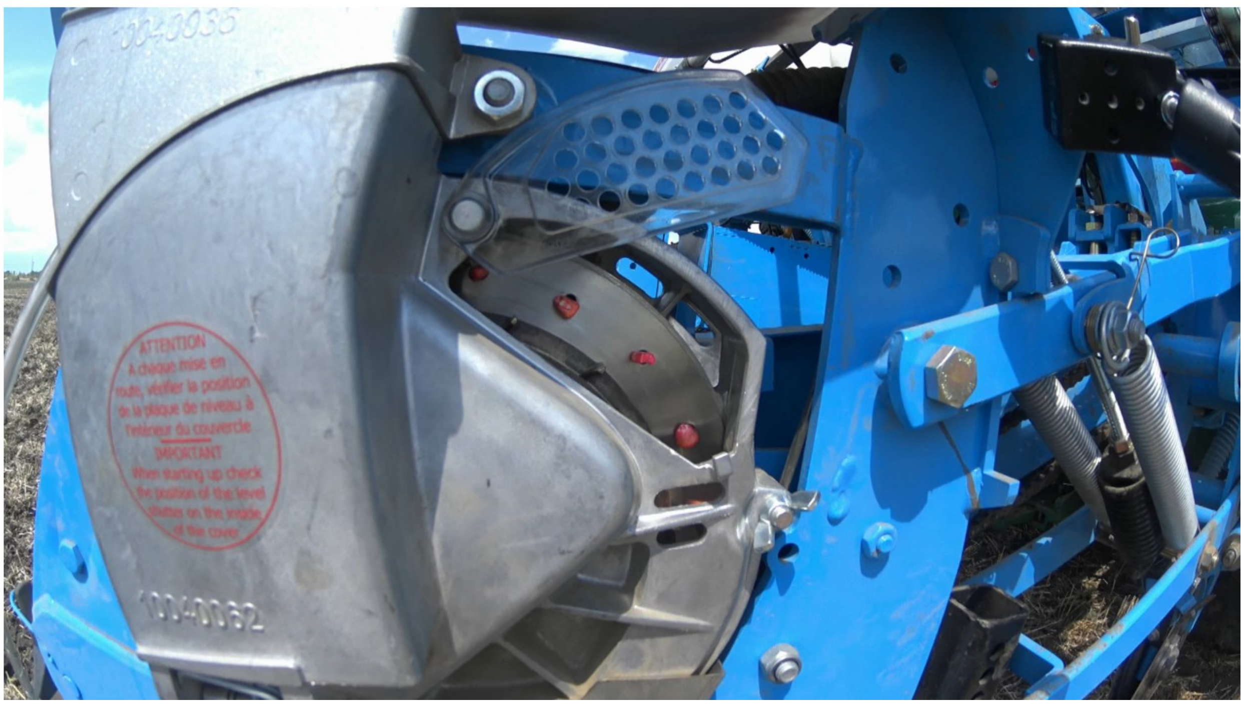

Pea Yield Response to Rescue Products – No Hail (kg/ha)
Kg/ha
3500
3000
2500
2000
1500
1000
500
0
Check
Fungicide
Nutrient
Check
Fungicide
Nutrient
Check
Fungicide
Nutrient
Early June 17
Mid June 30
Late July 17
0%
0%
0%


Pea Yield Response to Rescue Products w/ Light Hail (kg/ha)
Kg/ha
3500
3000
2500
2000
1500
1000
500
0
Check
Fungicide
Nutrient
Check
Fungicide
Nutrient
Check
Fungicide
Nutrient
Early June 17
Mid June 30
Late July 17
33%
33%
33%


Pea Yield Response to Rescue Product w/ Heavy Hail (kg/ha)
Kg/ha
3500
3000
2500
2000
1500
1000
500
0
Check
Fungicide
Nutrient
Check
Fungicide
Nutrient
Check
Fungicide
Nutrient
Early June 17
Mid June 30
Late July 17
67%
67%
67%

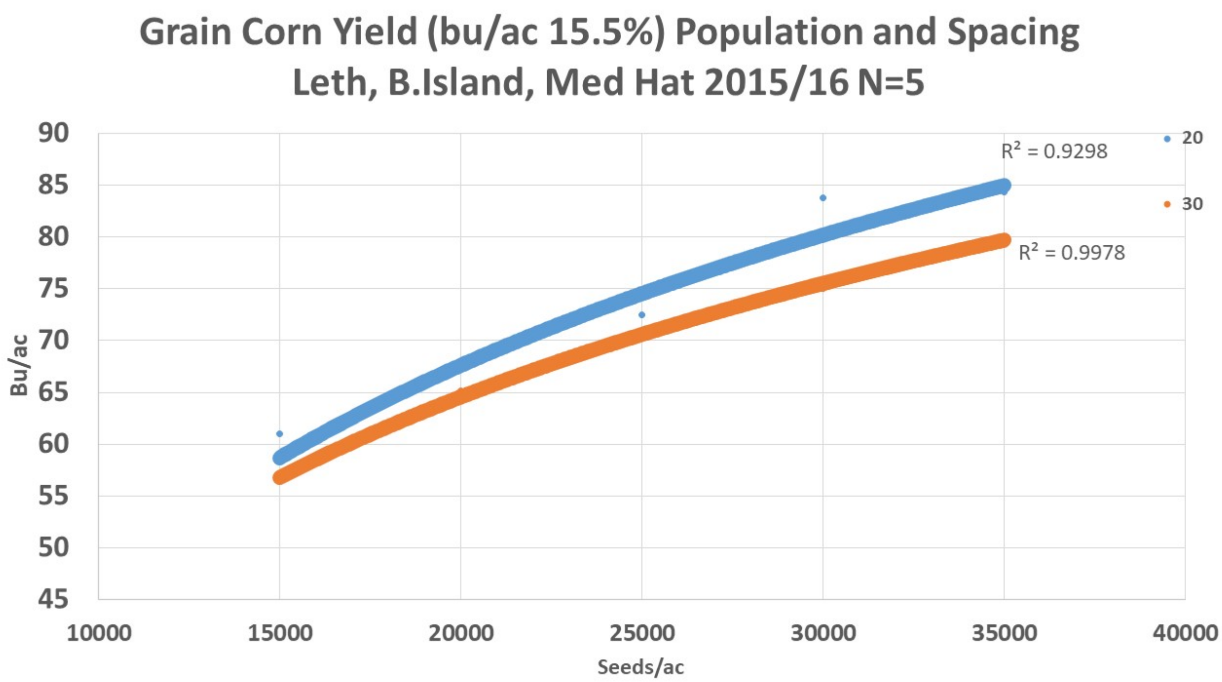

Dry-land Grain Corn
ACIDF
• Population and Spacing
• Nitrogen Fertility
• Crop Sequences


JOHN DEERE


ATTENTION
IMPORTANT
When starting up check
10040062

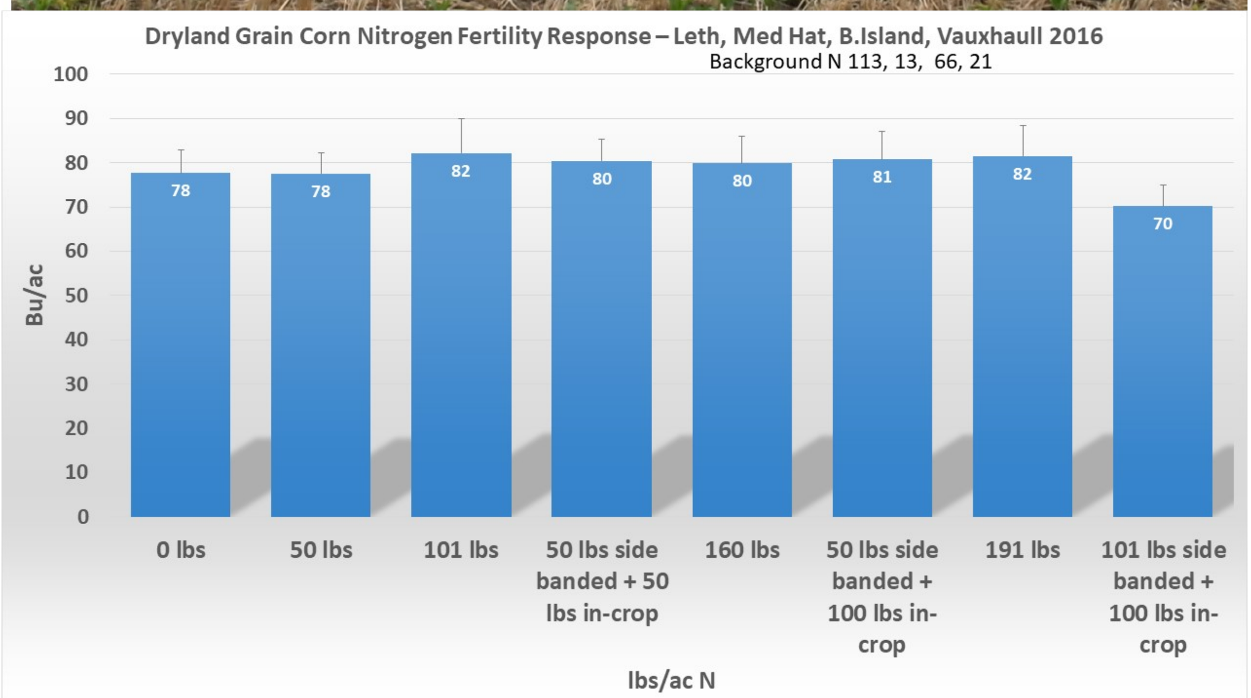

MAIS STAR


• Population and Spacing

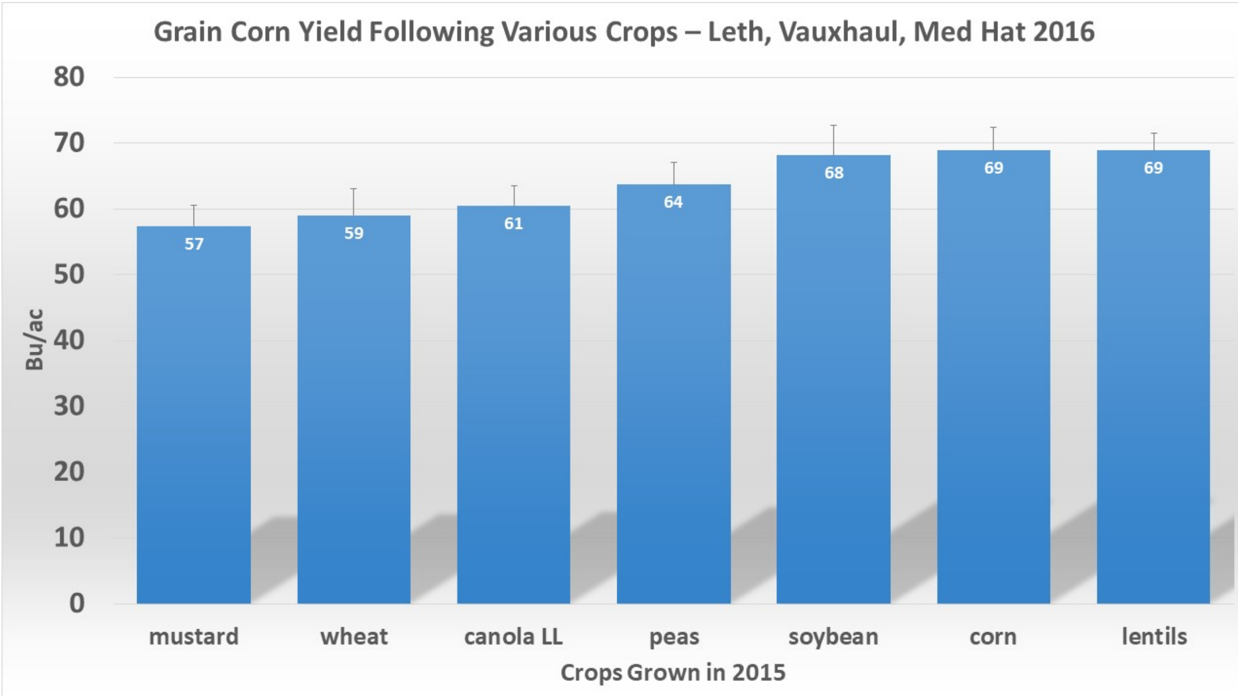


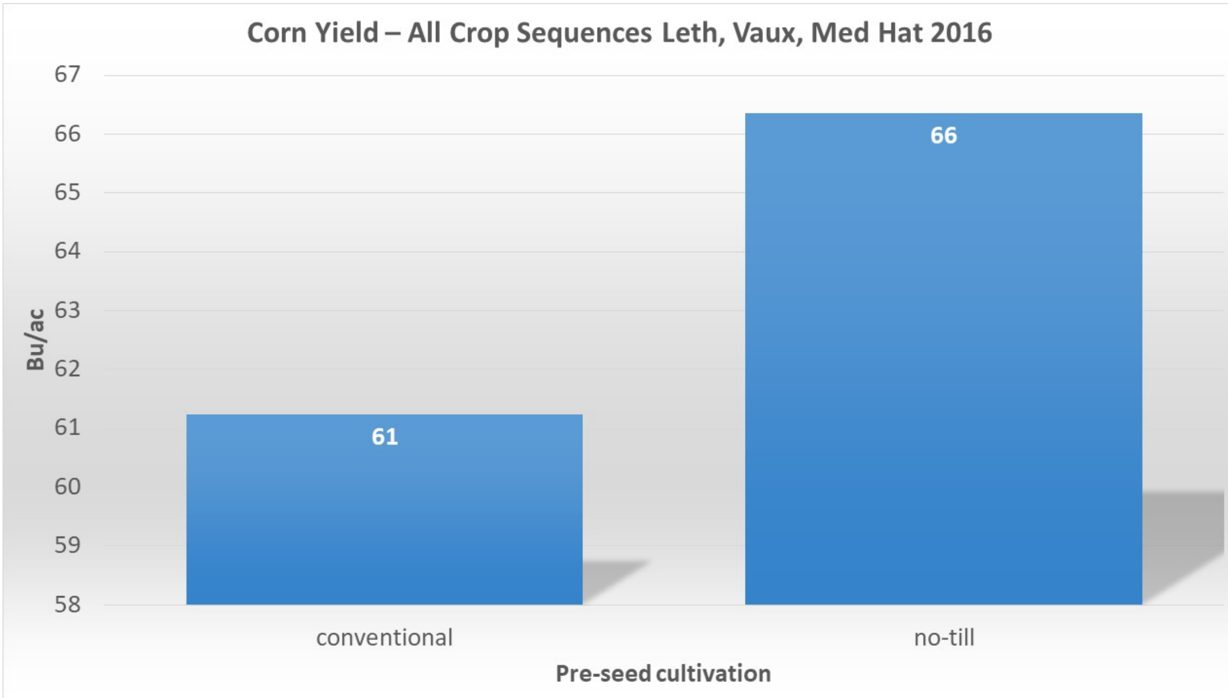
Grain Corn Yield (bu/ac 15.5%) Population and Spacing
Leth, B.Island, Med Hat 2015/16 N=5
90
85
80
75
70
65
60
55
50
45
Bu/ac
10000
15000
20000
25000
30000
35000
40000
Seeds/ac
R² = 0.9298
R² = 0.9978
20
30

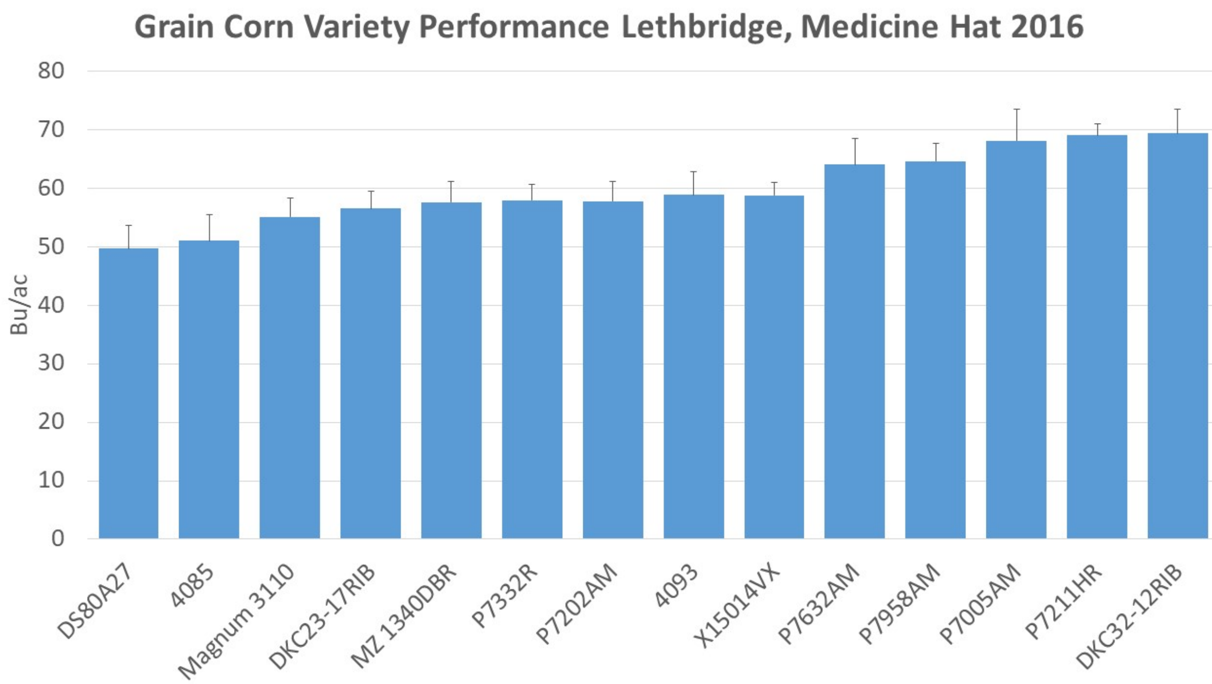

• Nitrogen Fertility


Dryland Grain Corn Nitrogen Fertility Response – Leth, Med Hat, B.Island, Vauxhaull 2016
Background N 113, 13, 66, 21
Bu/ac
100
90
80
70
60
50
40
30
20
10
0
78
78
82
80
80
81
82
70
0 lbs
50 lbs
101 lbs
50 lbs side banded + 50 lbs in-crop
160 lbs
50 lbs side banded + 100 lbs in-crop
191 lbs
101 lbs side banded + 100 lbs in-crop
lbs/ac N


• Crop Sequences


Grain Corn Yield Following Various Crops – Leth, Vauxhaul, Med Hat 2016
80
70
60
50
40
30
20
10
0
Bu/ac
57
59
61
64
68
69
69
mustard
wheat
canola LL
peas
soybean
corn
lentils
Crops Grown in 2015


Corn Yield – All Crop Sequences Leth, Vaux, Med Hat 2016
67
66
65
64
63
62
61
60
59
58
Bu/ac
61
66
conventional
no-till
Pre-seed cultivation


Grain Corn Variety Performance Lethbridge, Medicine Hat 2016
80
70
60
50
40
30
20
10
0
Bu/ac
DS80A27
4085
Magnum 3110
DKC23-17RIB
MZ 1340DBR
P7332R
P7202AM
4093
X15014VX
P7632AM
P7958AM
P7005AM
P7211HR
DKC32-12RIB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