Recovery of pulse crops from hail in Alberta using foliar fungicides and nutrient blends

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 at the mercy of mother nature when it comes to hailstorms. Crop losses from hail damage vary with intensity, timing and spatially. Producers have few available options after hail damage other than reseeding, silaging, greenfeeding or waiting to harvest what remains. Recently, some promotions suggest that commercial foliar fungicides and nutrient blends may be effective at enhancing crop recovery from wind and hail damage, not only for restoring yields, but also to improve vertical orientation for better crop harvestability.

This project tested products under different hail intensities and crop stages to determine to what extent recovery from hail damage is possible. Damage was inflicted using a hail simulator at light (33% defoliation) and heavy (67% defoliation) intensity at three growth stages - early 4-6 leaf, flowering and podding. Crop adjusters with Agriculture Financial Services Corporation (AFSC) assisted with calibrating the hail simulators and assessing actual crop damage on research trials. AFSC has in interest in the findings of this project as they relate to hail damage payouts.

Research took place during 2016-2018 at Farming Smarter in Lethbridge (southern AB), InnoTech Alberta in Vegreville (central AB) and SARDA Ag Research in Falher (Peace region) on peas. Beans research ran from 2016-2018 at the Farming Smarter site in Lethbridge.

The principle outcome is that yield recovery is only possible when plants were damaged at an early growth stage while damage level and recovery products applied had very little effect. Yield damage is permanent once the reproductive stage is reached.

Independent of hail damage, a fungicide application proved effective in improving yield, but the nutrient did not. In most cases, neither a fungicide nor nutrient application improved yield after hail damage. We cannot conclude that a timely application may not result in a benefit. However, after nine site years of data, we believe the likelihood of a positive response is very low, as is a return on investment. It is prudent for producers to ensure they have sufficient hail insurance to cover operating costs (at minimum).

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

There is currently very little scientific data in Alberta to support difficult management decisions faced by farmers after a hail event. When a hail storm strikes they need to ask?

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, insurance levels and payouts, feed availability and prices and irrigation.

Some studies in past decades showed yield improvements with fungicide applications. There is also a body of anecdotal evidence of crops recovering with certain fungicidal applications. 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). Specifically, several studies found triazoles and strobilurins group fungicides had fungitoxic and growth regulatory effects on cereal and broad leaf crops. Many product labels also claim to help aid in hail recovery, but without specific details on yield improvement and ROI. We designed the study to see if there was merit to these claims, and determine a best course of action following a hailstorm.

Objectives:

1. Evaluate the response of pulse crops to simulated hail damage at different growth stages
2. Evaluate the agronomic/economic effect of using fungicides and nutrient blends on pulse crops 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.

METHODS

Design

It is difficult to study crop responses to natural hailstorms because of unpredictability and variability. There is no way to control the timing, severity or spatial variance of the storm. Also, 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. The first two factors addressed *Objective 1. Evaluate the response of pulse 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 timing factor relied on the use of hail simulator to damage the pulses at three timings with respect to critical growth stages of the crop. For this, we applied hail damage at early vegetative (4-6 leaf), mid (flowering) and late reproductive timing (poding). Using those timings allowed approximately two weeks between simulated damages to cover the main hail periods through the pulse growing season. The beans were planted later and consequently staggered approximately 2 weeks behind the peas at any given timing. For example, we damaged peas (mid) at the same time as beans (early).

The intensity factor consisted of hail simulation at three damage severity levels including a check (0% damage), light (33% damage), and heavy (67% damage). Calibrating the hail simulator to inflict varying intensity levels 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 accordingly to achieve the desired defoliation level. The simulator drums ran 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. (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 for both crops. This factor addressed *Objective 2. Evaluate the agronomic/economic effect of using fungicides and nutrient blends on pulse crops damaged by simulated hail.*
In peas, we applied Headline as a fungicide and ReLeaf™ Canola + Kinetic Boron as the nutrient. In beans, we used Parasol WG (copper Hydroxide 50%)l; which has multi-site activity. We used Omex P3 for the nutrient. Additionally, for this factor, a check treatment was included with no nutrient or fungicide/bactericide application.

Study Sites
We carried out the project during 2016-2018 growing seasons at three locations in peas for a target of nine site years of data, and at one location in beans for three site years of data. Stats were analyzed using SAS proc Mixed. In 2017, the SARDA site received a real hailstorm before the final hail simulation timing. The data was analyzed but was ultimately discarded from the overall analysis. In 2018, the InnoTech site did not show difference between the damage levels suggesting a potential issue with the hail simulation (P = 0.19). Consequently, we choose to exclude the trial from the final 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) in the soil and limiting background N (<100lbs/ac) and Phosphorus (<30lbs/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 the dark grey soil zone. The pH ranges between 5.6 and 6.7, OM between 2.2 and 4.3%. There tends to be moderate Potassium (>220 lbs/ac) in the soil and limiting background N (< 11 lbs/ac), Sulfur (< 20 lbs/ac) and Phosphorus (<31 lbs/ac).

Cultural Information

The land used in the trial is 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

Trial seeding used custom built, zero-till air seeders. Farming Smarter has side banding Pillar Laser Disc/Hoe openers on 9.5” row spacing for a total plot area of $11.58m^2$. InnoTech is equipped with Acra-Plant double disc opener, with mid-row banders (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 $7.51m^2$. At Farming Smarter and SARDA, crops were damaged perpendicular to the seeding direction. At InnoTech, the plots were damaged parallel to the seeding direction. CDC Meadow was sown at 100 seeds/m^2 throughout years and locations. Tag Team/Establish peat and granular inoculants were used depending on year and location. Phosphorus was put in the seed row (11-52-0) at recommended rates to achieve a typical pea crop for the region.

Beans were planted with a 4 row Monosem vacuum planter on 20” rows. Six rows of each Resolute (great northern) and Island (pinto) beans were seeded perpendicular to the damage.

The chosen foliar applied nutrient was ReLeaf™ Canola @ 2 L/ac plus Boron Boost @ 1/3 L/ac. Fungicide was Headline @ 0.16 L/ac. Bean foliar treatments included Copper Hydroxide (Parasol) as the fungicide/bactericide @ 2 L/ac and Omex P3 @ 0.25 L/ac. They were applied with calibrated, custom 2 m hand booms at label rates and water volumes using 11001 or 11002 nozzles and $C0_2$ propellant. Appendix II, Figure 1-2 shows the seeding, spraying and harvesting operations. Appendix I, Table 2-3 lists the operational dates. Appendix I, Table 4 lists the average days to spray after damage. Appendix I, Tables 5-8 describe in-crop application for Farming Smarter, Innotech and SARDA for peas and beans.

Harvesting

Lethbridge harvested with a 2013 Wintersteiger Classic plot combine with a 1.5m straight cut header, InnoTech used a 1999 Wintersteiger Nurserymaster, and SARDA used a 2014 Wintersteiger Delta. They collected and weighed grain samples using a Harvest Master with on-board balance, moisture sensor and test weight chamber.

Data Collection was organized to achieve *Objective 3. Identify potential management practices to improve crop growth, harvestability and yield after hail damage.*

Data collection

- data collection for the study includes

- Pictures (UAV and plot)
- plant density (plants/m2)
- Greenseeker NDVI (1 week after damage)
- hail damage ratings (AFSC)
- disease ratings (if disease is present)
- days to flowering and maturity (if differences are seen)
- plant heights (before and after hail damage)
- biomass (1 week after damage, at maturity)
- maturity variability assessment (where applicable)
- yield (kg/ha and bu/ac)
- quality (TKW, moisture, protein, grading)

In order to complete the study, we started with *Objective 4. Develop a practical method for simulating hail damage.* Predecessors of hail research used ice cannons, threw rocks and tried other methods to simulate hail. These methods were labour and resource intensive. For simplicity sake, we opted to simulate hail damage, rather than the hail, then pass our pivot over to best simulate hailstorm conditions. We modeled our hail damage on the damage caused by whipping a dog chain across the crop foliage (Appendix II, Figure 3-5). We mechanized this method by attaching a series of short chains to a rotating drum mounted on a front end loader and drove it over the plots at a controlled height and speed through hydraulics. InnoTech added golf balls to the end of their chains to mimic larger hail stones. SARDA opted to use the same design but attach it to a motorized high clearance unit. We confirmed with local agronomists and AFSC adjusters that the mechanical damage closely resembled that of actual hail stones.

AFSC rated the damage levels 1 week after each timing to see how accurate we were to our 33% and 67% targets (Appendix II, Figure 6). 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.

RESULTS

Throughout this study, we found the biggest yield response to be the timing of hail damage. The damage level also effected yield, but not to the same extent. The foliar recovery products may have worked in some situations, but the response was very small (1-2 bu/ac) and there was no clear trend or explanation to the effect.

Plant counts

We measured plant counts to ensure a uniform trial area. An average plant stand of 70 plants/m^2 was achieved for peas from a seeding rate of 100 seeds/ m^2 (Appendix I, Figure 3). Plant counts differed across years and locations but remained uniform within each site and year. This variability is a normal response of peas to agronomic and environmental conditions among the research sites and years. The plant stand for beans was uniform across all years with average values of 22 plants/m^2 from a seeding rate of 22 seeds/ m^2 (Appendix I, Figure 4).

Biomass at 1 week after damage

Crop biomass was measured 1 week after damage to measure actual defoliations from inflicted damage by removing 4 quarter meter quadrats and weighing. For both pulse crops, the plant biomass 1 week after damage was highest in the undamaged check plots. Crop biomass was reduced by simulated hail damage at each application timing in 7 of 7 site years for peas and in 2 of 2 site years for beans (Appendix I, Table 9-10).

Peas biomass at the early timing was reduced from 743 g/m^2 for the check to 426 g/m^2 and 321 g/m^2 for the light and heavy damage levels. At the mid timing, crop biomass was reduced from 2001 g/m^2 (check) to 1484 g/m^2 (33%) and 1317 g/m^2 (67%). At the late timing, it was reduced from 2724 g/m^2 (check) to 1908 g/m^2 (33%) and 1735 g/m^2 (67%) (Appendix I, Figure 5). Similarly, the beans biomass at the early timing was reduced from 275 g/m^2 for the check to 126 g/m^2 and 102 g/m^2 for the light and heavy damage levels. At the mid timing, crop biomass was reduced from 1431 g/m^2 (check) to 596 g/m^2 (light) and 467 g/m^2 (heavy). At the late timing, it was reduced from 3602 g/m^2 (check) to 1701 g/m^2 (33%) and 1518 g/m^2 (67%) (Appendix I, Figure 6).

The foliar treatments did not the influence the biomass 1 week after damage for any of pulses (Appendix I, Table 9-10). 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 measured to see if there are differences in recovery between biomass and grain yield. We saw that the biomass was reduced by simulated hail damage at each application timing in 3 of 3 sites years for peas (Appendix I, Table 9). Pea biomass was highest in the undamaged plots. In the early damage timings, it was reduced from 312 g/m^2 to

270 g/m^2 (light) and 238 g/m^2 (heavy). At the mid timings it was reduced from 426 to 317 g/m^2 (light) and 297 g/m^2 (heavy). In the late timings it was reduced from 410 to 319 g/m^2 (light) and 260 g/m^2 (heavy) (Appendix I, Figure 7). The foliar treatments did not influence the peas biomass at harvest. Bean biomass at harvest did not exhibit differences among timings, damage levels or foliar treatments (Appendix I, Table 10, Figure 8).

NDVI at 1 week after damage

The NDVI measured before the hail damage showed no difference between the treatments. It was measured again one week after damage to see if there was a difference between the plots from the hail damage. The NDVI baseline for the check was different for each timing application as the growth stage was different, but regardless of timing, for both pulse crops the NDVI was reduced as damage levels increased (Appendix I, Table 9-10). For peas, at early timings, NDVI dropped from 0.52 (check) to 0.46 (light) and 0.41 (heavy). At mid timing it dropped from 0.65 (check) to 0.63 (light) and 0.62 (heavy). At late timing it dropped from 0.58 (check) to 0.48 (light) and 0.44 (heavy) (Appendix I, Figure 9). Similarly, for beans, at early timings, NDVI dropped from 0.33 (check) to 0.30 (light) and 0.29 (heavy). At mid timing it dropped from 0.64 (check) to 0.56 (light) and 0.55 (heavy). At late timing it dropped from 0.65 (check) to 0.60 (light) and 0.56 (heavy) (Appendix I, Figure 10). On average, foliar application of nutrient and fungicide did not influence the NDVI for either crop (Appendix I, Table 9-10). 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. For beans, height was measured by vine length. The plant height differed between timing as the growth stage was different. Average pea height before damage was 24 cm at 4-6 leaf stage, whereas at flowering and poding was 66 cm and 67 cm, respectively (Appendix I, Figure 11). For beans, average height before damage was 14 cm at 4-6 trifoliate stage, whereas at flowering and seed stages was 28 cm and 48 cm, respectively (Appendix I, Figure 12).

Height after damage

Plant height after damage was significantly reduced as hail damage level increased for both crops (Appendix I, Figure 13-14). The decrease of average plant height after hail damage was detected for each timing and increased with hail intensity. For peas, the average height at early timing was reduced from 34 cm (check) to 25 cm (light) and 22 cm (heavy). At mid timing it dropped from 71 cm (check) to 52 cm (light) and 44 cm (heavy. At late timing it dropped from 68 cm (check) to 50 cm (light) and 45 cm (heavy) (Appendix I, Figure 13). Similarly, for beans, at early timings, average height at early timing was reduced from 23 cm (check) to 20 cm (light) and 17 cm (heavy). At mid timing it dropped from 46 cm (check) to 37 cm (light) and 33 cm (heavy). At late timing it dropped from 67 cm (check) to 53 cm (light) and 50 cm (heavy) (Appendix I, Figure 14). On average, foliar application of nutrient and fungicide did not exhibit significant effect on plant height after damage for any of the pulse crops.

Grading

Grading represents an evaluation of a physical condition or features to determine the quality of the grain. The peas were graded according to CGC standards at nearest elevator. Peas from our trial were graded on if they were bleached, colored, cracked, damaged, wrinkled, pink or shrunken and given an overall grade. At each timing, a lower proportion of grade 2 and higher proportion of feed was observed as damage levels increased (Appendix I, Figure 18). At mid and late stages, a higher proportion of grade 3 was detected at damage levels of 33% and 67%.

Yield

Peas

Yield loss at the early damage timing was minimal, but increased as the season progressed (Appendix I, Figure 15). At the early damage timing, the check yielded 49 bu/ac while the the light and heavy damage yielded 44 bu/ac. With damage at heading, the peas yielded 35 bu/ac (light) and 31 bu/ac (heavy). Damage at flowering it was 23 bu/ac (light) and 14 bu/ac (heavy).

Yield loss due to an early simulated hail event was 10 % (44 bu/ac) for both damage levels. At the flowering timing, the yield loss was 30% (35 bu/ac) for light damage and 38% (31 bu/ac) for heavy damage. At podding the yield loss was 53% (23 bu/ac) for light damage and 71% (14 bu/ac) for heavy damage respectively.

Beans

Yield data for both resolute and Island beans were quite variable (Appendix I, Figure 16-17). For both bean cultivars, the highest yield recovery was detected on the undamaged nutrient treatment but only with the earliest damage timing.

For Resolute beans, the undamaged fungicide yielded on average 1 bu/ac higher than the check, but similar values were observed with the average yield between nutrient application and the check. In contrast, for Island beans, the undamaged fungicide and nutrient yielded on average 4 bu/ac and 5 bu/ac higher than the check.

For Resolute beans, yield loss was higher as damage level increased, regardless of the timing (Appendix I, Figure 16). At the early damage timing, light and heavy simulated hail damage resulted in yield loss of 7% (39 bu/ac) and 29% (30 bu/ac) respectively. At the flowering timing the yield loss for light and heavy damage was 18% (33 bu/ac) and 28% (29 bu/ac) respectively. At the pod stage timing the yield loss for light and heavy damage was 22% (25 bu/ac) and 53% (15 bu/ac) respectively.

For Island beans, at early damage timing it was detected an increased yield of 23% (38 bu/ac) compared with check with light simulated hail damage (Appendix I, Figure 17). However, at 67% hail damage a yield loss of 13% (27 bu/ac) was observed. Similarly, at the flowering and seed stages, the yield loss was higher as damage level increased. At the flowering timing the yield loss for light and heavy damage was 19% (30 bu/ac) and 24% (28 bu/ac) respectively. At the seed stage timing the yield loss for light and heavy damage was 24% (28 bu/ac) and 38% (23 bu/ac) respectively.

DISCUSSION

The timing of hail damage had the largest impact on peas and beans yield, followed by the damage level, and at a lesser extent the application of recovery products.

Timing

Timing had the greatest effect on peas and beans yield. For peas, simulated hail applications at early vegetative plant growth yielded only 10% less than the same as the checks indicating that early hail damage had minimal impact on yield (49 bu/ac vs 44 bu/ac). However, hail damage at flowering and podding stages lowered the yield to a much greater degree (Appendix I, Table 11 and 14, Figure 15). These results suggest that at early growth stages, pea plants affected by hail have enough growing degree days to recover from damage and reach maturity. In contrast, in the reproductive stages, pea plants are more susceptible to damage, since they don't have enough time to recover before reaching maturity. Bean plants were affected by hail damage at each timing, however, the response varied between the two cultivars at early timing. For Resolute beans, hail damage at vegetative plant stage produced a decreased yield as damage level increased whereas for Island beans, an increased yield occurred at light damage followed by a decrease at heavy damage (Appendix I, Table 12 and 15, Figure 16-17). The increased yield at moderated damage was most obvious on fungicide treated plants. This suggests that application of fungicide/bactericide may help to improve plant recovery at early foliar stages. At flowering and seed stages, there was a yield loss as hail damage intensity increased.

Damage levels

The damage severity of hail significantly reduced peas and beans yield in all site years ($P<0.0001$) (Appendix I, Table 11-12).

Damage x Timing

In 7 out 9 site years, reduced pea yield increased with the damage level (Appendix I, Table 11, Figure 15). Similarly, for beans, increased damage level resulted in yield drop in 2 of 3 years for Resolute and 1 of 3 years for Island (Appendix I, Table 12, Figure 16-17). Simulated hail damage at mid and late timing resulted in the higher yield losses. This is because at the earlier vegetative stage, the plant still has a substantial amount of growing season left to recover. 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 percent of the defoliation. These formulas are adjusted as the crop goes through vegetative growth. In contrast to this, any defoliation at the reproductive stage is 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.

Foliar

Foliar applications only improved yield after hail damage for peas at SARDA in 2018 ($P=0.0003$) (Appendix I, Table 11, Figure 15), whereas no improvement was detected for any of the bean cultivars (Appendix I, Table 12, Figure 16-17). At SARDA in 2018, pea plants treated with fungicide show a 326 bu/ac increase yield on average compared to check. Overall averages of all site years showed no increase in yield from the nutrient blends.

Damage x Foliar
Peas showed no interaction of damage and foliar treatments except for SARDA 2016 (Appendix I, Table 11). There was a small yield increase of 0.9 bu/ac with the fungicide application at the 33% and 67% damage levels (Appendix I, Figure 15). The undamaged pea plants had a 1.5bu/ac yield increase in response to fungicide. This suggests that fungicide treatments may have potential to recover pea plants. For beans, none of the cultivars showed response to fungicide or nutrient blend applications (Appendix I, Table 12, Figure 16-17). This suggests that the nutrients and fungicides were ineffective at helping beans recover from hail damage. There were no significant interactions of timing by foliar applications or timing by damage by foliar (Appendix 1, Table 11-12) suggesting that the products did not impact yield**.**

Grading
Peas were graded according to CGC specifications (Appendix I, Figure 18). We did not see any No. 1 peas in our study. The best graded peas were No. 2 in the undamaged checks. Fungicide and nutrient application did not improve grade, but grade decreased on average as damage severity increased and as the growing season progressed. We found that peas damaged before seed formation had the best grades compared to those damaged after pod formation, we also found that in the late timing the heavy damage had the highest proportion of No. 3 or worse, followed by the light damage and then the checks. These results indicate that hail damage causes the most downgrading of the seed quality at mid and late stages.

TKW
For peas, at mid and late timings TKW decreased as hail damage level increased (Appendix I, Figure 19). However, at early timing, TKW values were similar among hail damage levels. The TKW values were the same for both bean cultivars (360) (Appendix I, Figure 20-21). For Resolute and Island beans, the TKW were similar among timings, damage levels and foliar applications.

AFSC Percent Damage
AFSC adjusters use a formula to calculate the amount payable to a farmer based on the percent damage for the given growth stages. AFSC rated our damage levels 1 week after each timing to see how accurate we were to our light (33%) and heavy (67%) targets (Appendix I, Figure 22-23). 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. For peas, the AFSC ratings were similar at all timings. Light hail damage of 33% averaged an AFSC rating of 37%, and heavy hail damage of 67% was 62% (Appendix I, Figure 22).

CONCLUSIONS AND RECOMMENDATIONS

This project evaluated the response of peas and beans to hail damage using a practical method for simulating hail damage. This methodology is applicable to many agronomic studies focused on the influence of adverse climatic conditions to crop development. Simulating the effect of hail damage on field conditions allows the experimental control of treatments, which otherwise might be very difficult to perform under natural hailstorms.

The results shown in this project reveal that yield losses produced by simulated hail damage in peas and beans occur mainly at reproductive stages. When hail damage takes place at early vegetative stages, plants can recover yields and complete their life cycle. These findings have practical implications for management strategies to recover pulse crops from hail at early stages. At the early stage, the two beans cultivars showed different response to hail damage and foliar application products. This result implies more research could explore the potential of different pea and bean cultivars to recover from hail damage.

In order to understand the effect of fungicide on hail damage peas, additional research could investigate the influence of fungicide application to prevent fungal diseases on hail damaged peas. In the current project, the application of nutrient blends did not exhibit recovering effects on any of the pulse crops. Future studies may include additional recovery strategies that might include biostimulants, plant growth promoters and/or dual applications of these products.

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Appendix I

Tables and graphs

Table 1. Hail simulator specifications.

Crop Stage	% Damage	Direction	RPM	Chains	Speed
Early:	67%	4 passes	2300	on ground	A1
	33%	2 passes	2300	on ground	A1
Mid:	67%	1 pass	2300	on ground	A1
	33%	1 pass	2300	on ground	A3
Late:	67%	1 pass	2300	on ground	A1
	33%	1 pass	2300	on ground	A3

Table 2. Dates of operations on pea fields 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	2-May	30-Apr	11-May	18-May	na	6-May	11-May	19-May
Emergence Date	15-May	15-May	11-May	24-May	25-May	na	na	na	na
Plant Count Date	13-Jun	15-Jun	4-Jun	2-Jun	9-Jun	na	14-Jun	5-Jun	14-Jun
Days to Emergence	12	13	12	13	7	na	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	28-Jun	27-Jun	23-Jun	25-Jun
AFSC Early	22-Jun	19-Jun	25-Jun	10-Jun	29-Jun	na	na	na	21-Jun
NDVI Early	22-Jun	21-Jun	22-Jun	17-Jun	28-Jun	na	na	22-Jun	4-Jul
Biomass Early	22-Jun	28-Jun	22-Jun	17-Jun	27-Jun	na	4-Jul	22-Jun	4-Jul
Mid									
Hail Damage 2	29-Jun	26-Jun	3-Jul	12-Jul	13-Jul	5-Jul	11-Jul	7-Jul	18-Jul
Spray Mid	2-Jul	27-Jun	4-Jul	12-Jul	13-Jul	12-Jul	11-Jul	14-Jul	25-Jul
AFSC Mid	6-Jul	6-Jul	9-Jul	19-Jul	20-Jul	na	na	na	18-Jul
NDVI Mid	na	6-Jul	11-Jul	19-Jul	20-Jul	na	na	13-Jul	30-Jul
Biomass Mid	6-Jul	6-Jul	na	19-Jul	20-Jul	na	18-Jul	14-Jul	24-Jul
Late									
Hail Damage 3	15-Jul	10-Jul	16-Jul	19-Jul	26-Jul	19-Jul	18-Jul	15-Jul	31-Jul
Spray Late	18-Jul	11-Jul	12-Jul	19-Jul	26-Jul	26-Jul	18-Jul	Hail	7-Aug
AFSC Late	20-Jul	17-Jul	16-Jul	26-Jul	na	na	26-Jul	26-Jul	na
NDVI Late	na	17-Jul	24-Jul	26-Jul	2-Aug	na	na	hail	7-Aug
Biomass Late	22-Jul	17-Jul	27-Jul	26-Jul	2-Aug	na	25-Jul	6-Jul	30-Jul
Harvest									
Biomass Maturity	na	9-Aug	na	na	na	na	na	31-Jul	na
Harvest	1-Sep	15-Sep	na	16-Sep	1-Sep	26-Sep	9-Sep	5-Sep	5-Sep

Table 3. Dates of operations on bean fields for Farming Smarter (FS, Lethbridge, AB).

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

Table 4. Average Days to Spray for all site years.

Timing	Peas		Beans	
	Avg Days to Spray	SE	Avg Days to Spray	SE
Early	4.0	1.69	2.7	1.25
Mid	3.8	2.72	1.7	0.95
Late	4.3	2.75	2.7	2.37

Table 5. Peas Incrop applications for Farming Smarter

Spray Treatments	2016	2017	2018
Pre-seed Burn off:	Gly + Aim	Gly + Aim	Gly + Aim
Date:	1-May-17	4-May-17	30-Apr-18
Rate:	1L/ac	1 L/ac	1L/ac
Pre-seed Burn off:		Authority	Authority
Date:		4-May-17	30-Apr-18
Rate:		1 L/ac	1 L/ac
In-crop Treatment (s):	Matador		Matador
Date:	4-Jun-16		24-May-18
Stage:	4 leaf		4 leaf
Rate:	label		1 L/ac
In-crop Treatment (s):	Odyssey DLX	Viper	Pursuit
Date:	13-Jun-16	31-May-17	22-May-18
Stage:	4-6 leaf	6 leaf	6 leaf
Rate:	label	label	label
Pre-harvest Burn off:	Goldwing	Reglone	none
Date:	27-Aug-16	10-Aug-17	
Rate:	label	label	

Table 6. Peas Incrop applications for InnoTech

Spray Treatments	2016	2017	2018
Pre-seed Burn off:	glyphosate	Treflan EC	tandemn disced twice
Date:	9-May-16	3-May-17	
Rate:	360 gai/acre	1 L/acre	
Pre-seed Burn off:		tilled and packed instead	
Date:			
Rate:			
In-crop Treatment (s):	Odyssey/Poast/Merge	Odyssey/Poast/Merge	Poast/Merge
Date:	7-Jun-16	6-Jun-17	28-May-18
Stage:	4-5 node	4-5 node	2-3 node
Rate:	17g/150ml/0.5%w/w (acre)	17g/150ml/0.5%w/w (acre)	150ml/0.5%w/w (acre)
In-crop Treatment (s):			Odyssey/Poast/Merge
Date:			8-Jun-18
Stage:			4-5 node
Rate:			17g/150ml/0.5%w/w (acre)
Pre-harvest Burn off:	none	Reglone Ion	Reglone Ion
Date:		23-Aug-17	23-Aug-18
Rate:		0.7 L/acre (90 L/ac)	0.7 L/acre

Table 7. Peas Incrop application for SARDA

Spray Treatments	2016	2017	2018
Pre-seed Burn off:	Gly + Borax	Gly + Heat	Gly + Heat
Date:	29-Apr-16	10-May-17	
Rate:	500+ 228 mL/ac	0.33L/ac + 21mL/ac	
In-crop Treatment (s):	Solo + Basagran + Equinox + UAN	Viper + UAN	Viper + UAN
Date:	5-Jun-16	3-Jun-17	18-Jun-18
Stage:	4 leaf	4 leaf	4 leaf
Rate:	11.7g+361ml+65ml+404ml	0.4L/ac + 0.81L/ac	0.4L/ac + 0.81L/ac
Pre-harvest Burn off:	Reglone Ion		Reglone Ion
Date:	20-Aug-16		28-Aug-18
Rate:	700mL/ac		1.5L/ac

Table 8. Beans Incrop applications for Farming Smarter

Spray Treatments	2016	2017	2018
Pre-seed Burn off:	Edge + Rototill	Gly	Edge + Rototill
Date:	15-May-16	1-May-17	
Rate:		1 L/ac	
In-crop Treatment (s):	Solo + Basagran	Viper + Basagran + Forte	Odyssey + Merge
Date:	13-Jun-16	19-Jun-17	21-Jun-18
Stage:	V4	6 leaf	6 leaf
Rate:	label	label	label
Pre-harvest Burn off:	Reglone		Guardsman
Date:	15-Sep-16		4-Sep-18
Rate:	label		1 L/ac

Table 9. Number of times each factor was Significant at P<0.05 for Peas. T = Timing, D = Damage, F = Foliar.

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

Table 10. Number of times each factor was Significant at P<0.05 for Beans. T = Timing, D = Damage, F = Foliar.

Factor	Plant Counts	Yield Resolute	Yield Island	Biomass at Harvest	Biomass 1 week	NDVI 1 week
Timing	1	3	3	0	2	3
Damage	0	3	3	0	2	2
T*D	1	2	2	0	2	0
Foliar	0	0	0	0	0	0
T*F	0	0	0	0	0	0
D*F	0	0	0	0	0	0
T*D*F	0	0	0	0	0	0
Site Years Data	3	3	3	1	2	3

Table 11. Analysis of Variance for Peas 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	0.907	0.655	0.999	0.236	0.941	-0.2	0.3
FS17	0.000	0.000	0.000	0.461	0.857	0.348	0.169	0.1	-0.2
FS18	0.000	0.000	0.000	0.209	0.920	0.853	0.071	0.3	1.1
IT16	0.000	0.000	0.000	0.866	0.473	0.441	0.853	0.8	2.4
IT17	0.000	0.000	0.000	0.989	0.138	0.620	0.685	0.3	1.4
IT18	0.047	0.000	0.117	0.995	0.318	0.967	0.534	0.5	0.2
SD16	0.000	0.000	0.000	0.000	0.039	0.241	0.406	0.0	-0.3
SD17	0.000	0.000	0.001	0.138	0.663	0.839	0.532	0.4	0.7
SD18	0.000	0.000	0.000	0.860	0.943	0.995	0.962	0.3	0.3

Table 12. Analysis of Variance for Beans yield at all years. FS = Farming Smarter. Grey cells are significantly different at 95%.

LocYr	Damage	Timing	D*T	Foliar	D*F	T*F	D*T*F	Skewness	Kurtosis
Resolute									
FS16	0.000	0.010	0.017	0.448	0.976	0.870	0.172	-0.2	0.1
FS17	0.000	0.000	0.670	0.165	0.392	0.387	0.948	-0.1	0.0
FS18	0.000	0.000	0.042	0.793	0.638	0.904	0.172	-0.1	-0.4
Island									
IT16	0.000	0.010	0.017	0.448	0.976	0.870	0.172	-0.2	0.1
IT17	0.000	0.022	0.429	0.472	0.111	0.872	0.559	-0.4	0.7
IT18	0.001	0.007	0.148	0.374	0.064	0.400	0.414	0.4	1.7

Table 13. Combined analysis of peas and beans yield for site years.

Factor	LocYr	D	T	D*T	F	D*F	T*F	D*T*F	Skewness	Kurtosis
Peas	8	0.000	0.000	0.000	0.354	0.675	0.905	0.572	0.5	2.7
Beans (Resolute)	3	0.000	0.000	0.117	0.279	0.445	0.263	0.391	0.0	0.4
Beans (Island)	2	0.000	0.020	0.113	0.522	0.323	0.965	0.399	-0.2	2.0

Table 14. Average of plant counts (P/m^2), biomass (g/m^2), NDVI, plant height (cm), yield (bu/ac), TKW and damage (AFSC) of peas grown at Lethbridge, Vegrevile and Falher during 2016-2018. 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.

	P/m^2	g/ m^2 1wk	g/ m^2 crop	NDVI	cm pre	cm post	bu/ac	TKW	AFSC dam
Early (tiller)	70	497	274	0.4647	24	27	46	224.1	32
Early 0	71	743	312	0.5253	24	34	49	226.0	
Check	71	822	303	0.5306	24	34	48	226.4	
Fungicide	71	681	310	0.5229	23	33	46	226.1	
Nutrient	72	717	323	0.5223	24	34	53	225.4	
Early 33	70	426	270	0.4554	24	25	44	223.3	37
Check	68	474	272	0.4623	24	26	44	220.3	36
Fungicide	71	409	284	0.4565	24	25	47	222.3	37
Nutrient	71	391	255	0.4475	25	25	42	227.2	37
Early 67	69	321	238	0.4133	24	22	44	222.9	59
Check	70	339	257	0.4163	24	23	45	223.3	59
Fungicide	68	318	225	0.4202	24	22	45	222.2	58
Nutrient	68	306	233	0.4035	24	22	42	223.3	59
Mid (flag)	70	1581	347	0.6342	66	55	39	206.3	32
Mid 0	71	2001	427	0.6514	67	71	50	226.2	
Check	72	1993	444	0.6553	69	72	51	224.8	
Fungicide	72	1991	437	0.6403	67	69	51	225.8	
Nutrient	71	2021	400	0.6584	67	71	49	227.8	
Mid 33	70	1484	318	0.6272	65	52	35	200.6	36
Check	71	1556	300	0.6272	65	52	34	200.7	37
Fungicide	72	1519	325	0.6281	64	52	35	204.6	37
Nutrient	69	1366	328	0.6263	65	52	36	196.7	33
Mid 67	70	1317	297	0.6241	65	44	31	191.9	60
Check	70	1412	302	0.6250	65	44	31	193.3	61
Fungicide	70	1261	294	0.6256	65	44	33	198.4	59
Nutrient	68	1263	296	0.6216	65	43	30	184.1	60
Late (flower)	72	2147	329	0.5009	67	54	28	196.0	32
Late 0	72	2724	410	0.5796	66	68	49	222.1	
Check	71	2630	415	0.5741	66	69	46	226.4	
Fungicide	72	2796	418	0.5878	66	68	53	223.9	
Nutrient	73	2746	398	0.5769	67	68	49	215.8	
Late 33	69	1908	319	0.4845	67	50	23	191.6	42
Check	70	2013	332	0.4941	67	51	24	190.0	41
Fungicide	69	1889	333	0.4744	67	49	22	197.6	44
Nutrient	67	1821	290	0.4850	67	50	22	187.1	42
Late 67	74	1735	260	0.4386	67	45	14	174.4	69
Check	72	1667	231	0.4266	68	44	14	171.3	69
Fungicide	74	1820	289	0.4334	67	46	14	177.9	66
Nutrient	77	1719	261	0.4559	68	44	13	173.9	73

Table 15. Average of plant counts (P/m²), biomass (g/m²), NDVI, plant height (cm), yield (bu/ac), TKW and damage (AFSC) of beans grown at Lethbridge during 2016-2018. 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 al years.

	P/m²	g/ m² 1wk	g/ m² crop	NDVI	cm pre	cm post	bu/ac Resolute	bu/ac Island	TKW Resolute	TKW Island	AFSC dam
Early (tiller)	21	167	1251	0.3099	14	20	37	32	183.4	359.4	38
Early 0	22	275	1140	0.3342	13	23	42	31	188.3	361.6	
Check	23	228	1046	0.3050	13	23	44	28	189.8	361.5	
Fungicide	21	259	1300	0.3313	13	23	43	30	185.5	356.6	
Nutrient	22	337	1072	0.3663	13	22	40	35	189.5	366.7	
Early 33	21	126	1216	0.3063	14	20	39	38	186.1	363.3	53
Check	20	114	1326	0.3125	14	19	39	36	190.5	359.7	51
Fungicide	21	119	1124	0.3050	14	21	45	43	187.0	366.9	54
Nutrient	21	145	1197	0.3013	14	20	33	35	180.8	363.3	55
Early 67	20	102	1397	0.2892	14	17	30	27	176.0	353.2	61
Check	21	67	1321	0.2688	14	17	31	33	174.5	352.8	63
Fungicide	21	171	1326	0.3188	14	17	38	30	179.0	357.5	67
Nutrient	19	67	1544	0.2800	13	19	22	18	174.5	348.8	53
Mid (flag)	22	832	1293	0.5821	28	39	34	32	175.6	358.2	22
Mid 0	22	1431	1392	0.6356	28	46	40	37	188.8	356.5	
Check	23	1575	1072	0.6396	28	46	41	34	185.5	349.3	
Fungicide	22	1300	1725	0.6173	27	46	39	42	188.3	361.2	
Nutrient	22	1419	1378	0.6497	29	47	39	36	192.5	359.4	
Mid 33	22	596	1243	0.5626	27	38	33	30	174.9	359.9	27
Check	22	653	1274	0.5554	28	39	38	29	174.0	362.8	21
Fungicide	22	596	1103	0.5687	27	36	34	31	182.5	366.3	28
Nutrient	22	539	1352	0.5637	27	37	28	29	168.3	350.6	32
Mid 67	22	468	1243	0.5472	29	33	29	28	163.2	358.0	40
Check	22	352	1134	0.5348	28	33	28	32	176.8	365.7	39
Fungicide	23	710	1352	0.5584	29	33	28	25	152.0	351.6	41
Nutrient	22	342	1243	0.5485	29	33	30	26	160.8	356.8	40
Late (flower)	22	2274	1126	0.6004	48	57	24	29	181.4	361.1	5
Late 0	22	3602	1283	0.6479	48	67	32	37	180.3	352.1	
Check	22	3471	1357	0.6519	47	68	31	35	174.5	360.3	
Fungicide	23	3574	1181	0.6688	49	67	29	37	175.5	345.5	
Nutrient	22	3761	1311	0.6232	47	66	37	38	191.0	350.4	
Late 33	22	1701	1008	0.5975	47	53	25	28	187.2	365.4	8
Check	22	1787	1103	0.5835	47	54	27	28	185.5	365.2	10
Fungicide	22	1818	943	0.6033	48	52	28	28	198.5	363.1	10
Nutrient	21	1497	979	0.6057	47	54	21	28	177.5	368.1	5
Late 67	22	1518	1086	0.5557	49	50	15	23	176.8	365.9	6
Check	23	1513	1046	0.5661	49	52	13	22	183.8	371.6	
Fungicide	23	1544	1000	0.5395	49	50	17	22	179.3	362.8	8
Nutrient	22	1497	1212	0.5615	50	50	14	25	167.3	363.3	9

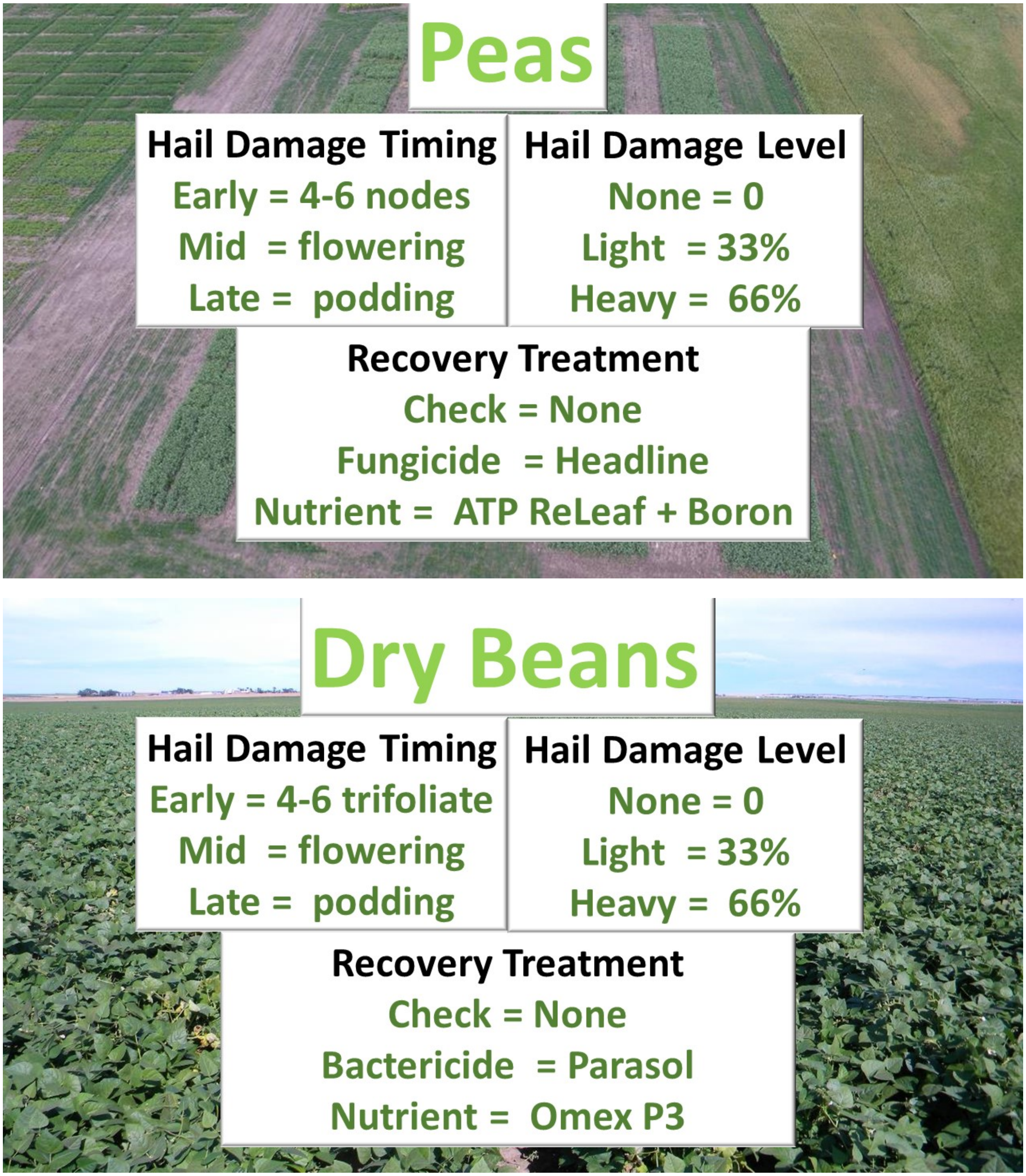


Figure 1. Experimental design of hail damage simulation on peas and beans in Alberta during 2016-2018.

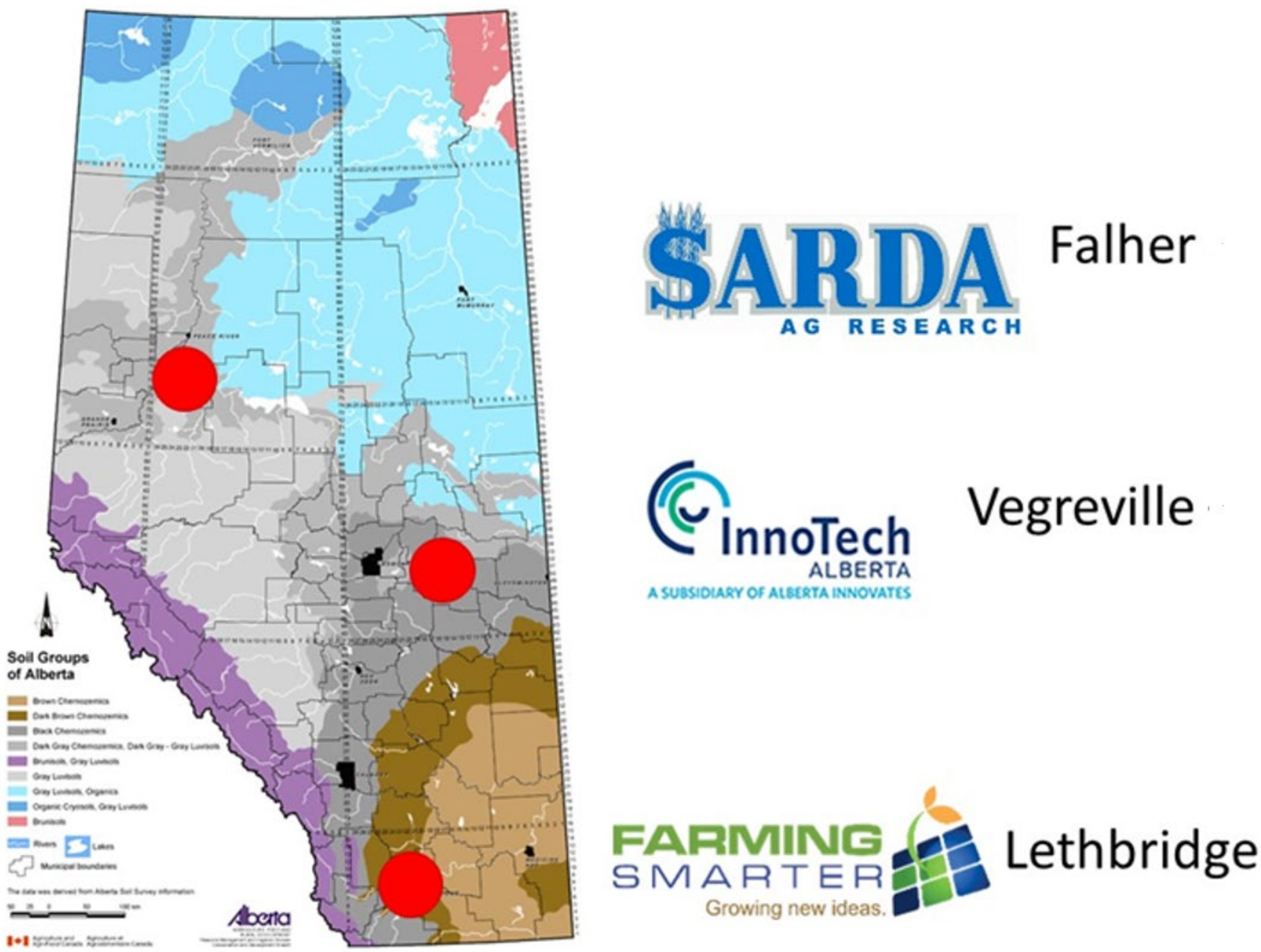


Figure 2. Location of experimental peas fields used for hail damage simulation in Alberta during 2016-2018. Beans fields were located only at Lethbridge.

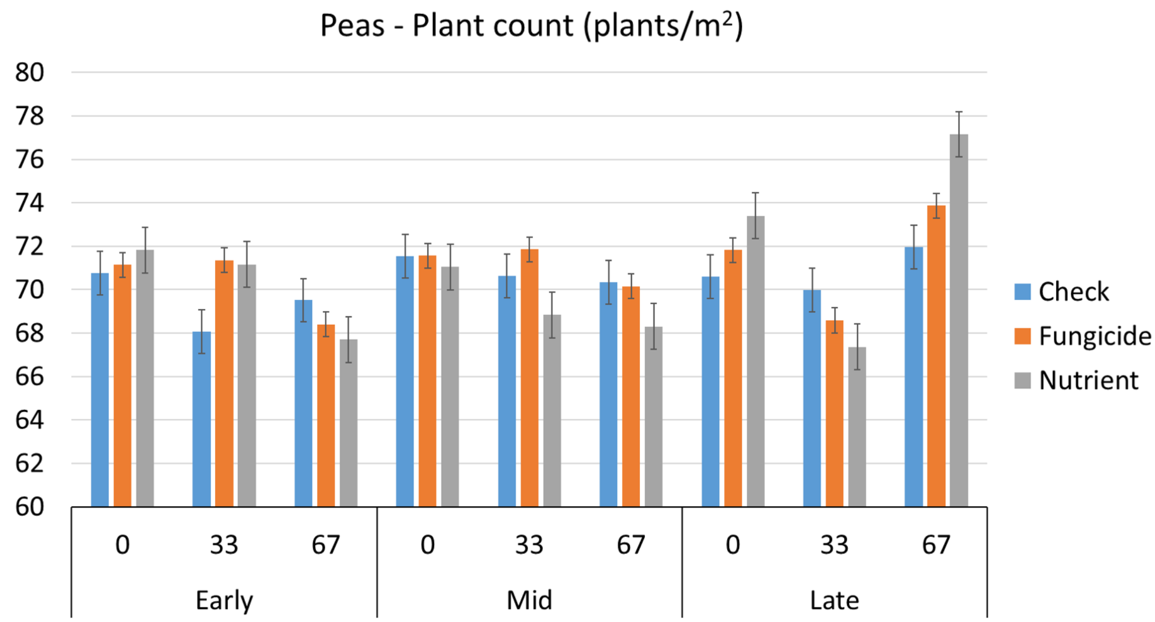


Figure 3. Plant counts of peas grown at Lethbridge, Vegrevile and Falher during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

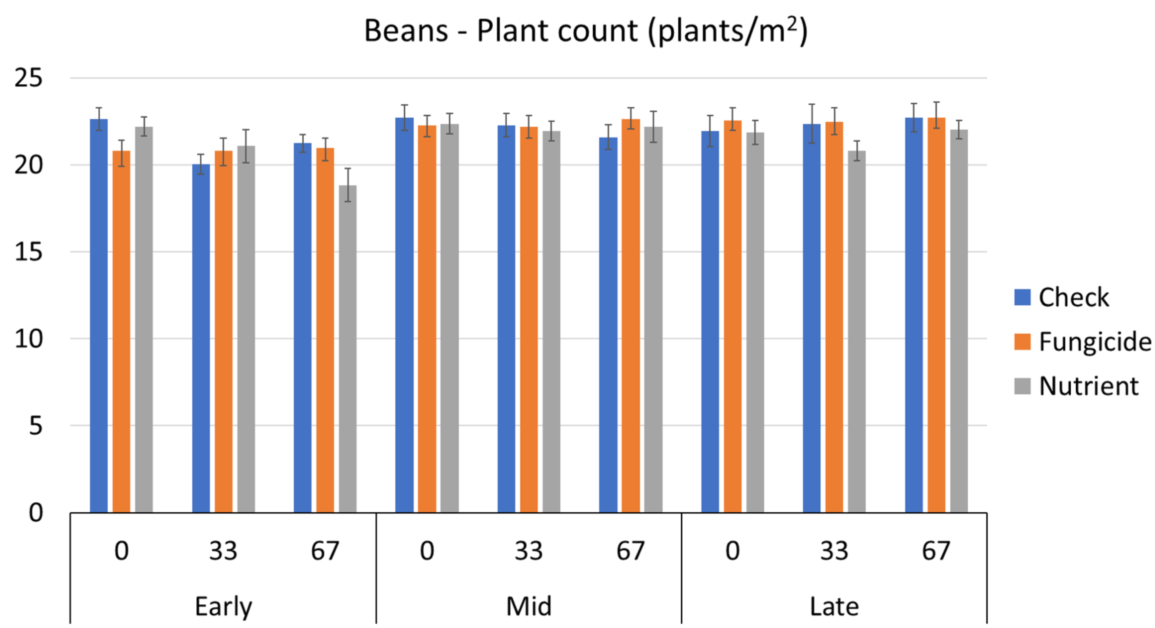


Figure 4. Plant counts of beans grown at Lethbridge during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 6). Error bars represent standard error.

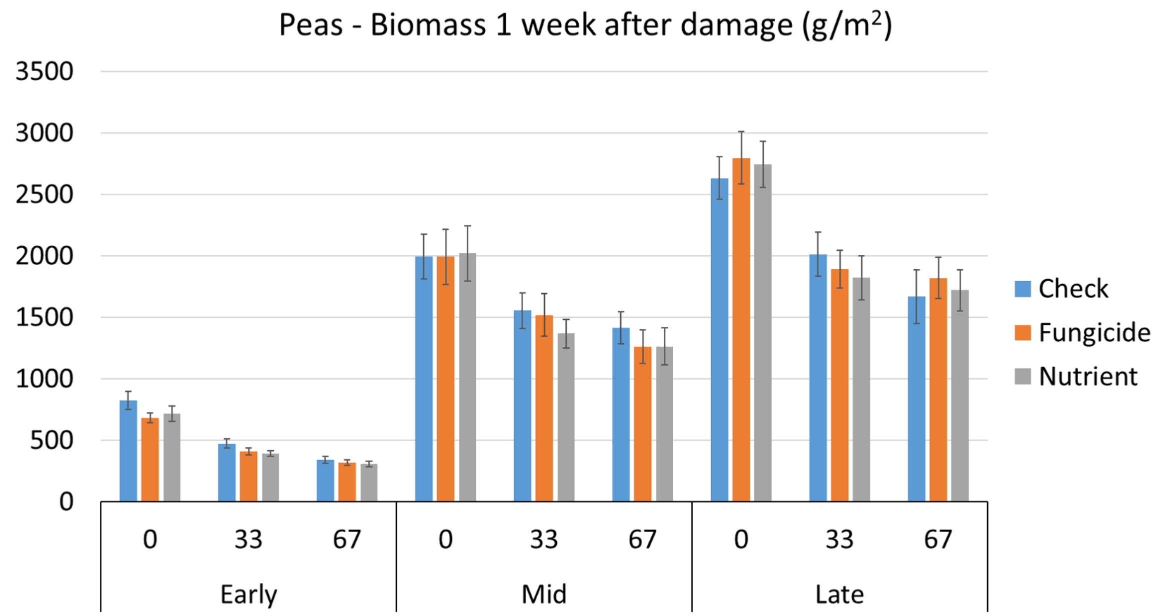


Figure 5. Biomass 1 week after damage hail damage of peas grown at Lethbridge, Vegrevile and Falher during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent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

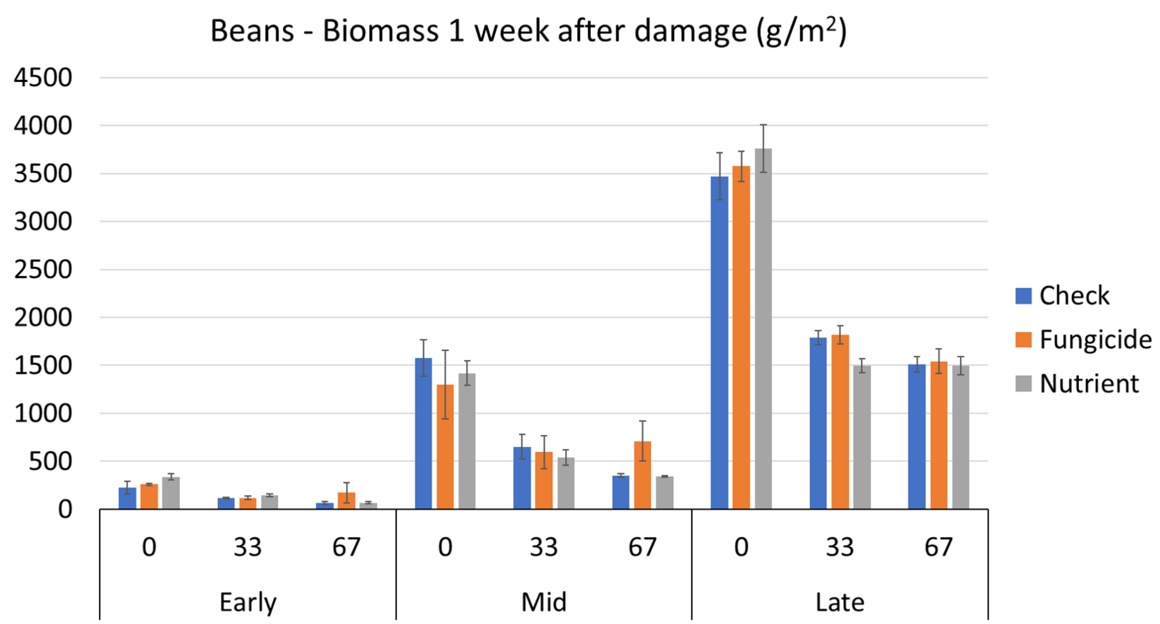


Figure 6. Biomass 1 week after damage hail damage of beans grown at Lethbridge during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 6). Error bars represent standard error.

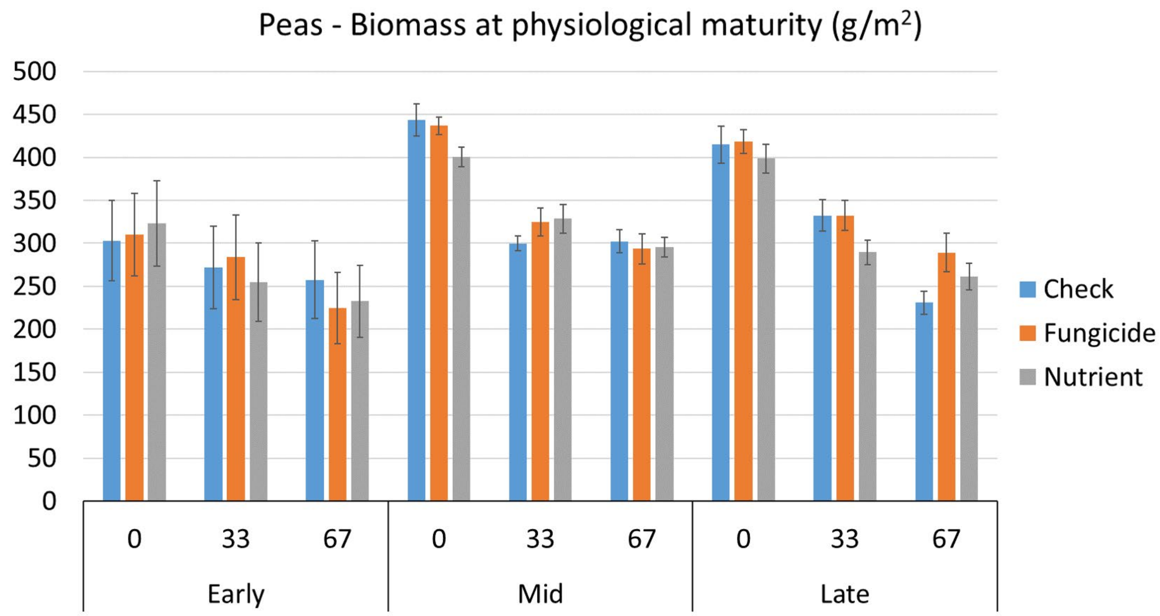


Figure 7. Biomass at maturity of peas grown at Lethbridge, Vegrevile and Falher during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages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

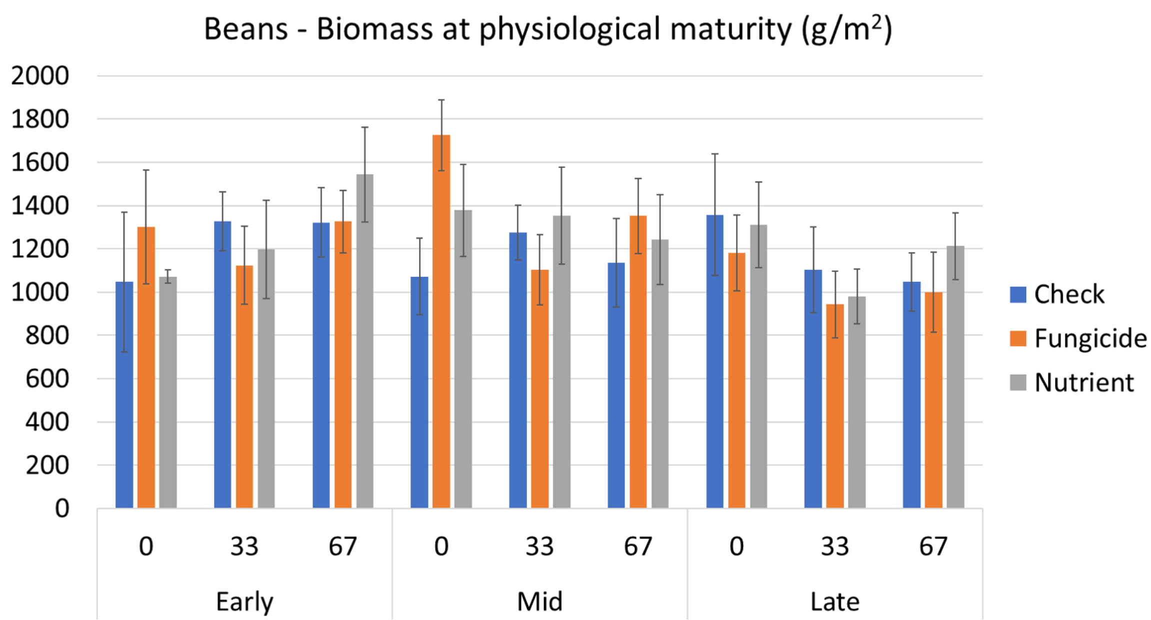


Figure 8. Biomass at maturity of beans grown at Lethbridge during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 6). Error bars represent standard error.

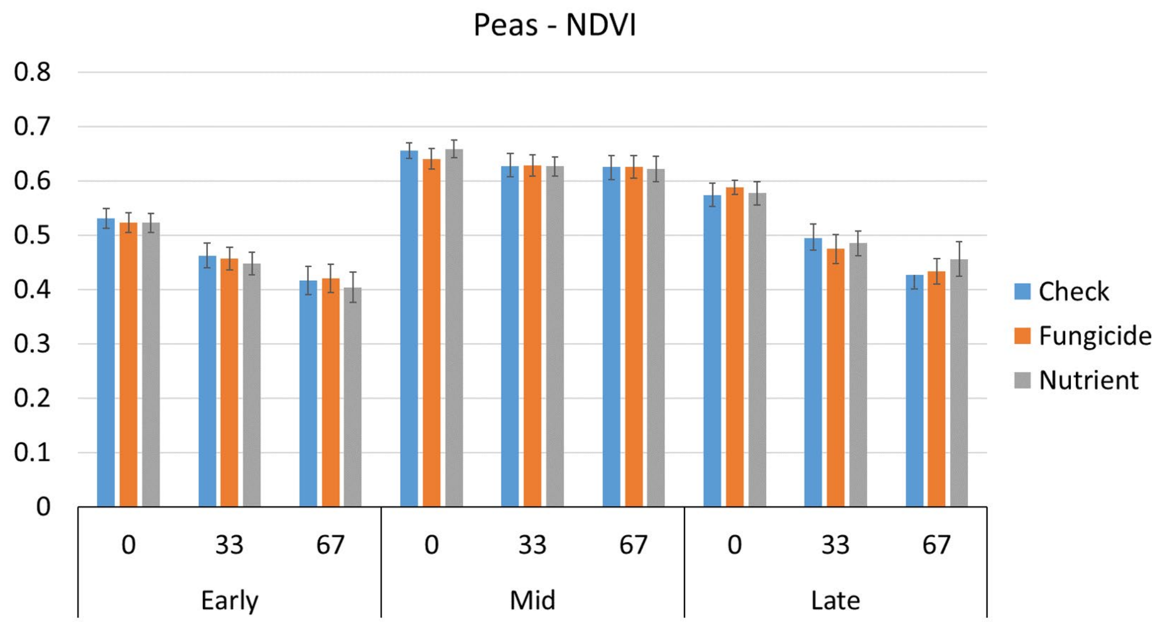


Figure 9. NDVI of peas grown at Lethbridge, Vegrevile and Falher during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all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

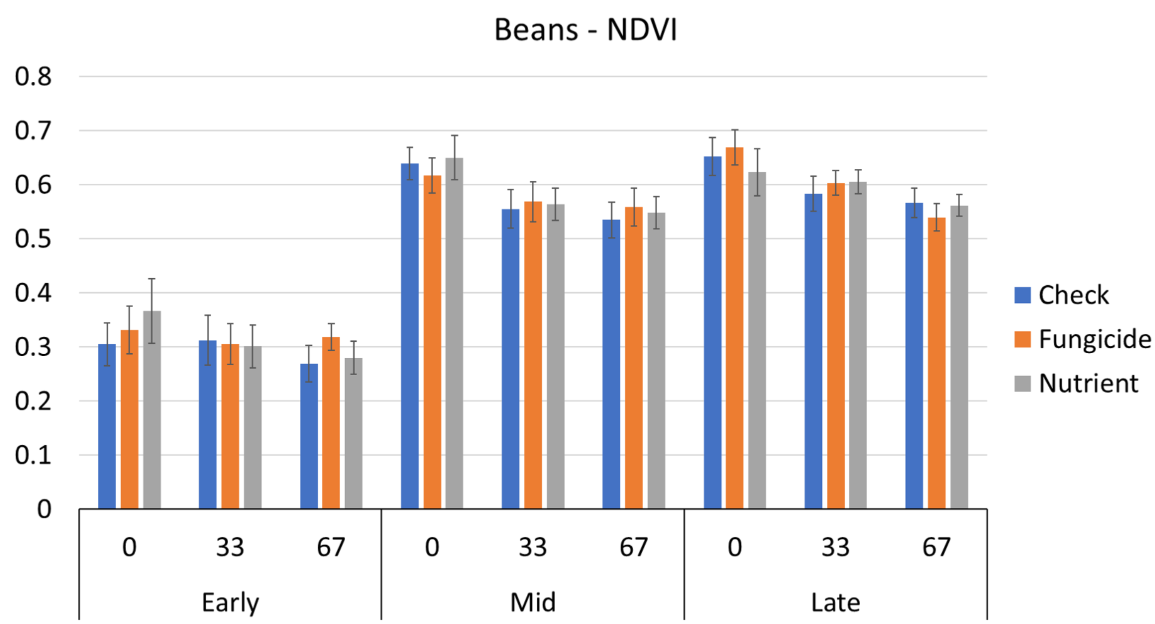


Figure 10. NDVI of beans grown at Lethbridge during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 6). Error bars represent standard error.

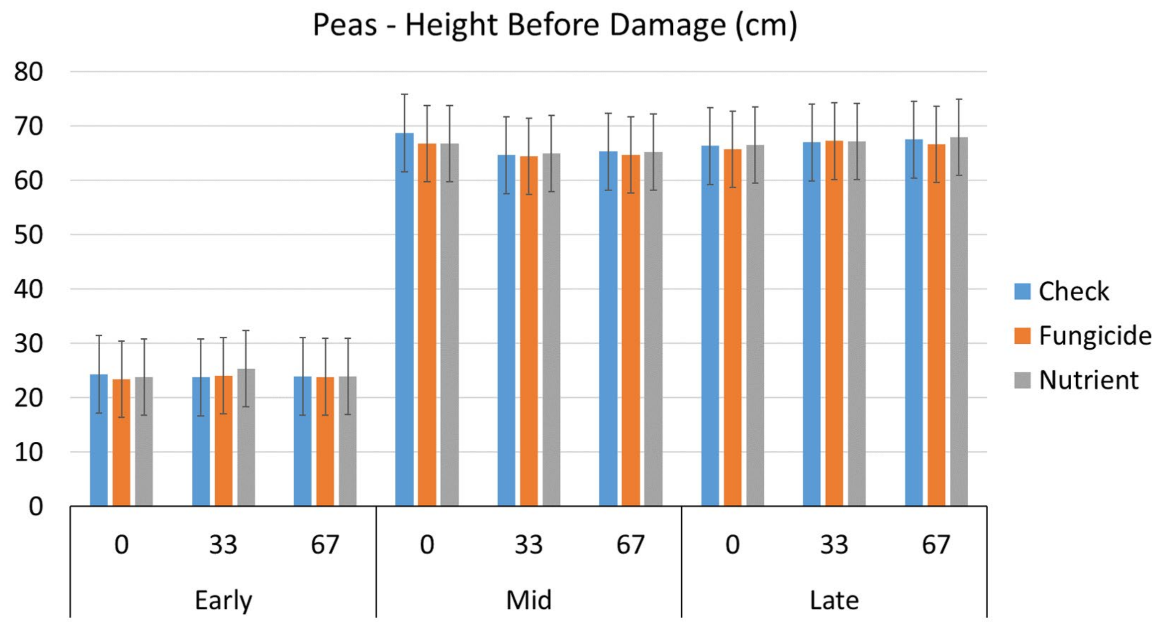


Figure 11. Plant height before hail damage of peas grown at Lethbridge, Vegrevile and Falher during 2016-2018. Plants were further exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

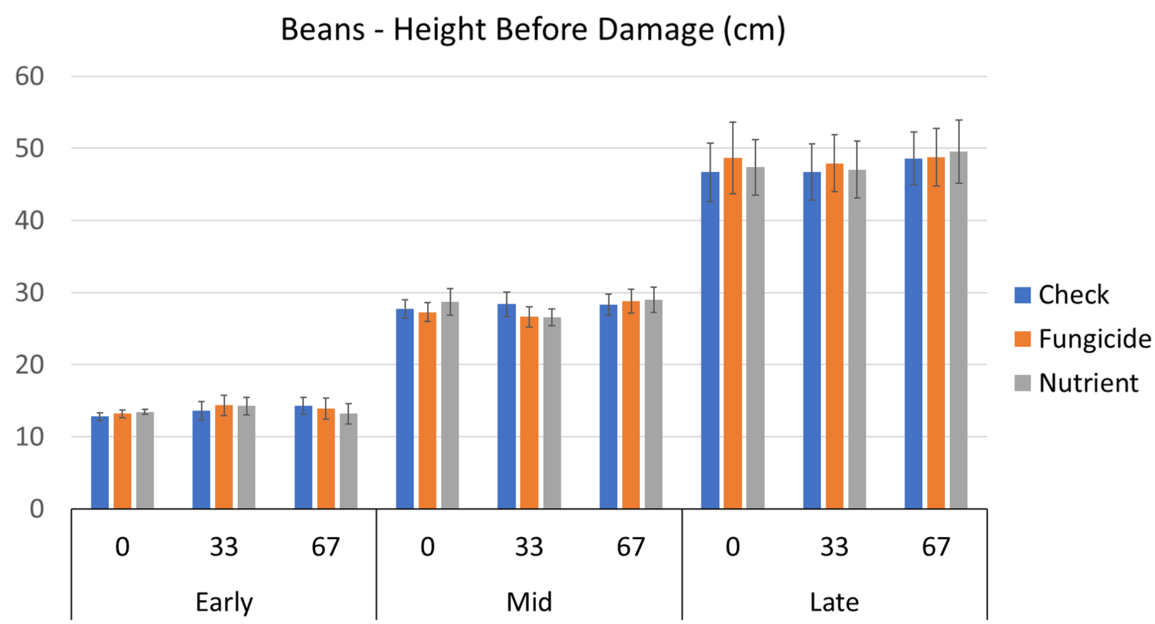


Figure 12. Plant height before hail damage of beans grown at Lethbridge during 2016-2018. Plants were further exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 6). Error bars represent standard error.

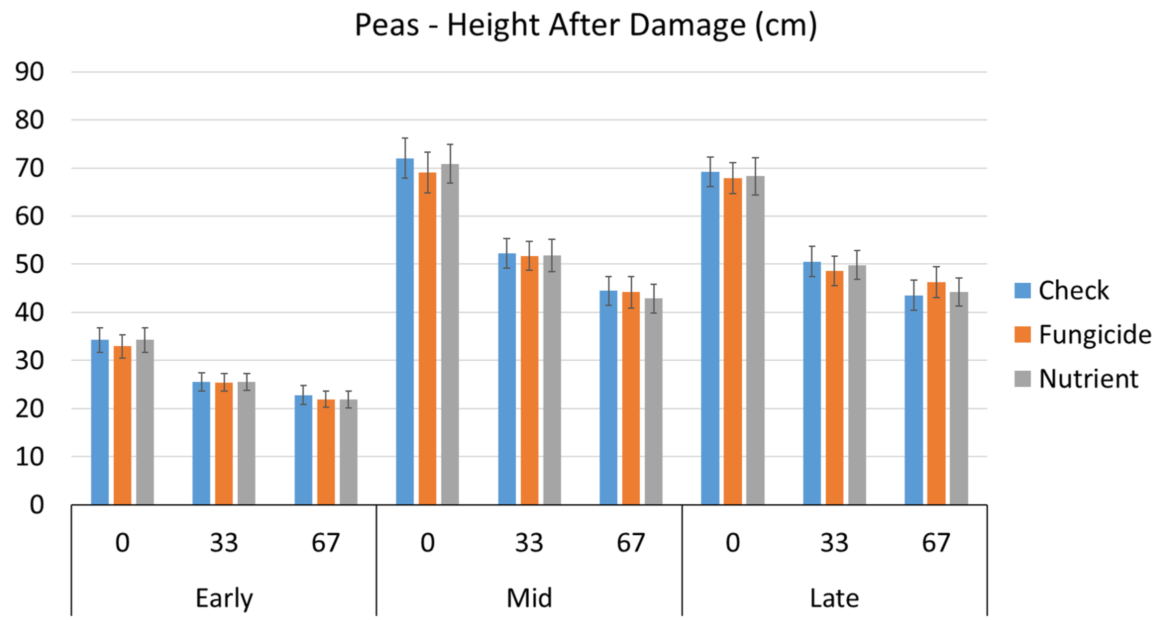


Figure 13. Plant height after hail damage of peas grown at Lethbridge, Vegrevile and Falher during 2016-2018. Plants were further exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

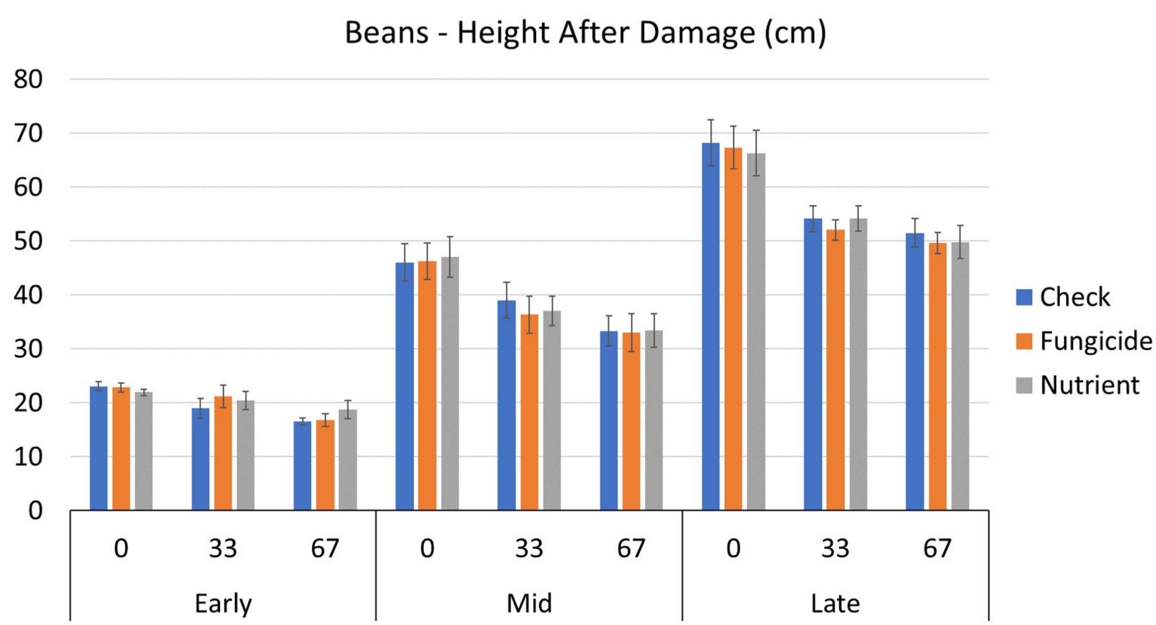


Figure 14. Plant height after hail damage of beans grown at Lethbridge during 2016-2018. Plants were further exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 6). Error bars represent standard error.

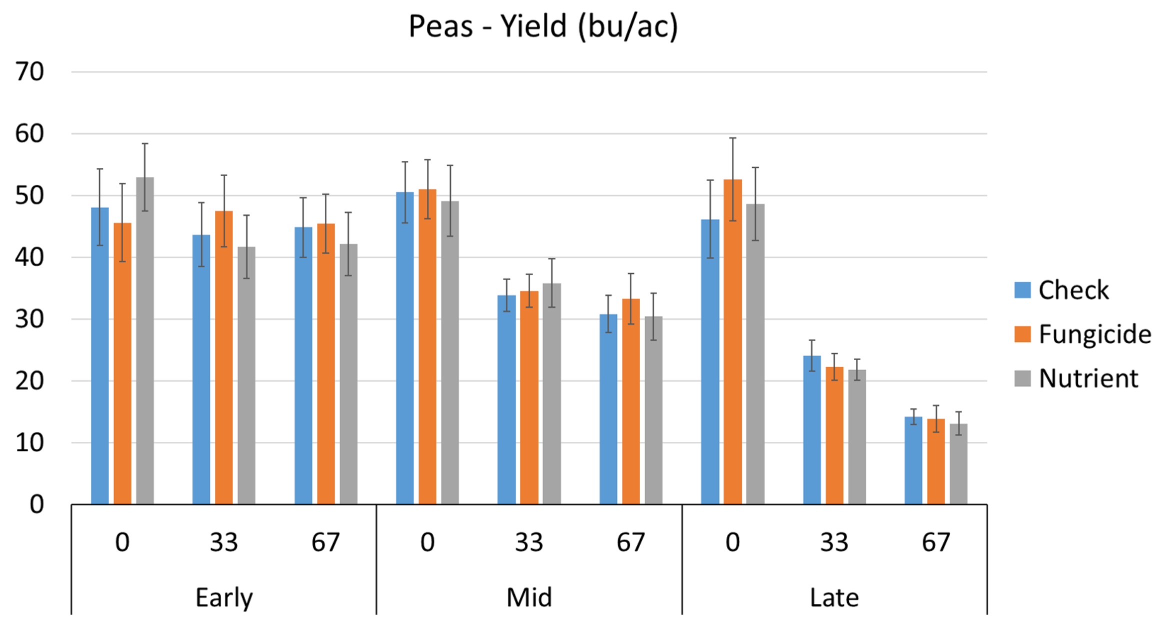


Figure 15. Yield of peas grown at Lethbridge, Vegrevile and Falher during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all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

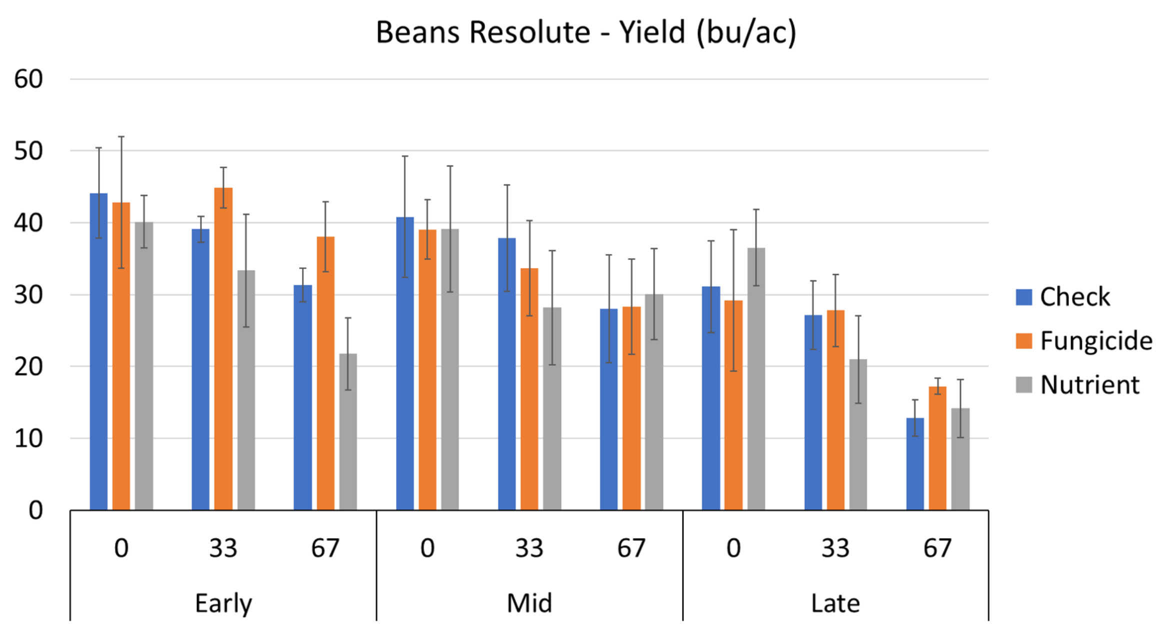


Figure 16. Yield of beans (Resolute) grown at Lethbridge during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 3). Error bars represent standard error.

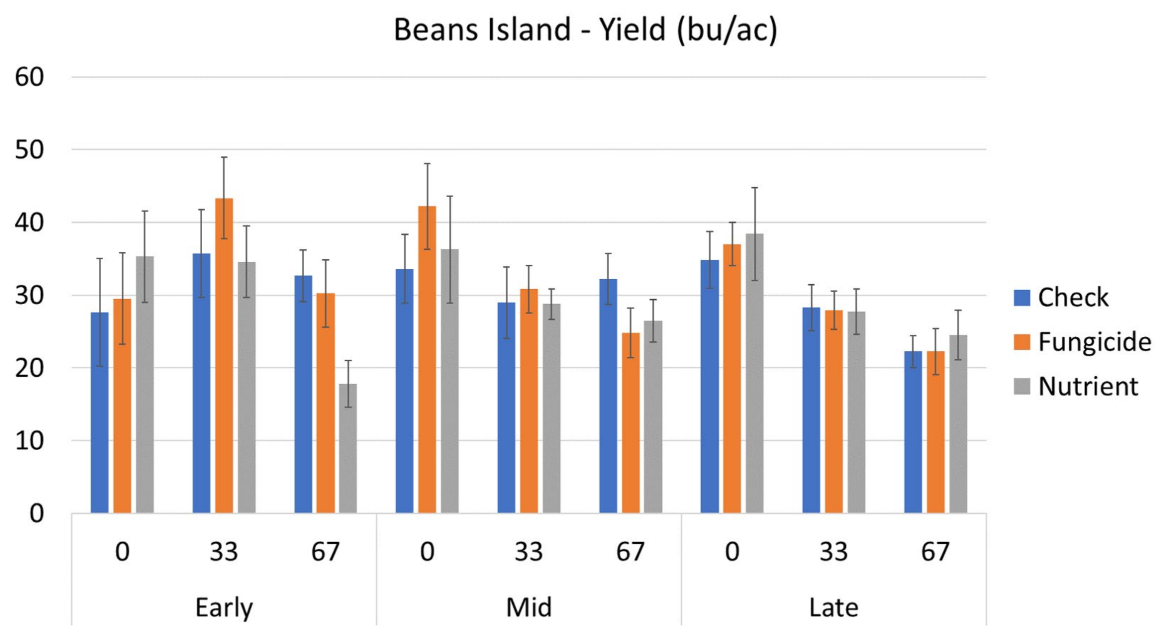


Figure 17. Yield of beans (Island) grown at Lethbridge during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 3). Error bars represent standard error.

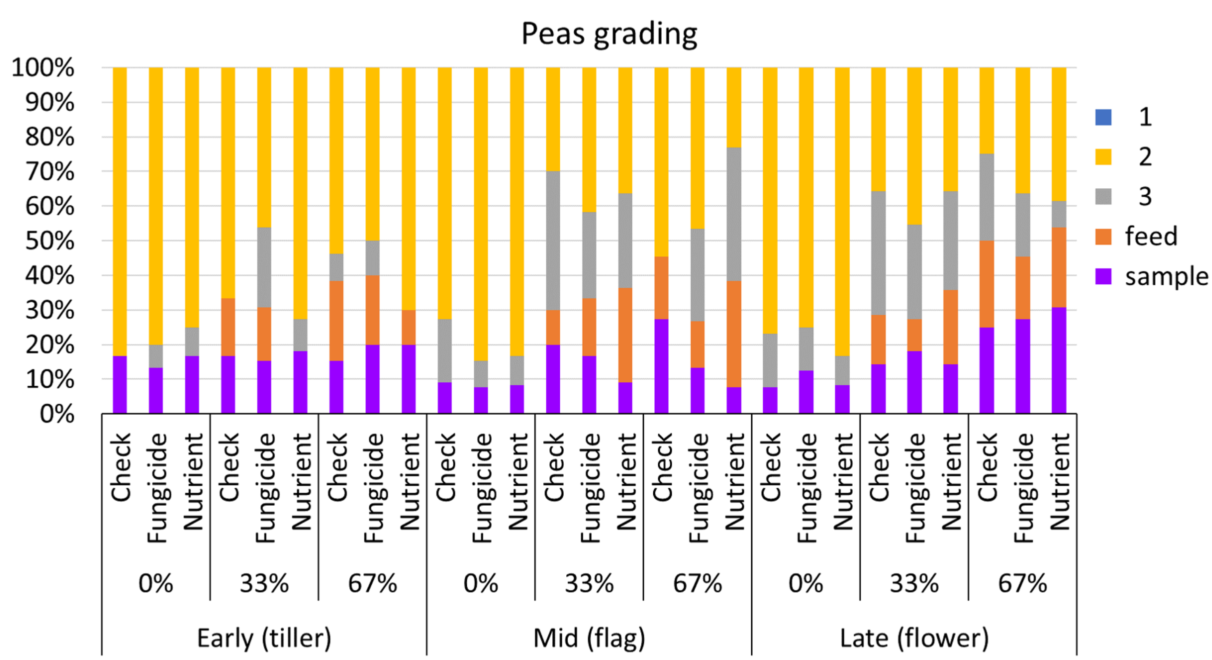


Figure 18. Peas grading at Lethbridge, Vegrevile and Falher during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient).

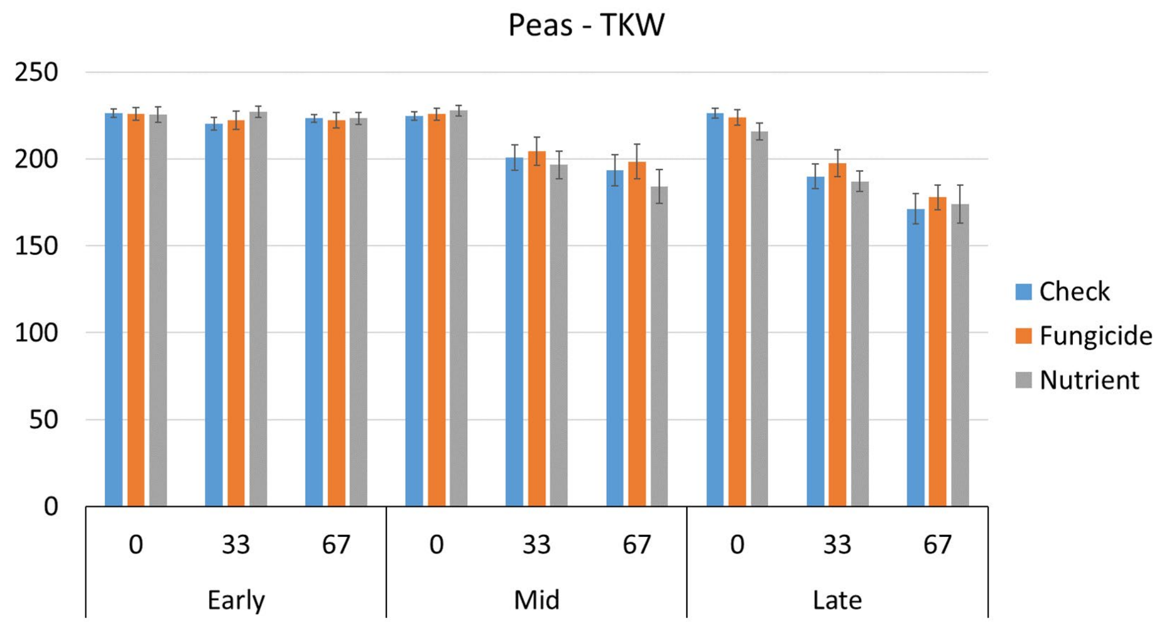


Figure 19. TKW of peas grown at Lethbridge, Vegrevile and Falher during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 9). Error bars represent standard error.

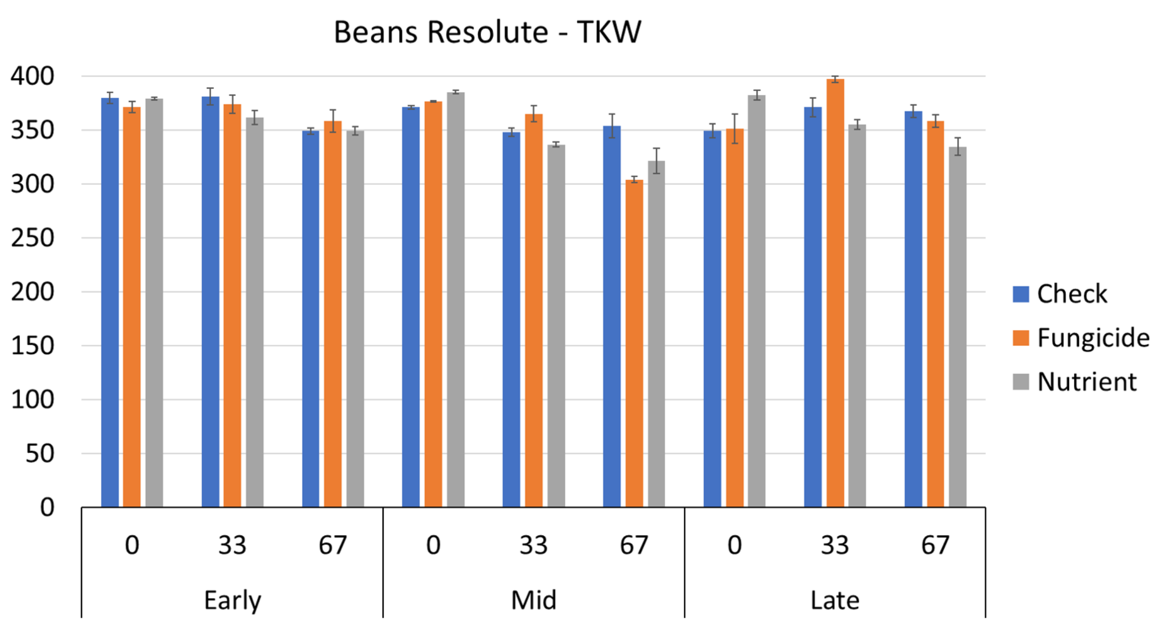


Figure 20. TKW of beans (Resolute) grown at Lethbridge during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 3). Error bars represent standard error.

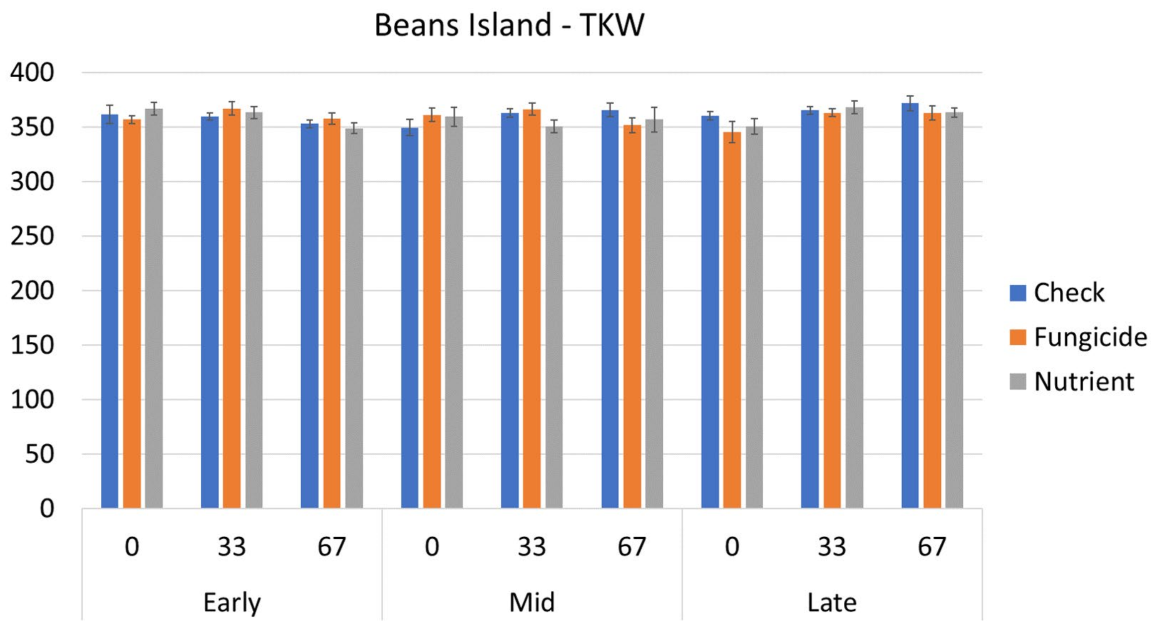


Figure 21. TKW of beans (Resolute Island) grown at Lethbridge during 2016-2018. Plants were exposed to hail damage at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide and Nutrient). Bars represent combined averages from all locations and years (N = 3). Error bars represent standard error.

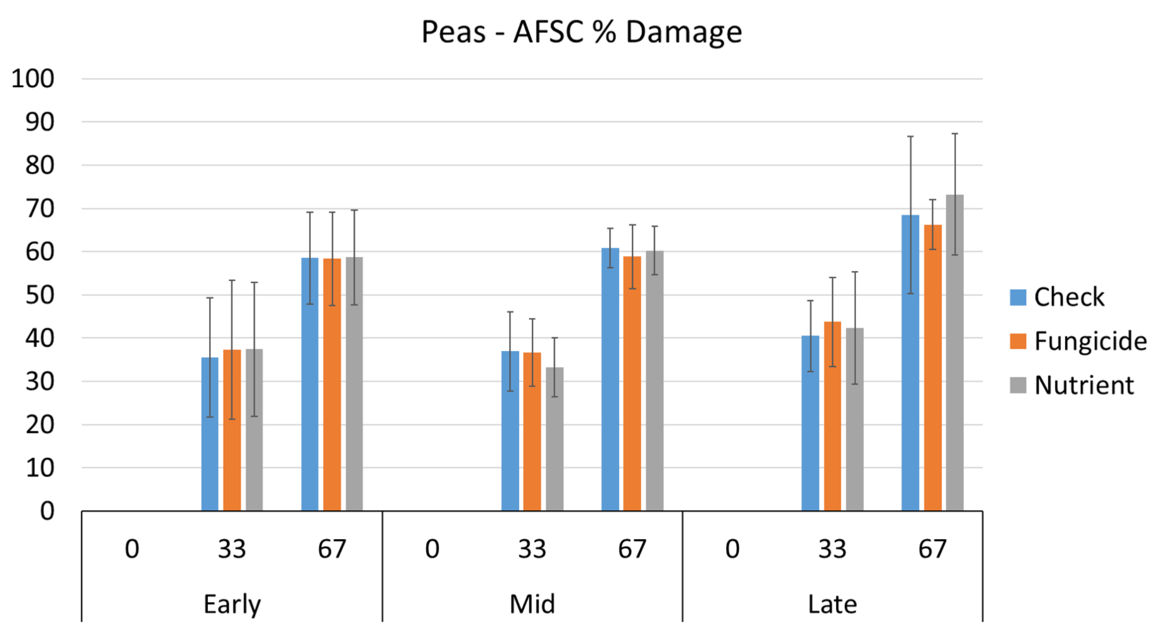


Figure 22. Percentage of damage (Defoliation) determined by AFSC 1 week after rating on peas grown at Lethbridge, Vegrevile and Falher during 2016-2018. Plants were exposed to hail at different timing (Early, Mid and Late), damage levels (0%, 33% and 67%) and using hail rescue treatments (Check, Fungicide 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. Seeding peas.

Figure 2. Spraying peas.

Figure 3. Farming Smarter Hail machine practices on peas.

Figure 4. Farming Smarter Hail machine practices on peas.

Figure 5. Farming Smarter Hail machine practices on peas.

Figure 6. Pea damage levels

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
- 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
- Agronomy 911: Can inputs save a hailed-out crop? Alberta Pulse Growers https://www.farmingsmarter.com/wp-content/files/2018/03/APG-Agronomy-911-Can-inputs-save-a-hailed-out-crop.pdf
- Managing your hail damage, March 28, 2017, Grainews - https://www.farmingsmarter.com/wp-content/files/2012/10/GN-Managing-Your-Hail-Damage.pdf
- 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)

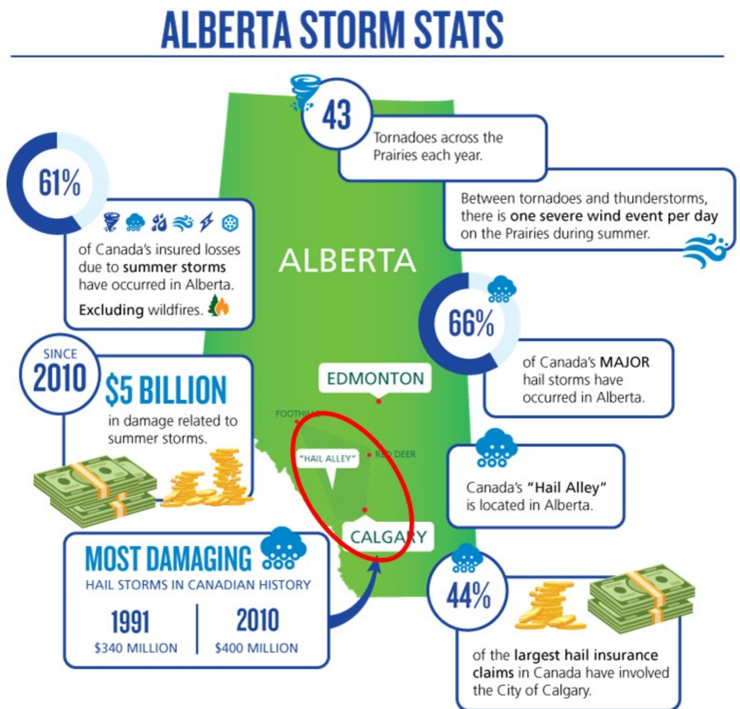
FARMING SMARTER

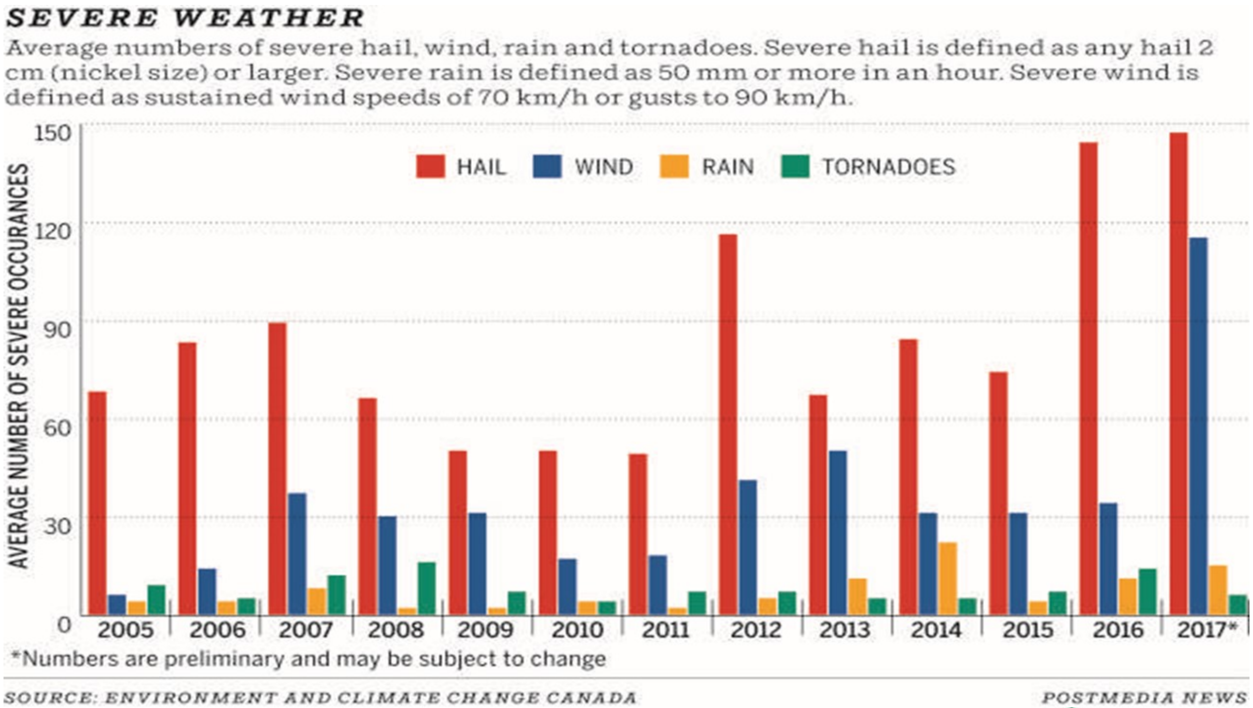
Growing new ideas.

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.

AFSC Annual Crops Hail Endorsement – subsidized premiums

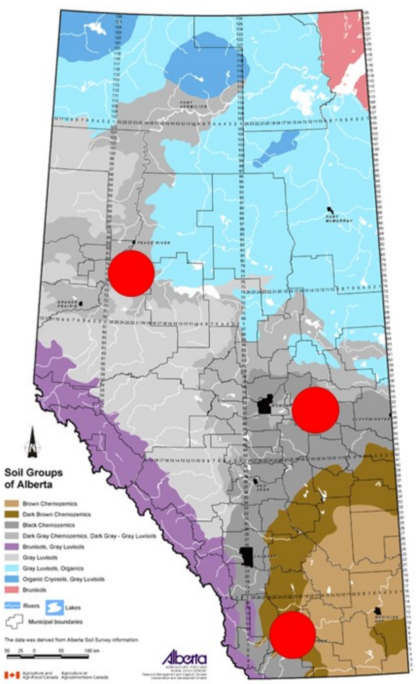
Year	Overall Cause of Loss = Hail	Contracts	Acres	Liability	Claims	Loss-premium ratio
2017	43%	10,251	13.1 million	$4 billion	$161 million	59.2%
2016	78%	10,679	13.5 million	$4.1 billion	$307 million	113%
2015	50%	10,481	13.3 million	$3.6 billion	$206 million	95.2%

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



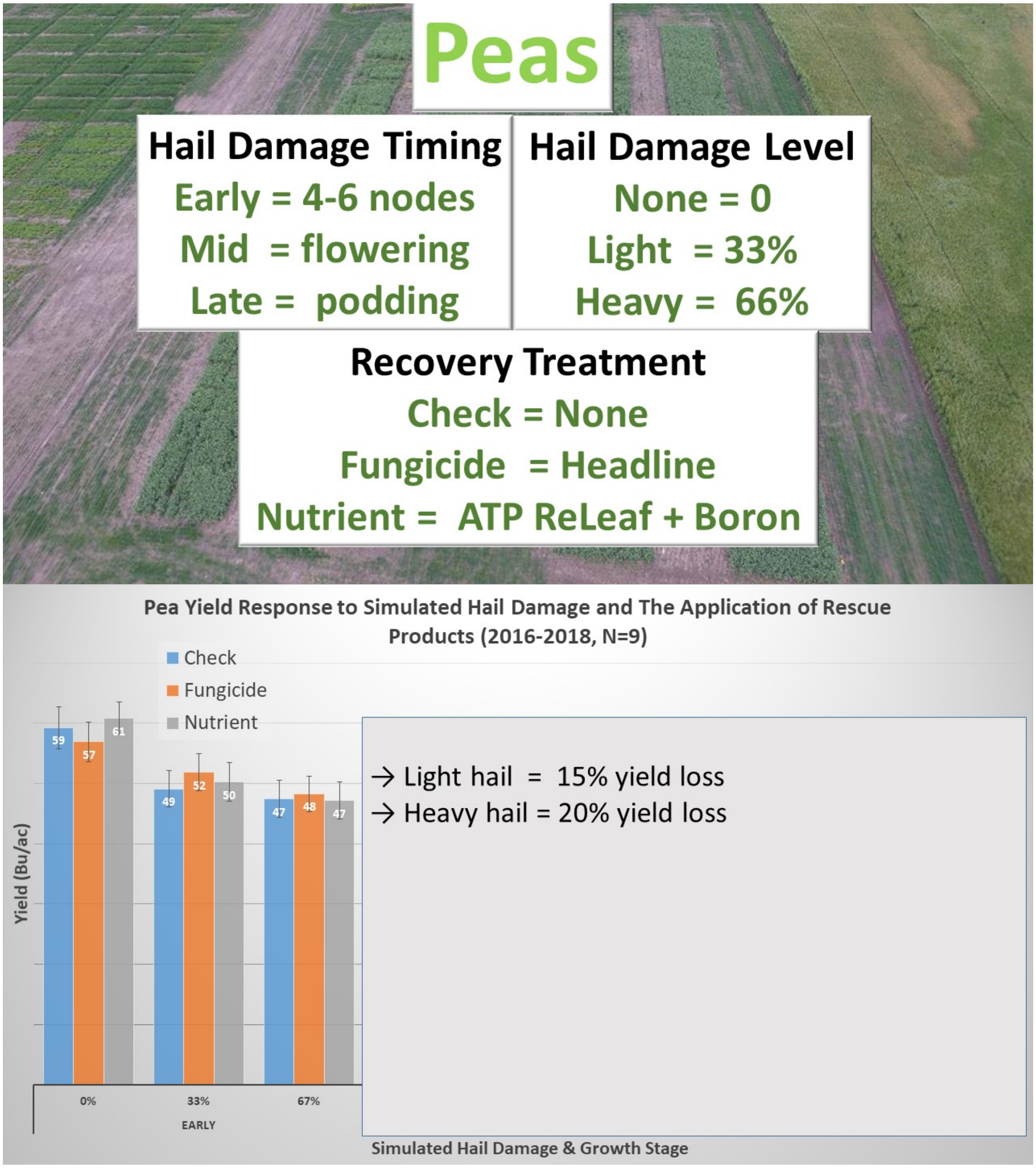
3 year study @ 3 locations

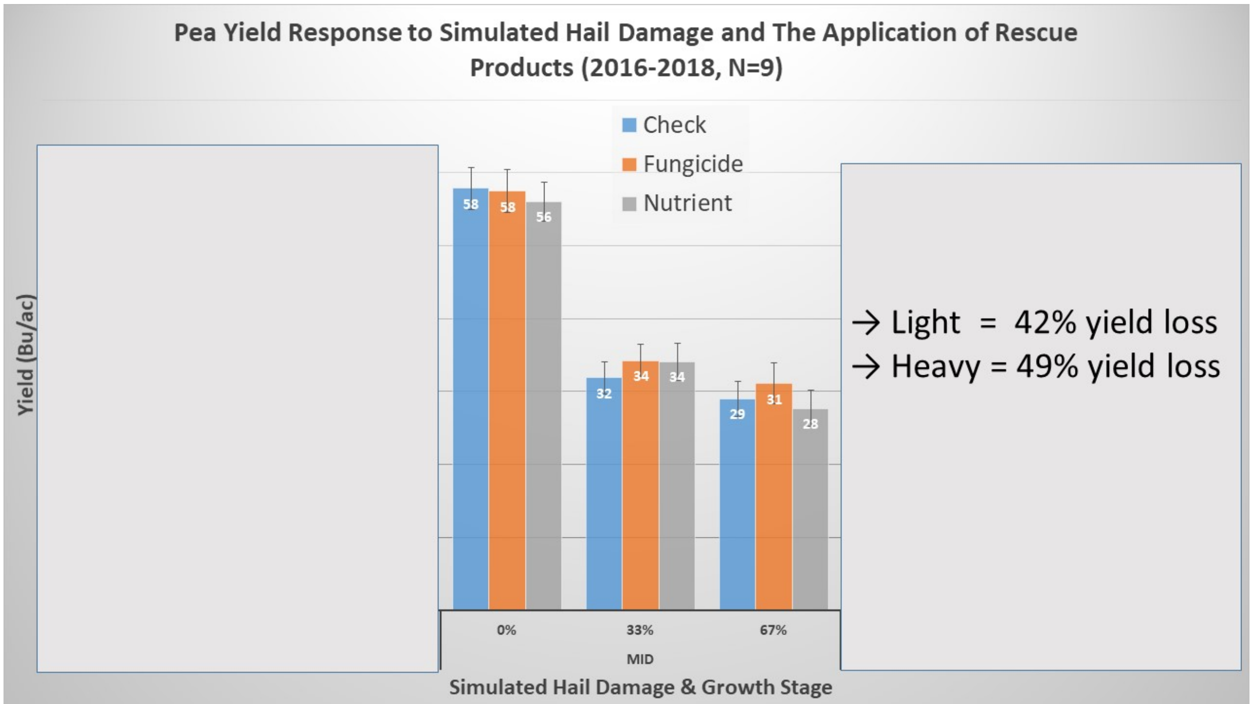
SARDA AG RESEARCH — Falher – Vance Yaremko, Darcy Boisevert

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

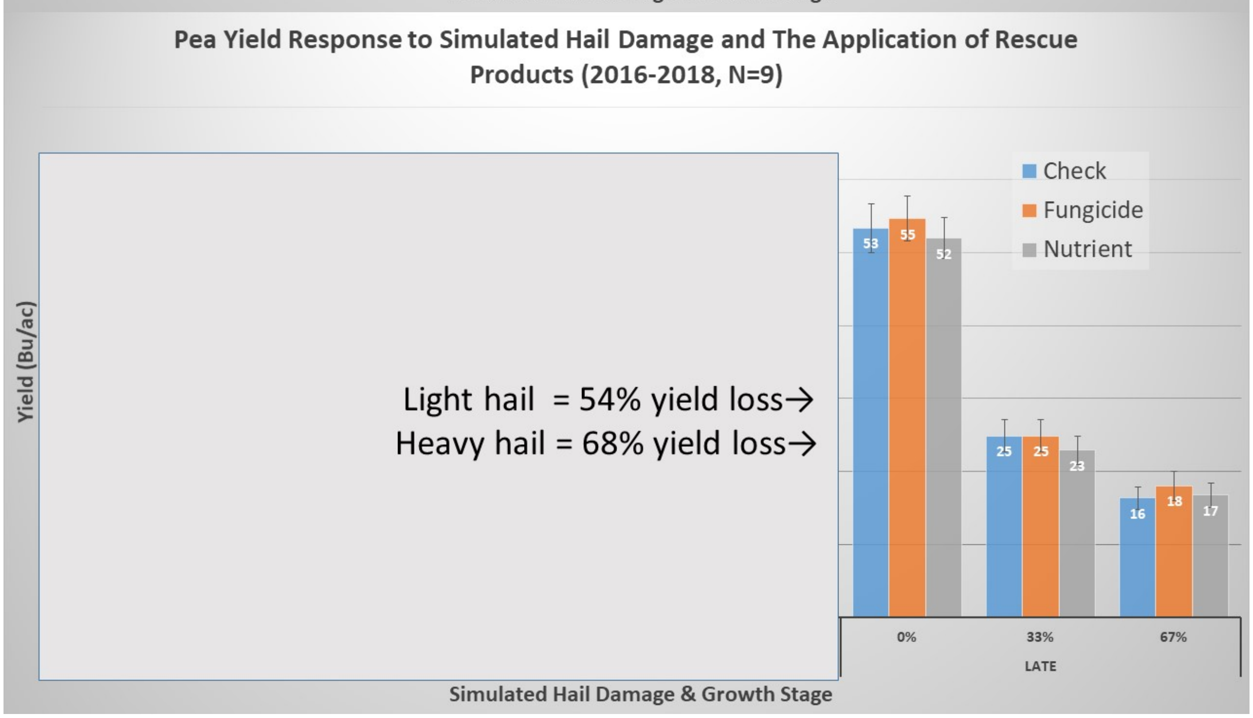
FARMING SMARTER, Growing new ideas. — Lethbridge – Ken Coles, Mike Gretzinger


ALBERTA PULSE
GROWERS

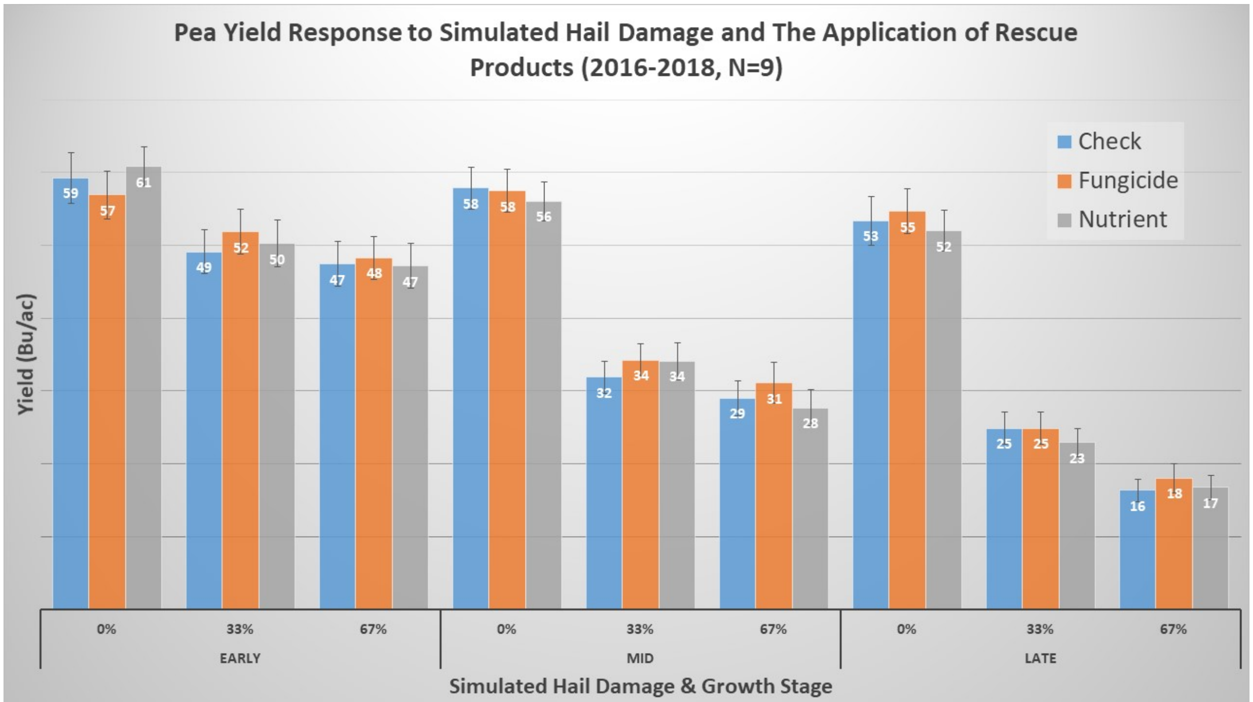

Peas
Hail Damage Timing
Early = 4-6 nodes
Mid = flowering
Late = podding
Hail Damage Level
None = 0
Light = 33%
Heavy = 66%
Recovery Treatment
Check = None
Fungicide = Headline
Nutrient = ATP ReLeaf + Boron
Pea Yield Response to Simulated Hail Damage and The Application of Rescue Products (2016-2018, 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

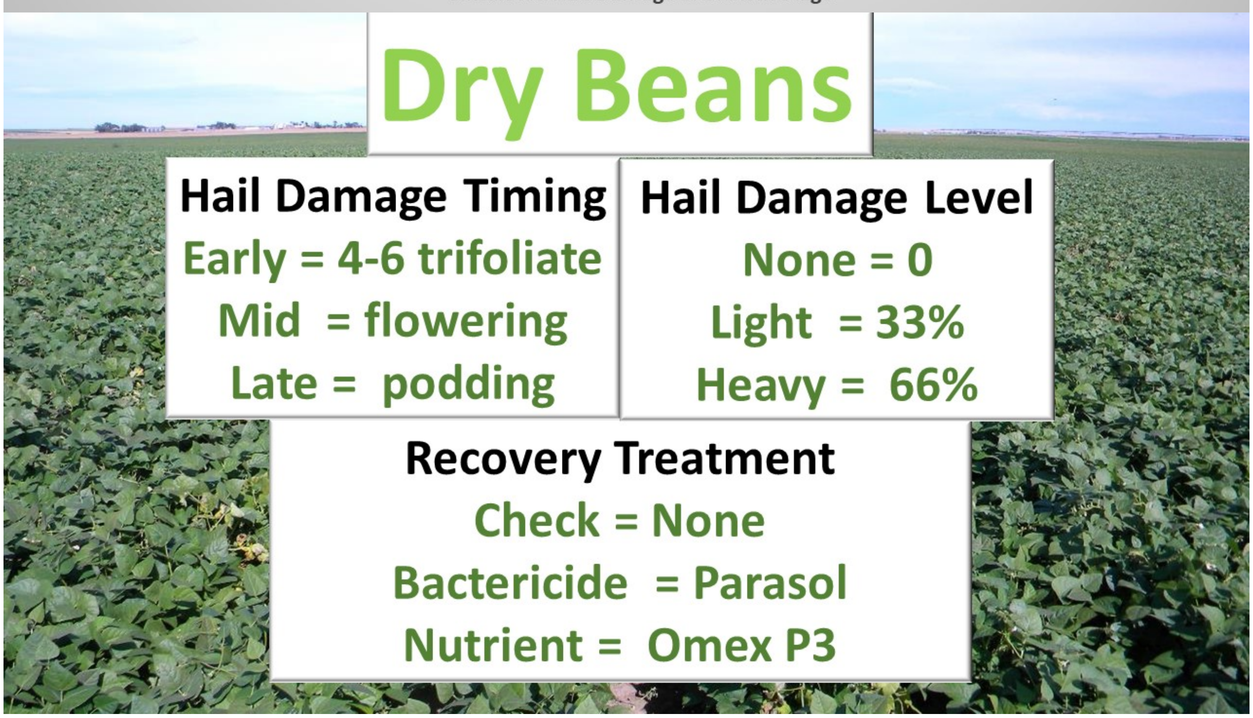


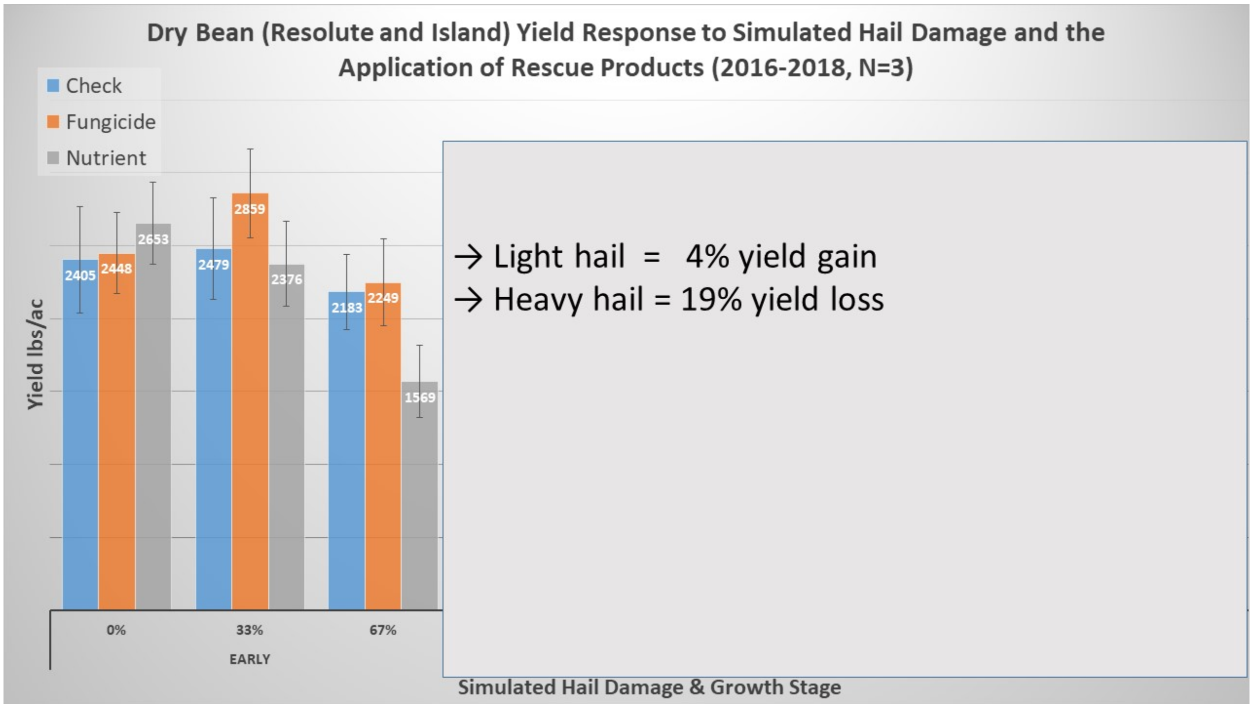
Pea Yield Response to Simulated Hail Damage and The Application of Rescue Products (2016-2018, N=9)
Check
Fungicide
Nutrient
Yield (Bu/ac)
58
58
56
32
34
34
29
31
28
0%
33%
67%
MID
Simulated Hail Damage & Growth Stage
→ Light = 42% yield loss
→ Heavy = 49% yield loss

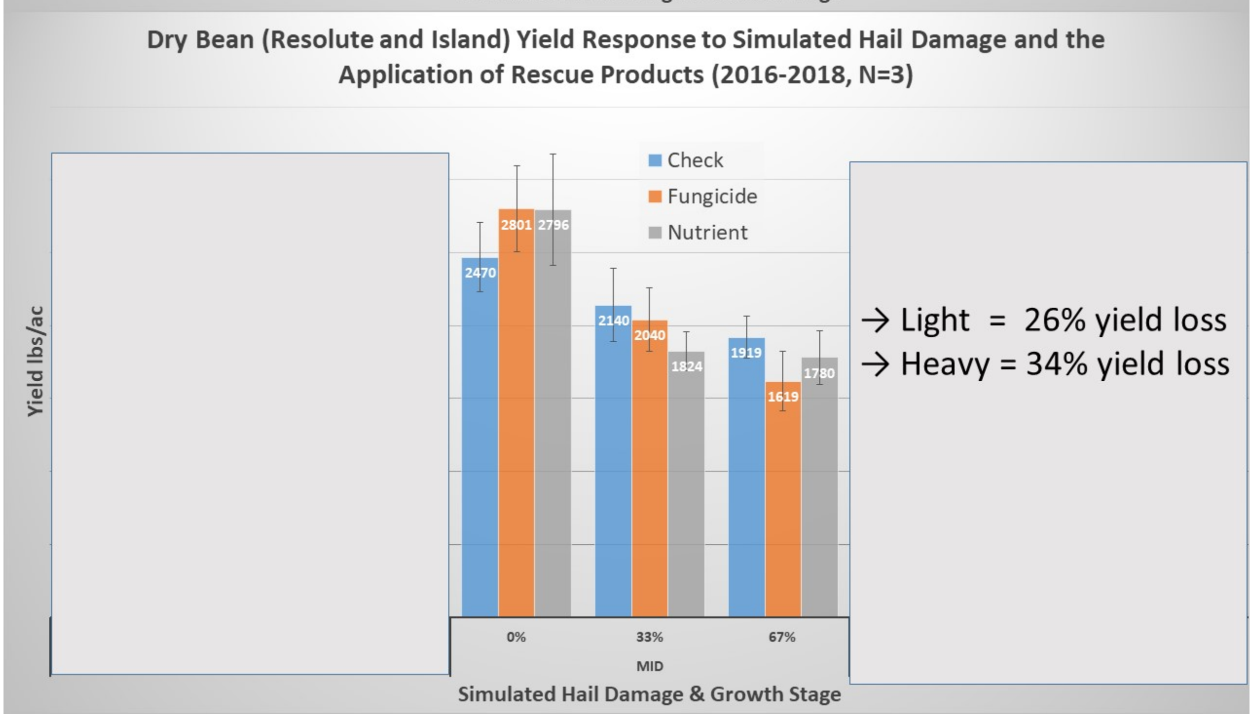


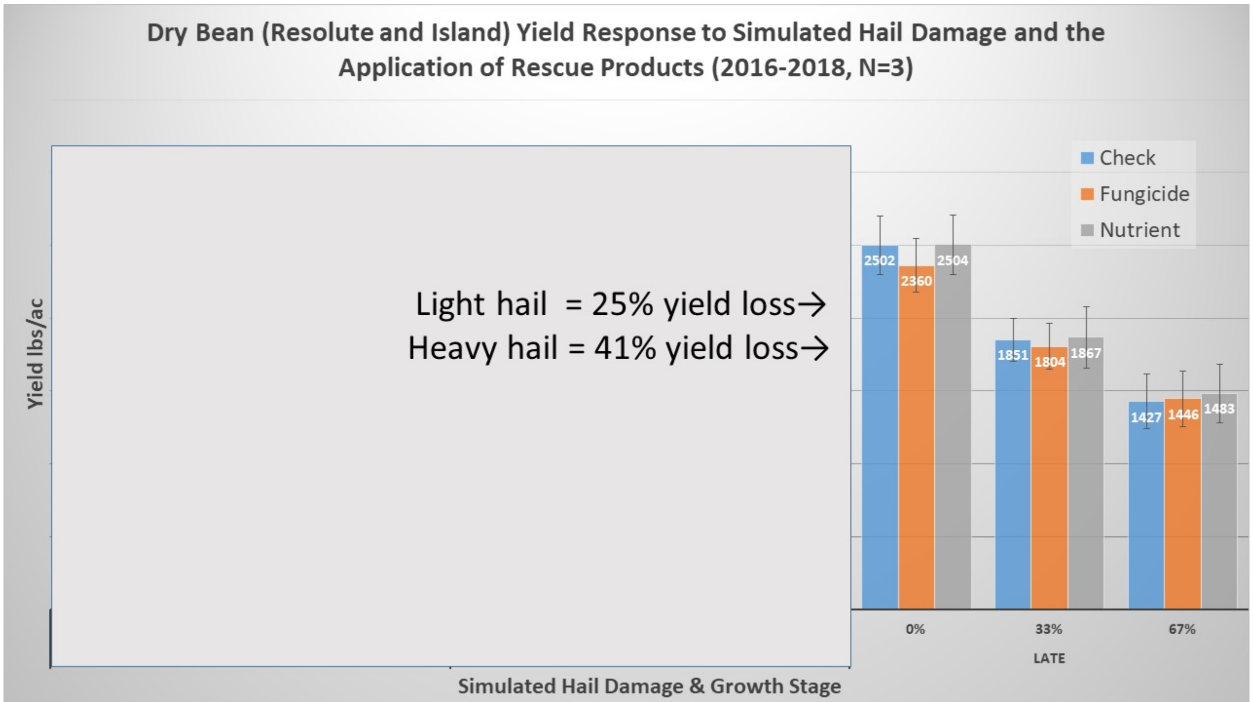
Pea Yield Response to Simulated Hail Damage and The Application of Rescue Products (2016-2018, N=9)
Check
Fungicide
Nutrient
Yield (Bu/ac)
Light hail = 54% yield loss→
Heavy hail = 68% yield loss→
53
55
52
25
25
23
16
18
17
0%
33%
67%
LATE
Simulated Hail Damage & Growth Stage


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

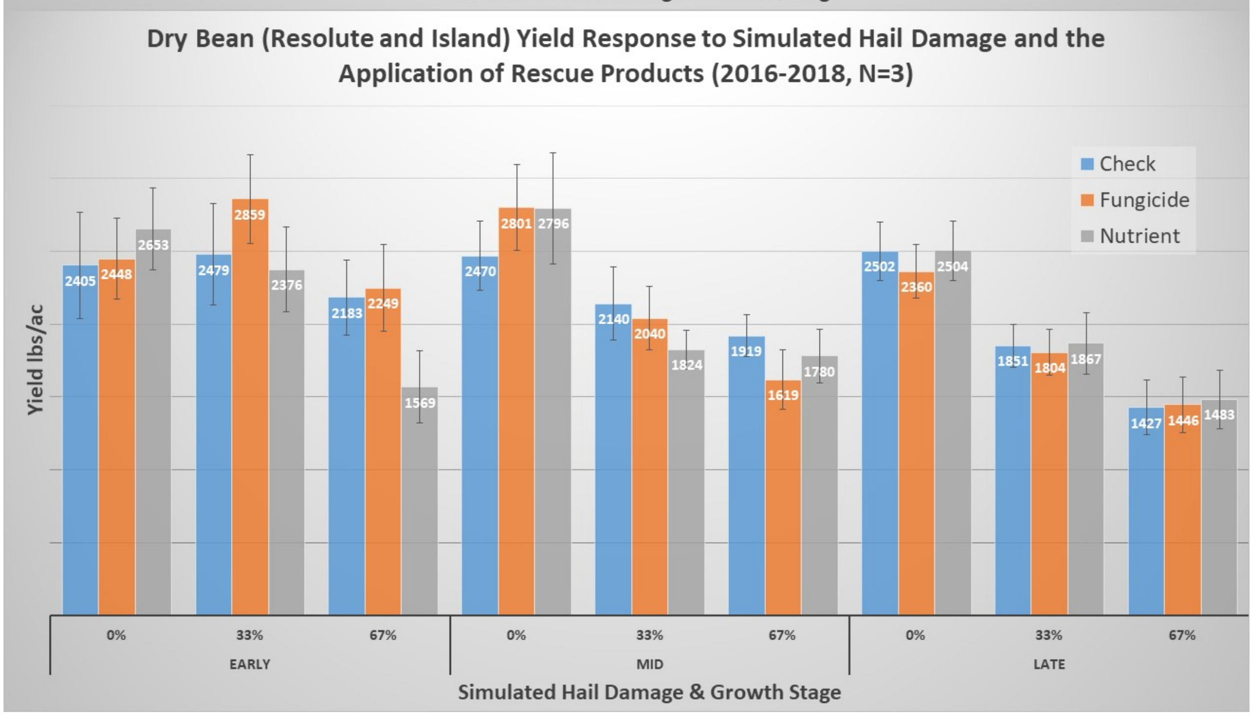

Dry Beans
Hail Damage Timing
Early = 4-6 trifoliate
Mid = flowering
Late = podding
Hail Damage Level
None = 0
Light = 33%
Heavy = 66%
Recovery Treatment
Check = None
Bactericide = Parasol
Nutrient = Omex P3


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

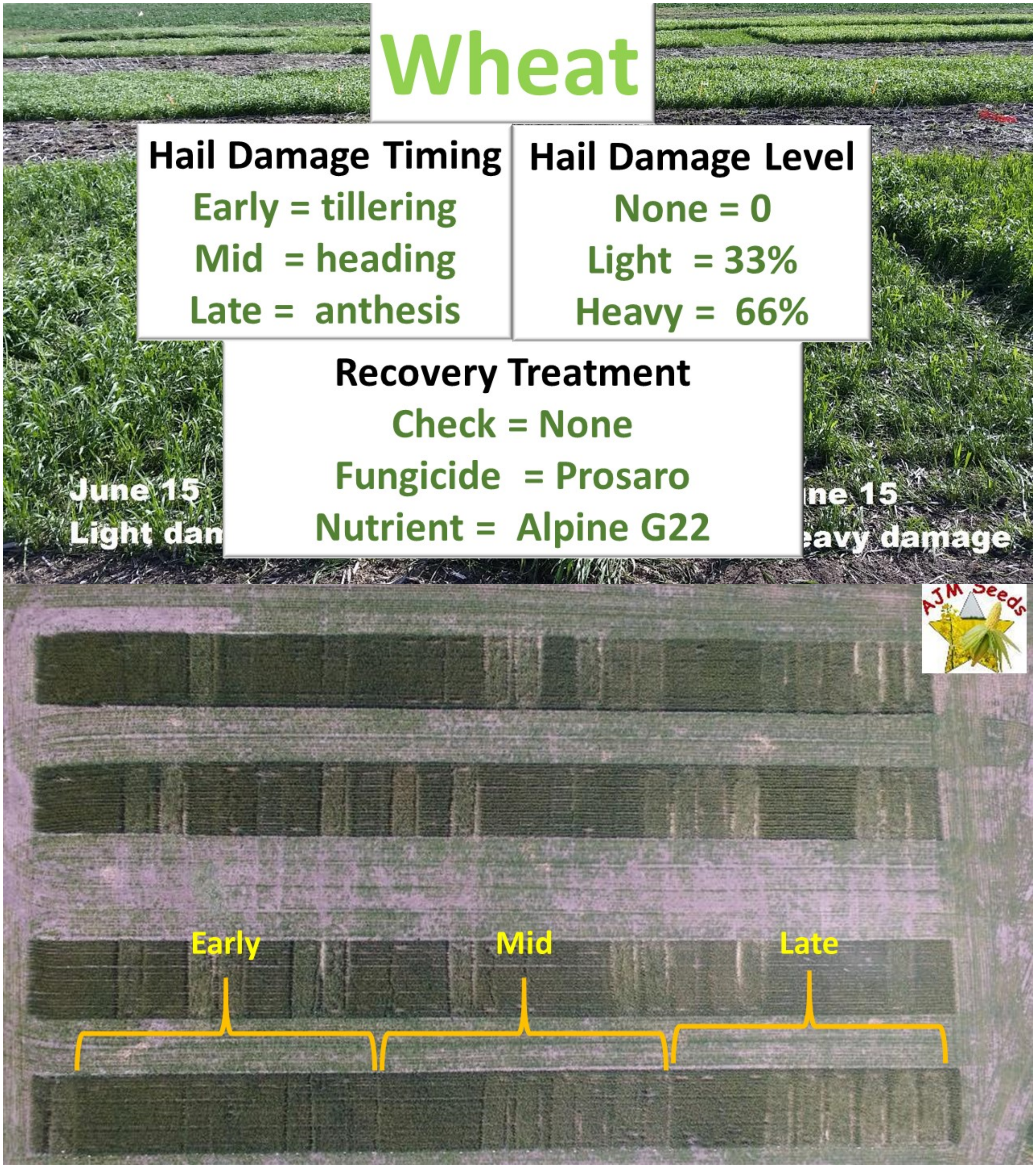

Dry Bean (Resolute and Island) Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=3)
Check
Fungicide
Nutrient
Yield lbs/ac
2470
2801
2796
2140
2040
1824
1919
1619
1780
0%
33%
67%
MID
→ Light = 26% yield loss
→ Heavy = 34% yield loss
Simulated Hail Damage & Growth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

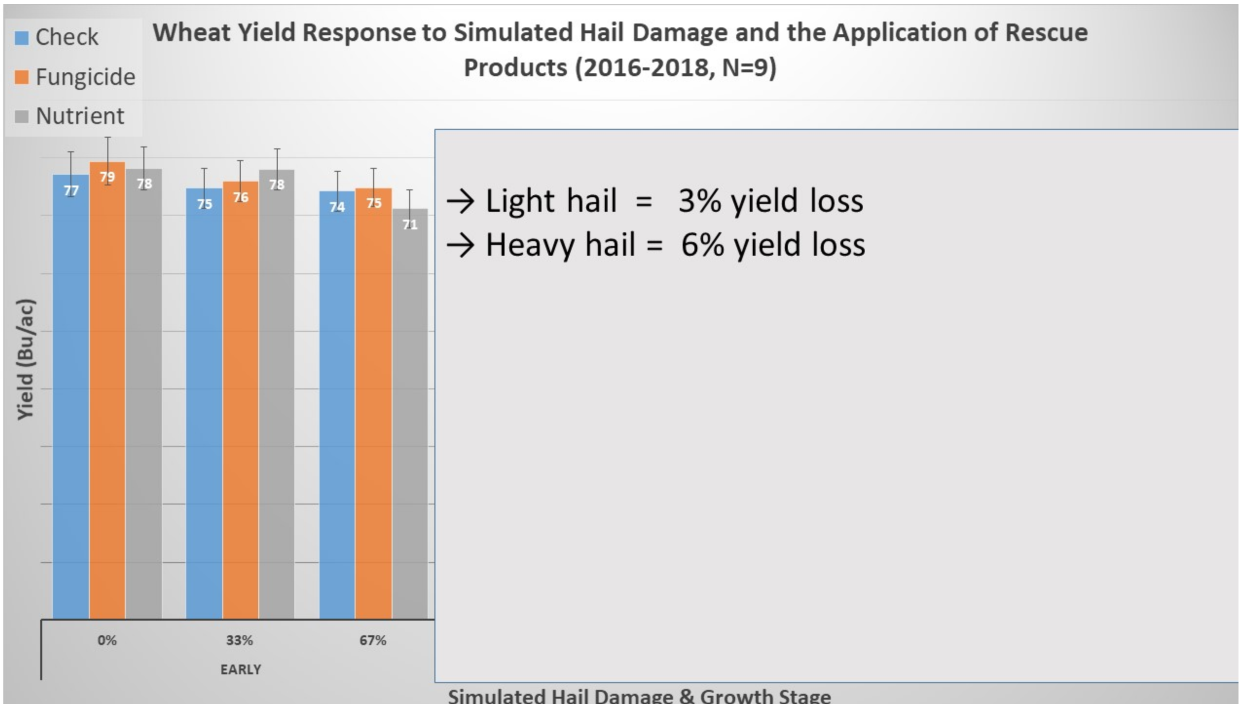


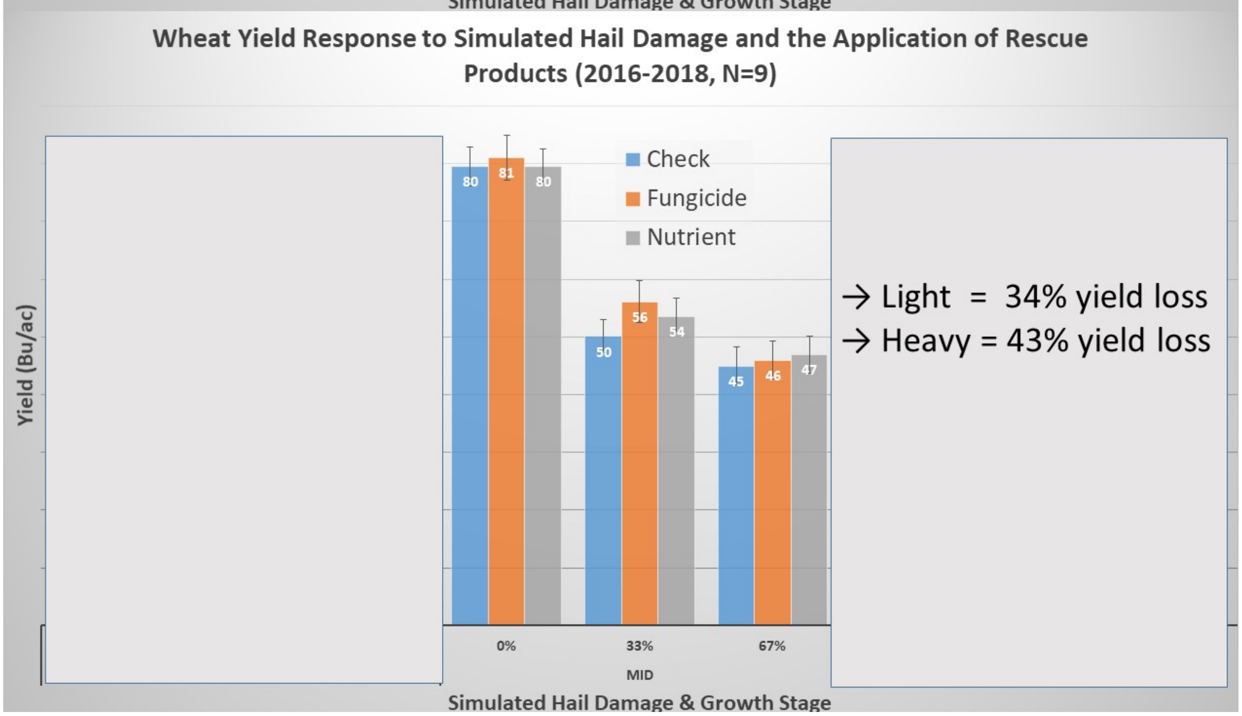
Dry Bean (Resolute and Island) Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=3)
Check
Fungicide
Nutrient
Light hail = 25% yield loss→
Heavy hail = 41% yield loss→
Yield lbs/ac
2502
2360
2504
1851
1804
1867
1427
1446
1483
0%
33%
67%
LATE
Simulated Hail Damage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

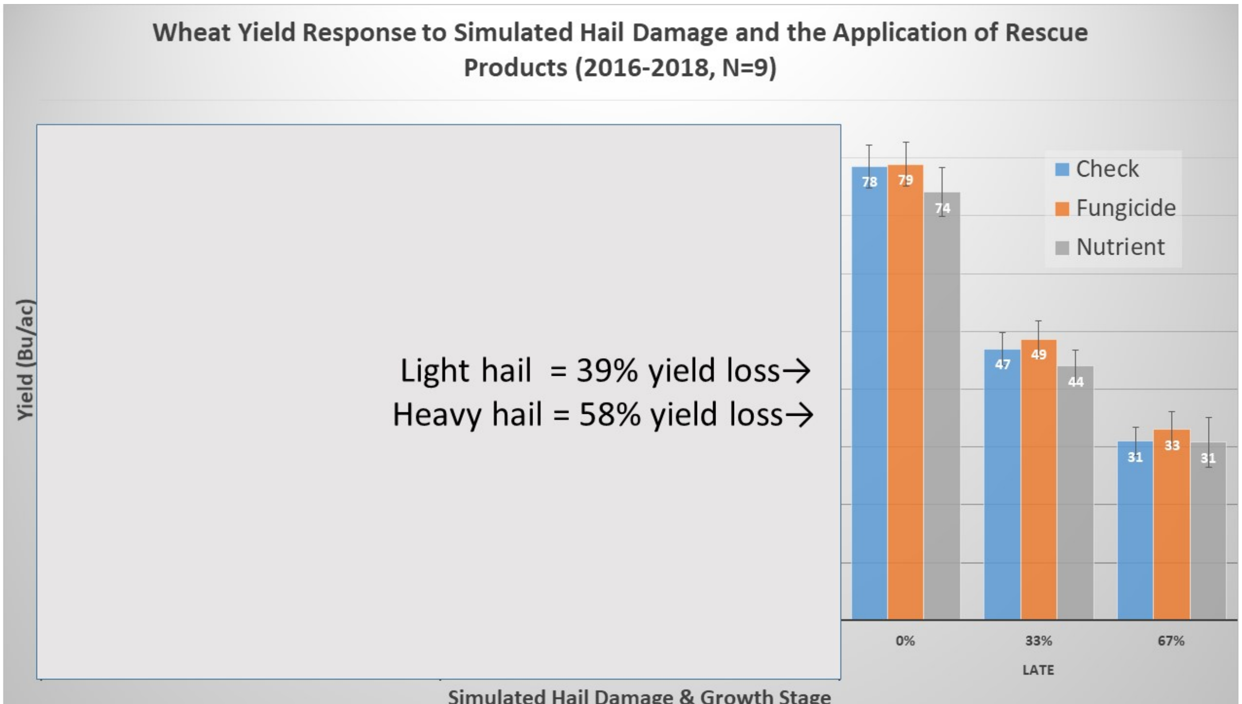


Dry Bean (Resolute and Island) Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=3)
Check
Fungicide
Nutrient
Yield lbs/ac
2405
2448
2653
2479
2859
2376
2183
2249
1569
2470
2801
2796
2140
2040
1824
1919
1619
1780
2502
2360
2504
1851
1804
1867
1427
1446
1483
0%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

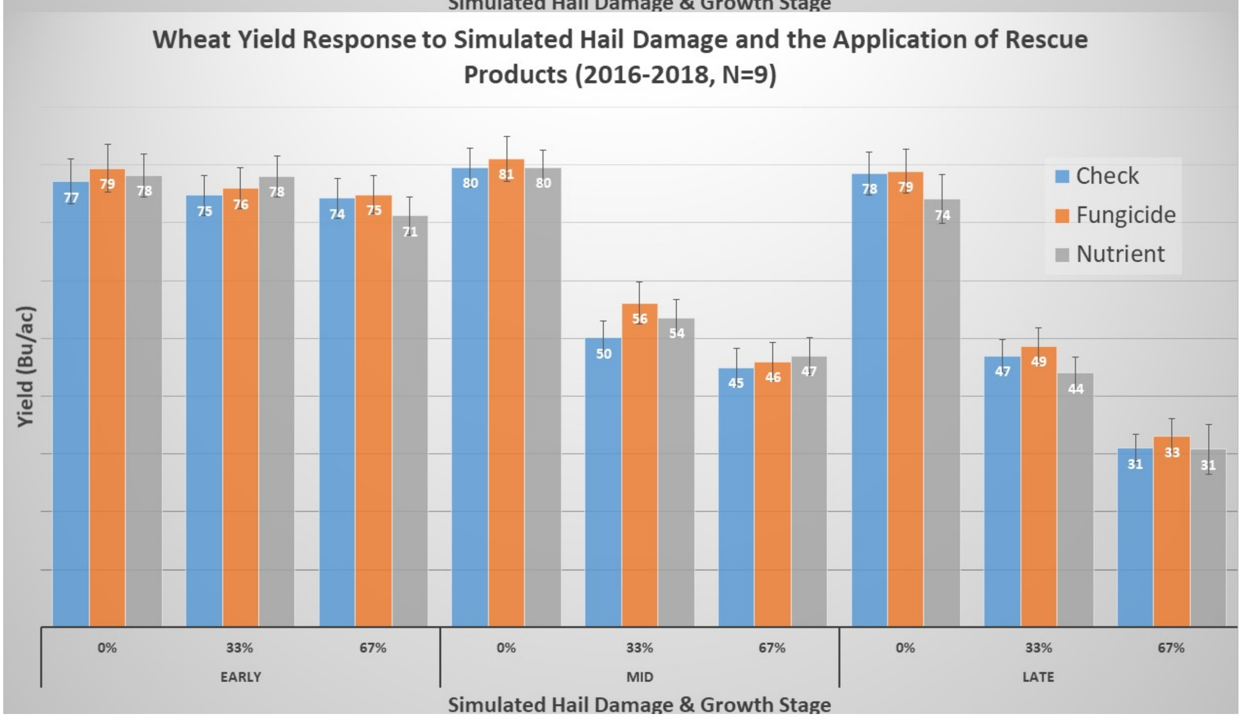

Wheat
Hail Damage Timing
Early = tillering
Mid = heading
Late = anthesis
Hail Damage Level
None = 0
Light = 33%
Heavy = 66%
Recovery Treatment
Check = None
Fungicide = Prosaro
Nutrient = Alpine G22
June 15
AJM Seeds
Early
Mid
Late


Check
Fungicide
Nutrient
Wheat Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=9)
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

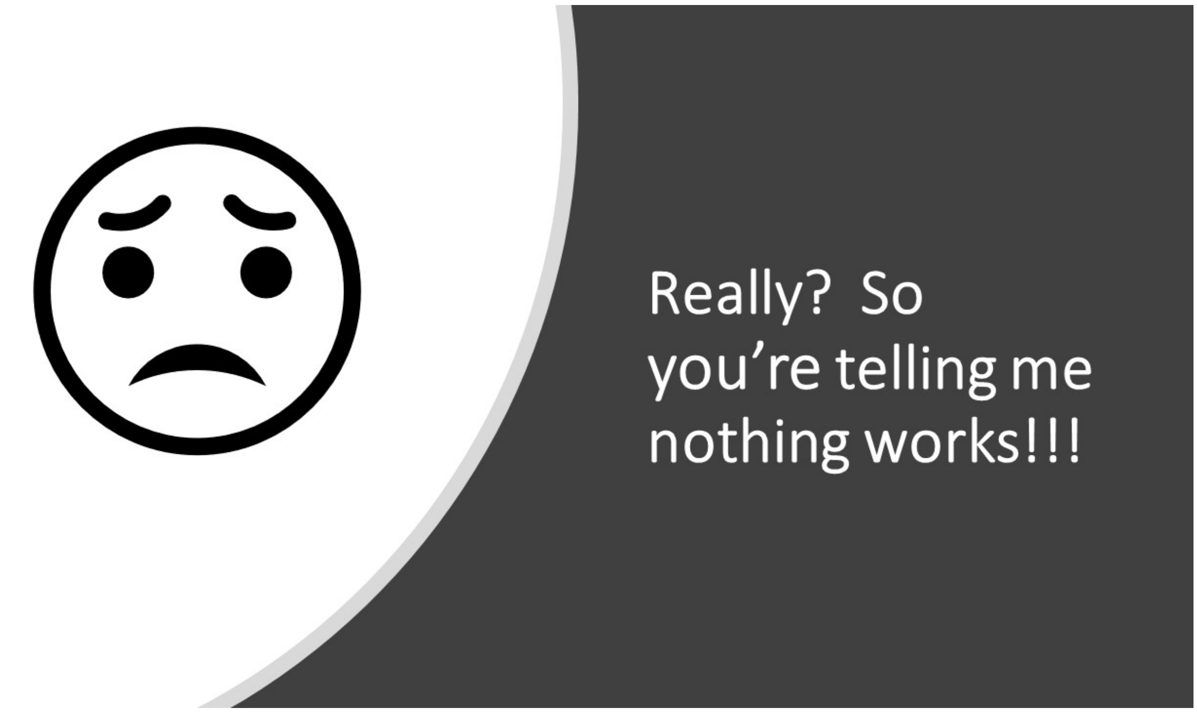

Wheat Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=9)
Yield (Bu/ac)
80
81
80
50
56
54
45
46
47
Check
Fungicide
Nutrient
→ Light = 34% yield loss
→ Heavy = 43% yield loss
0%
33%
67%
MID
Simulated Hail Damage & Growth Stage



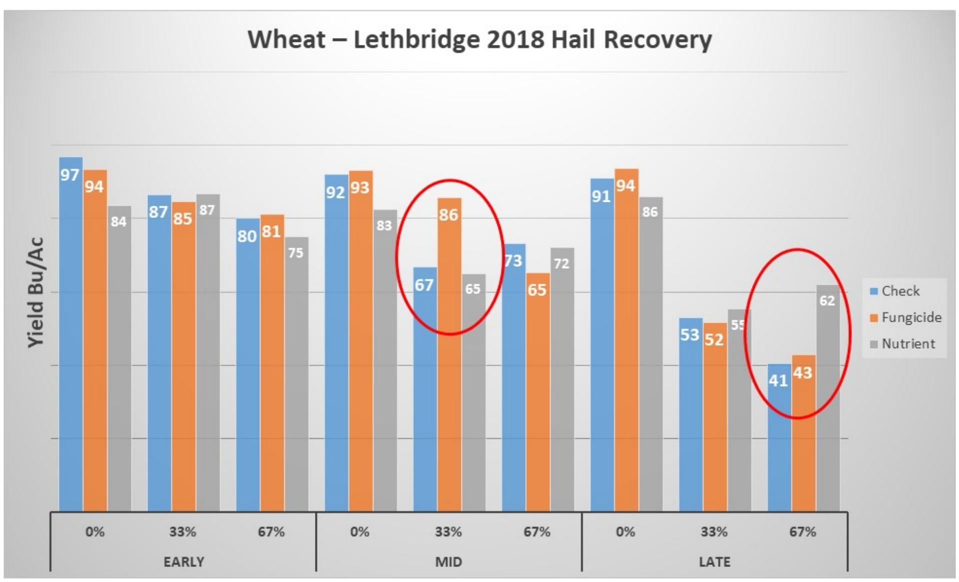
Wheat Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=9)
Yield (Bu/ac)
Light hail = 39% yield loss→
Heavy hail = 58% yield loss→
78
79
74
47
49
44
31
33
31
Check
Fungicide
Nutrient
0%
33%
67%
LATE
Simulated Hail Damage & Growth Stage



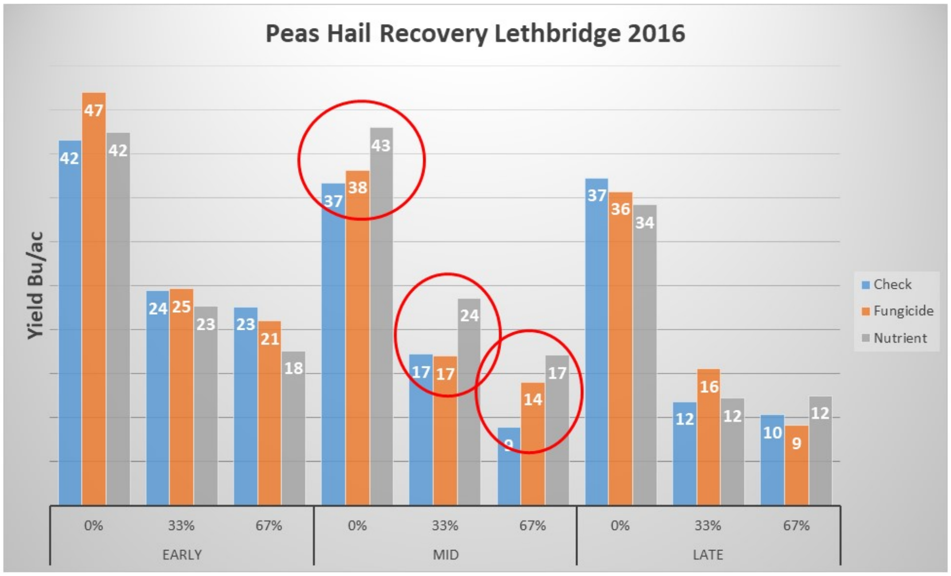
Wheat Yield Response to Simulated Hail Damage and the Application of Rescue Products (2016-2018, N=9)
Yield (Bu/ac)
77
79
78
75
76
78
74
75
71
80
81
80
50
56
54
45
46
47
78
79
74
47
49
44
31
33
31
Check
Fungicide
Nutrient
0%
33%
67%
EARLY
0%
33%
67%
MID
0%
33%
67%
LATE
Simulated Hail Damage & Growth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

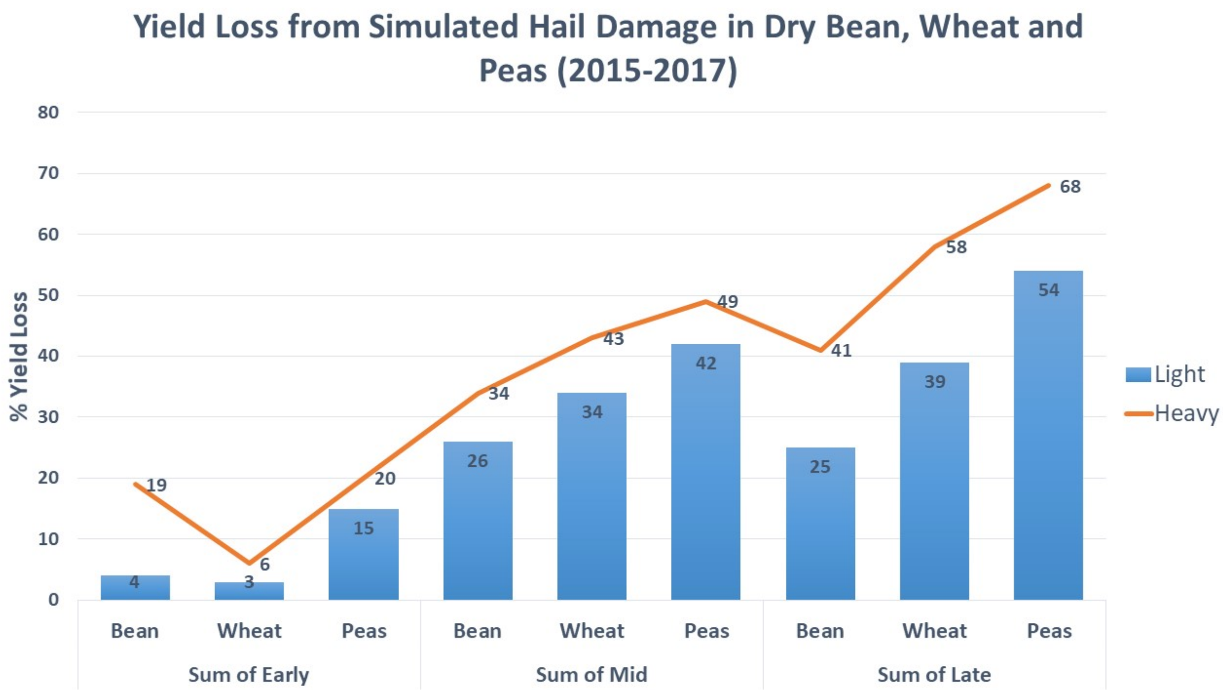


Well….. we did see a response 1 in 9 years in wheat



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


FARMING
SMARTER
Growing new ideas.
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

December 6, 2017
Lethbridge Weather
Forecast

Today: Chance of sunshine; or cloudy; unseasonably hot; or freezing; chance of rain and wind; snow possible; or hail; or stuff from the sky for which there isn't even a name yet.

Hail Sucks!

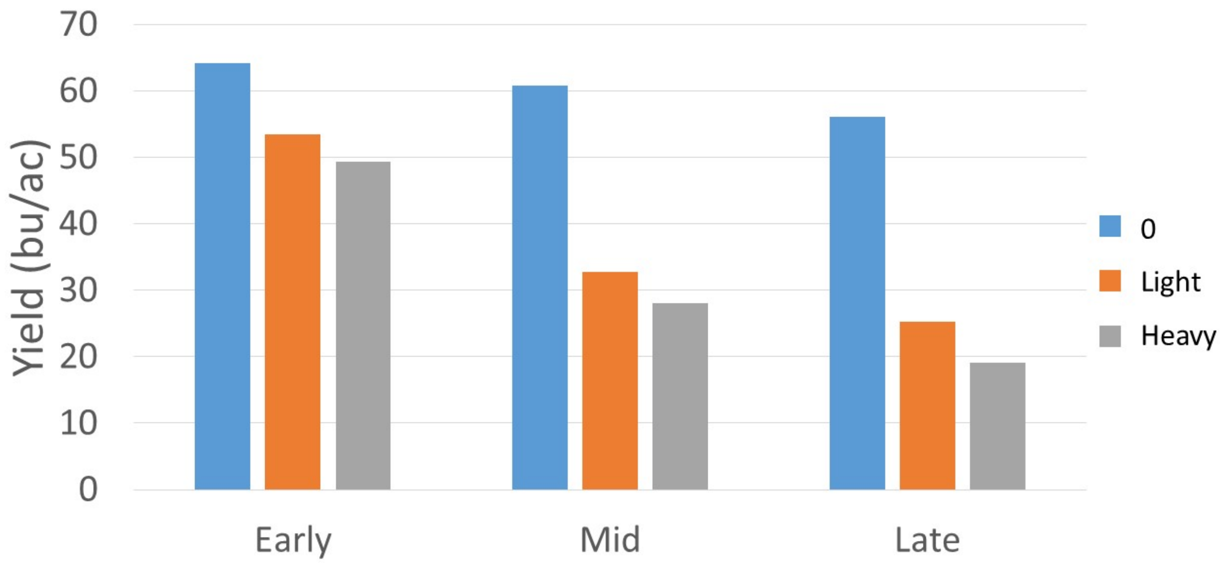
Things to Learn:

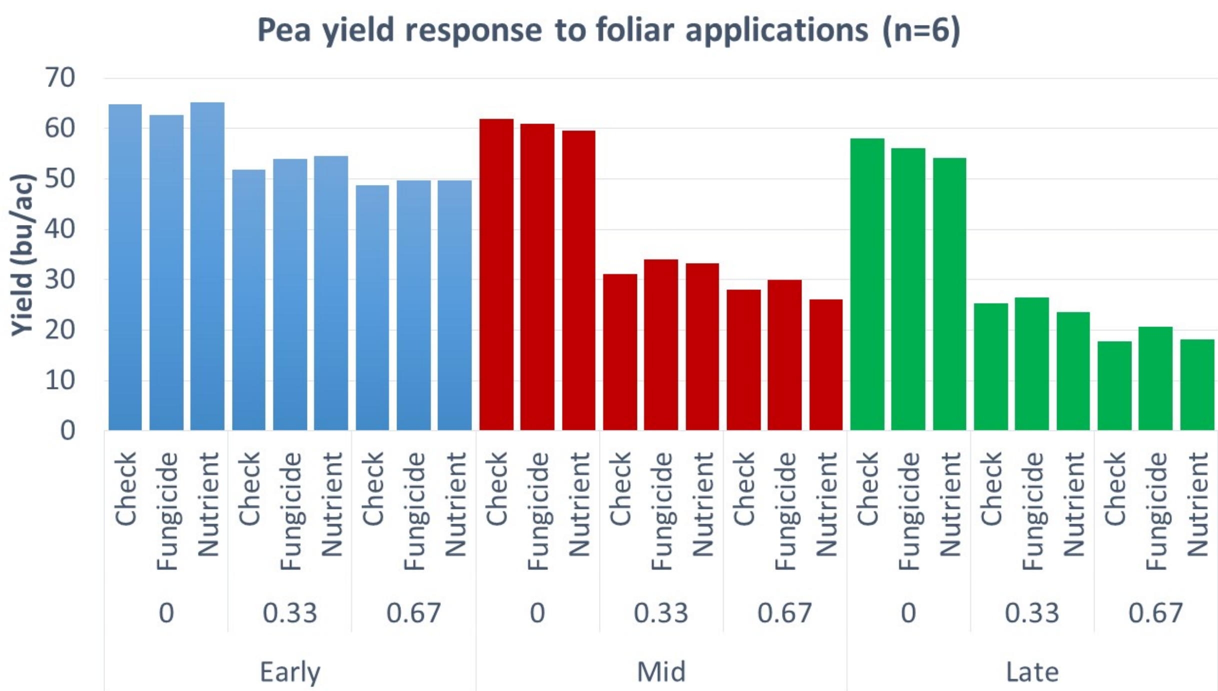
1. **Timing of Hail - Crop Stage and Recovery Period**
   a. Peas: 4-6 nodes, flowering, podding
   b. Dry Beans: 4-6 trifoliate, flowering, podding
   c. Wheat: tillering, heading, flowering

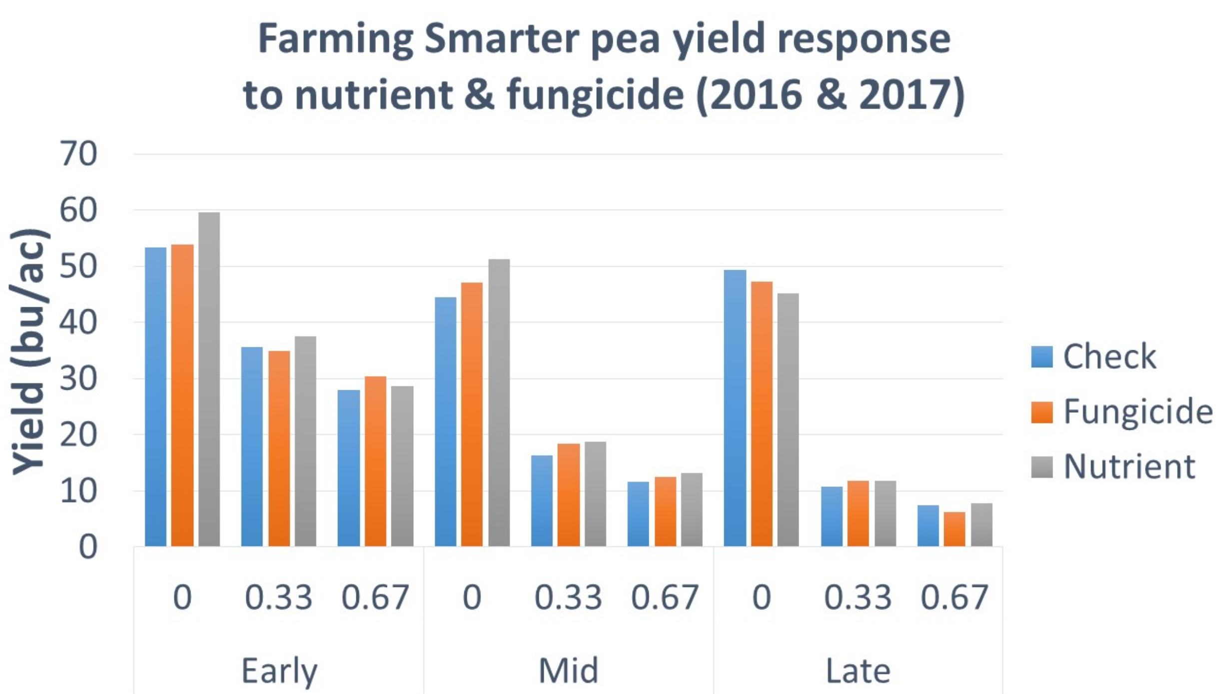
2. **Damage Level: None, Light (33%), Heavy (66%)**

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)

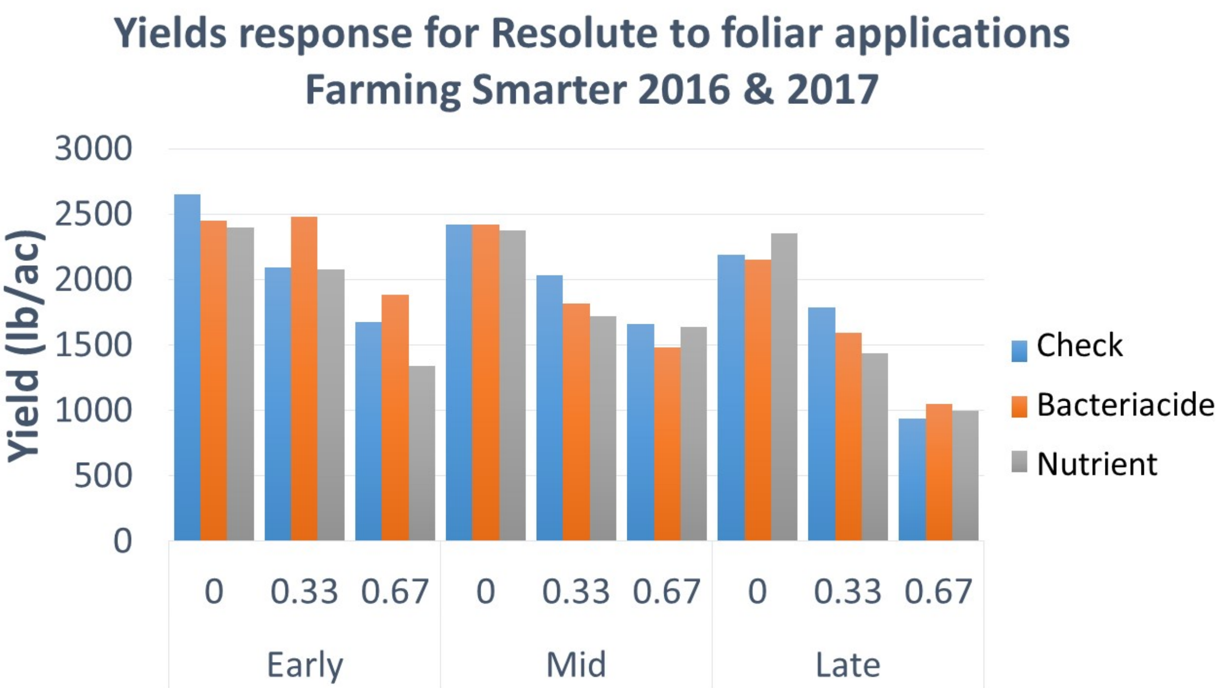
Pea yields with simulated hail damage 2016 & 2017 average from FS, SARDA & Innotech (bu/ac)

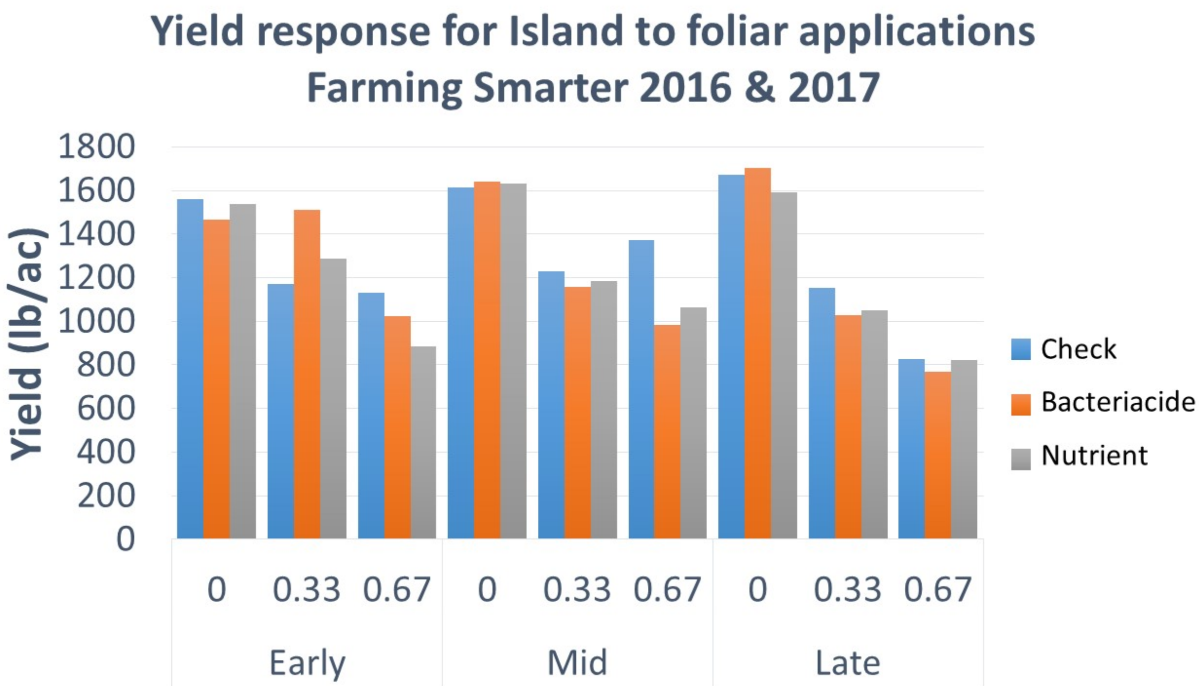



Pea yield response to foliar applications (n=6)
Yield (bu/ac)
70
60
50
40
30
20
10
0
Check
Fungicide
Nutrient
0
0.33
0.67
Early
Mid
Late

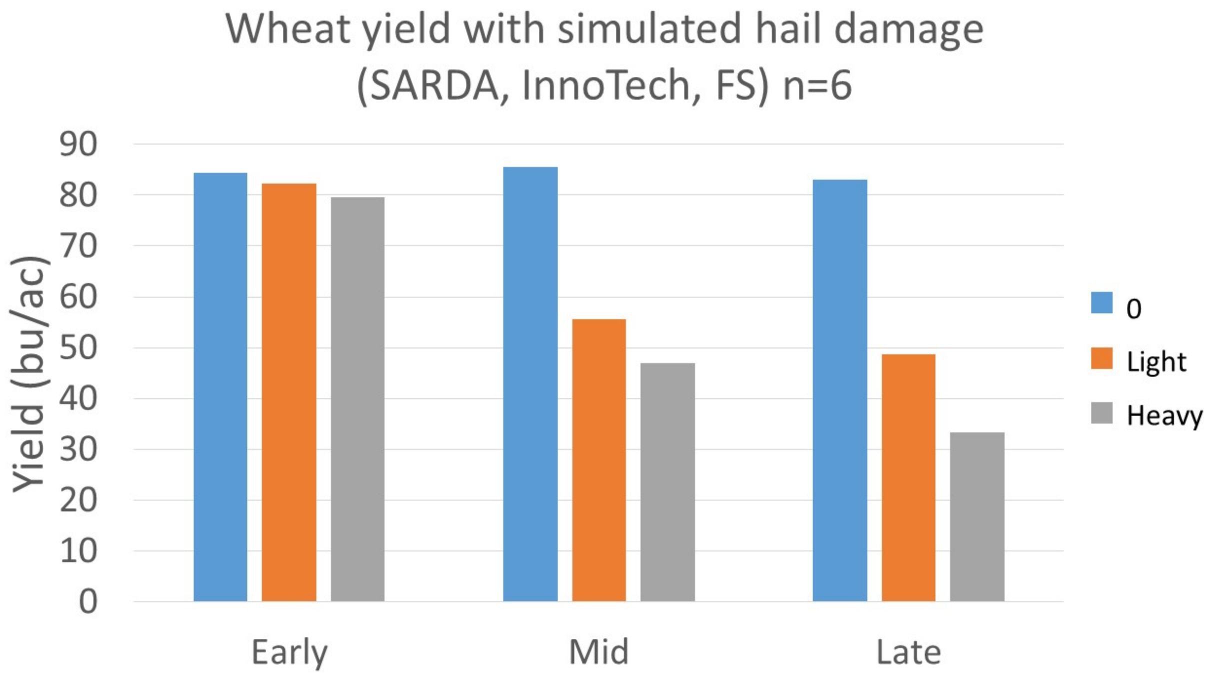

Farming Smarter pea yield response to nutrient & fungicide (2016 & 2017)
Yield (bu/ac)
70
60
50
40
30
20
10
0
0
0.33
0.67
Early
Mid
Late
Check
Fungicide
Nutrient

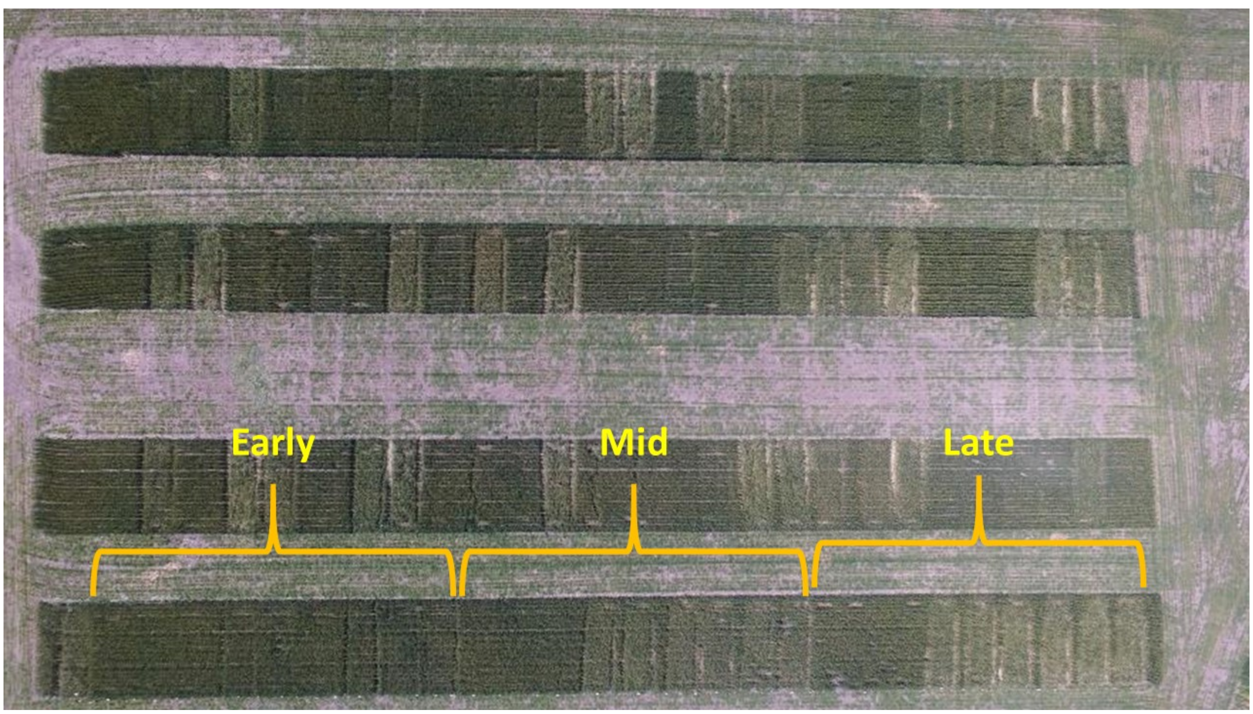

Pulse Hail Recovery Project - Beans

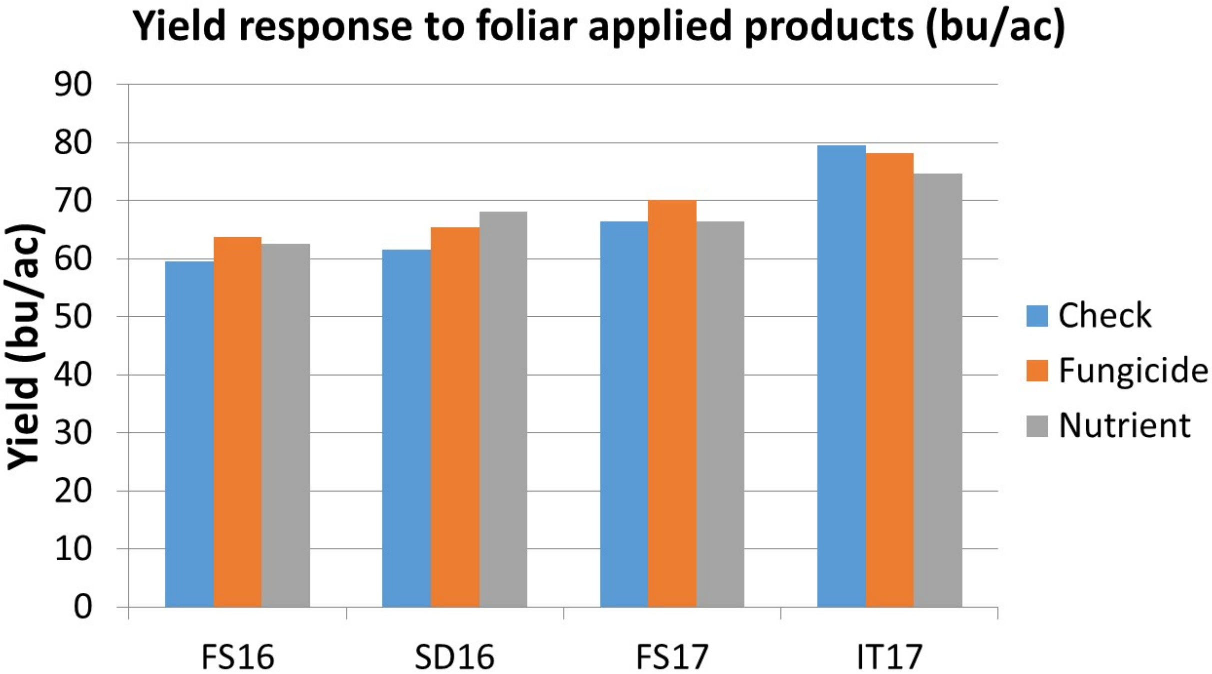

Yields response for Resolute to foliar applications
Farming Smarter 2016 & 2017
Yield (lb/ac)
3000
2500
2000
1500
1000
500
0
0
0.33
0.67
0
0.33
0.67
0
0.33
0.67
Early
Mid
Late
Check
Bacteriacide
Nutrient


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)
0
10
20
30
40
50
60
70
80
90
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

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
JOHN DEERE
ALBERTA PULSE
GROWERS



ΚΑΙΚΙΑΣ

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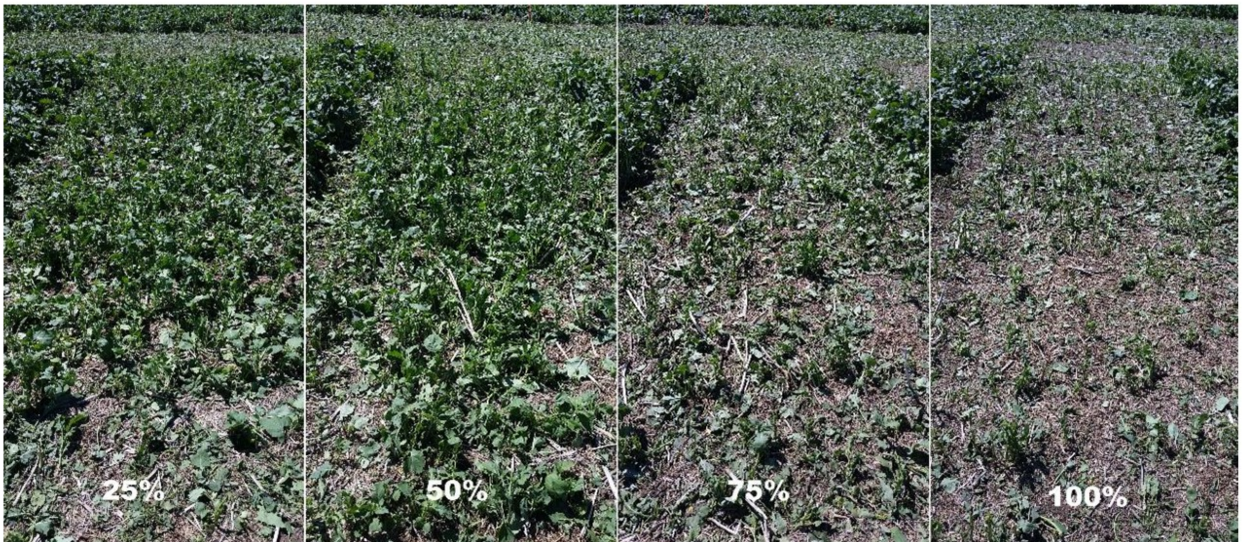
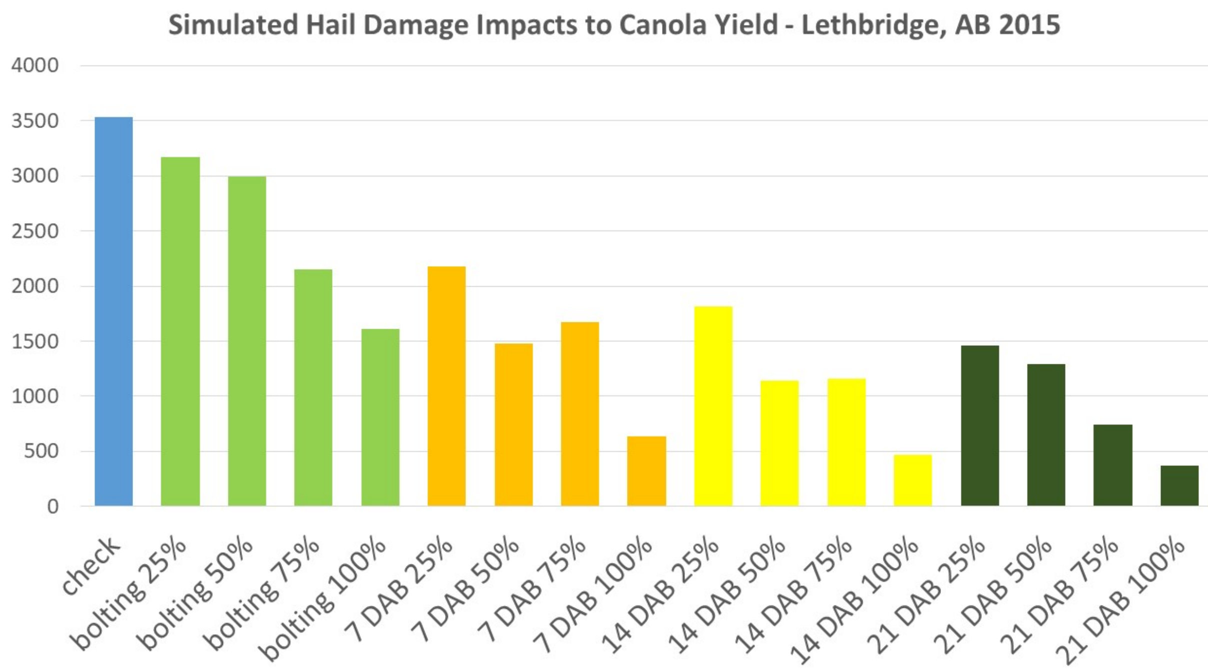
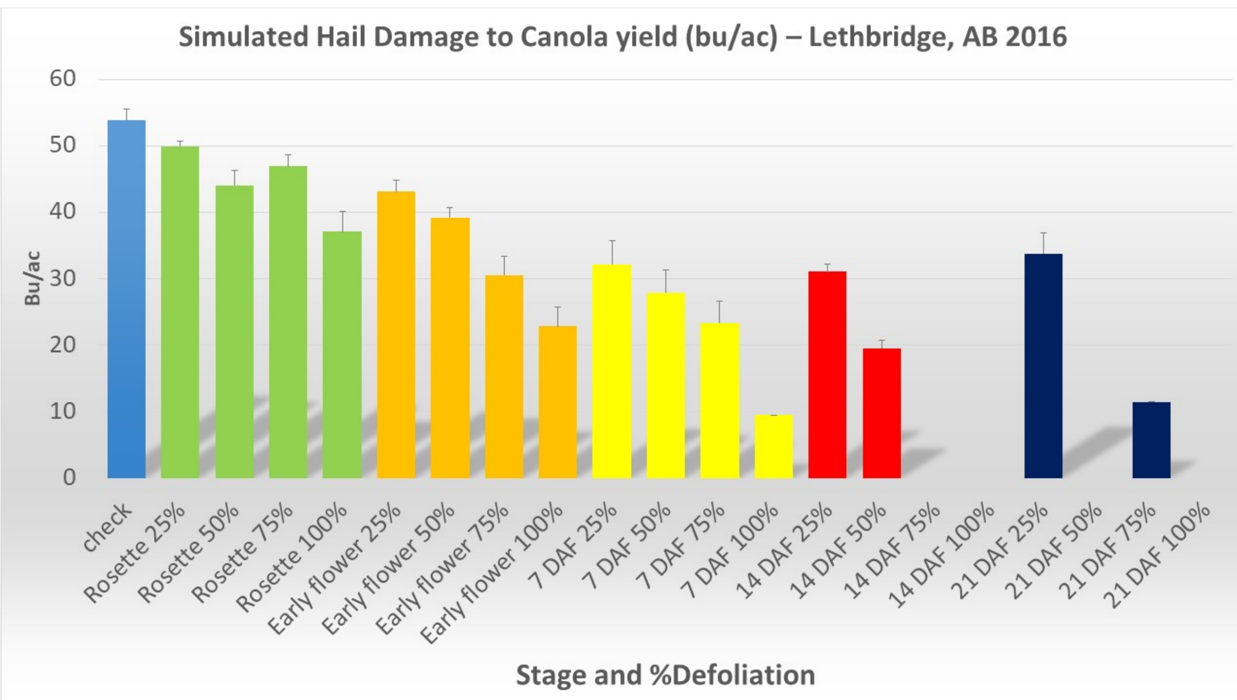
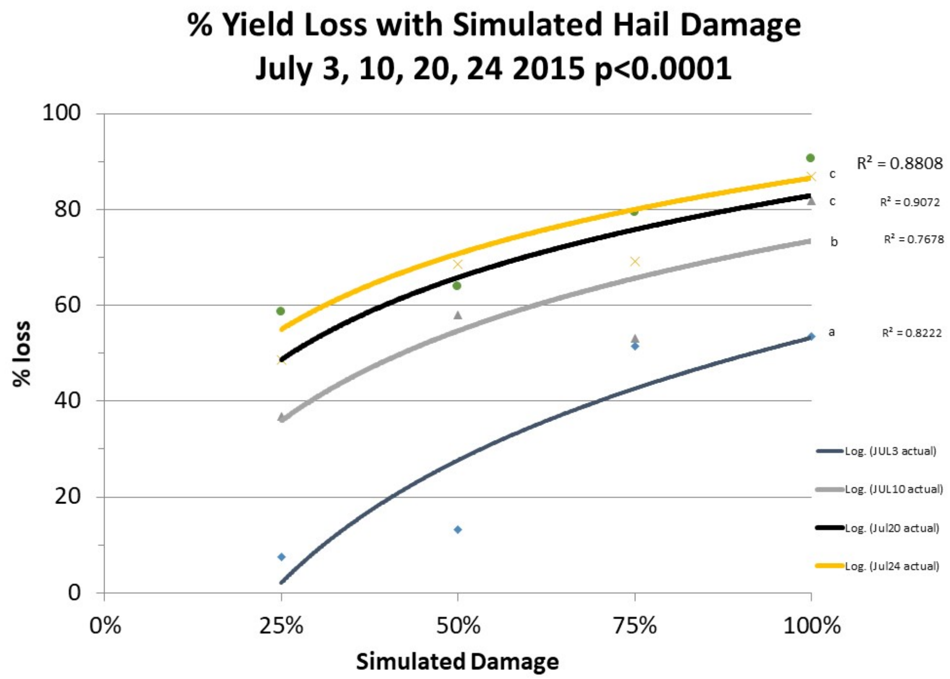
Hail Canola Study – 5 Timings & 4 Levels

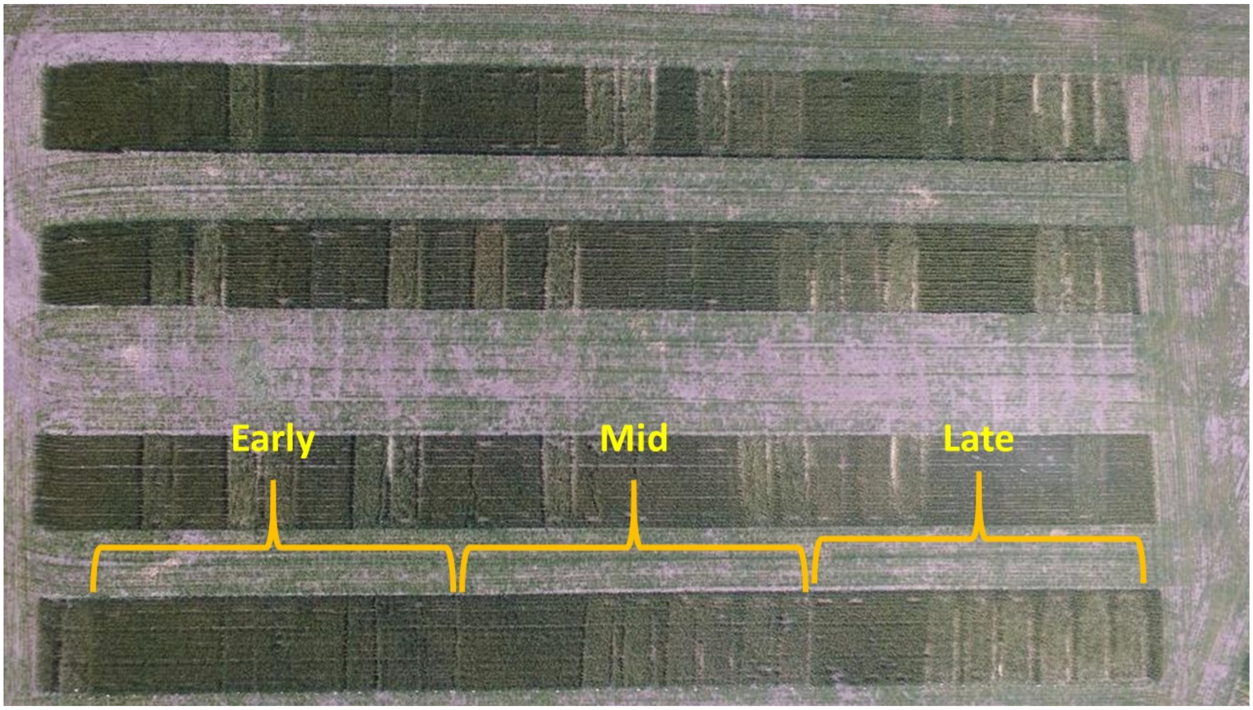



Simulated Hail Damage Impacts to Canola Yield - Lethbridge, AB 2015
4000
3500
3000
2500
2000
1500
1000
500
0
check
bolting 25%
bolting 50%
bolting 75%
bolting 100%
7 DAB 25%
7 DAB 50%
7 DAB 75%
7 DAB 100%
14 DAB 25%
14 DAB 50%
14 DAB 75%
14 DAB 100%
21 DAB 25%
21 DAB 50%
21 DAB 75%
21 DAB 100%

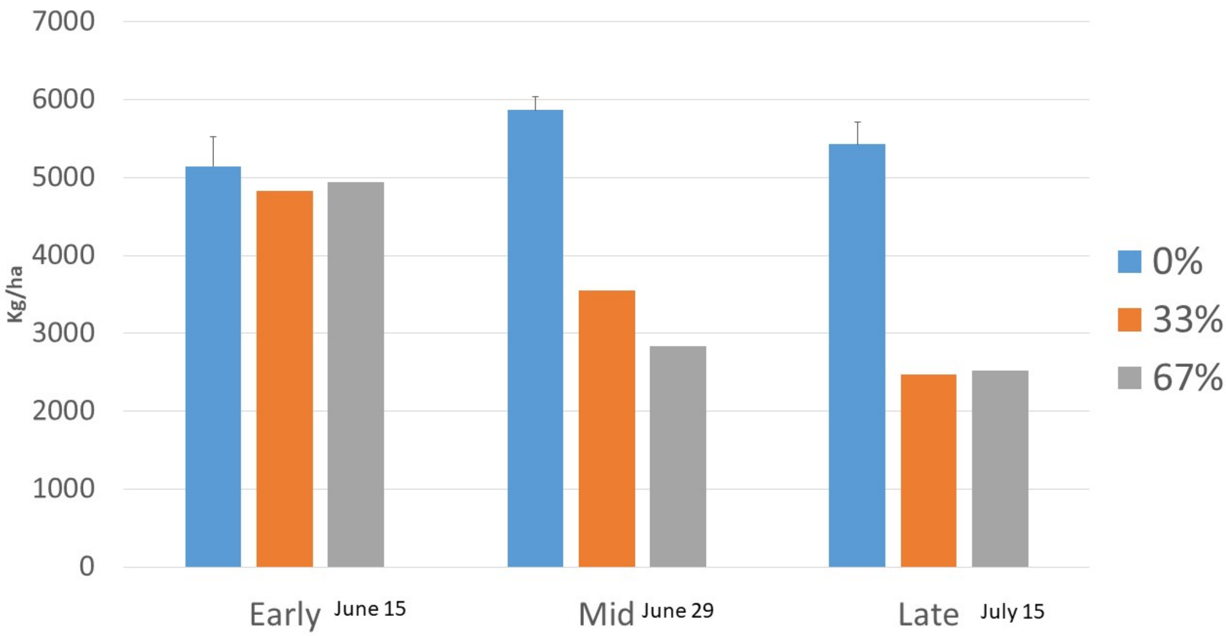

Simulated Hail Damage to Canola yield (bu/ac) – Lethbridge, AB 2016
60
50
40
30
20
10
0
Bu/ac
check
Rosette 25%
Rosette 50%
Rosette 75%
Rosette 100%
Early flower 25%
Early flower 50%
Early flower 75%
Early flower 100%
7 DAF 25%
7 DAF 50%
7 DAF 75%
7 DAF 100%
14 DAF 25%
14 DAF 50%
14 DAF 75%
14 DAF 100%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

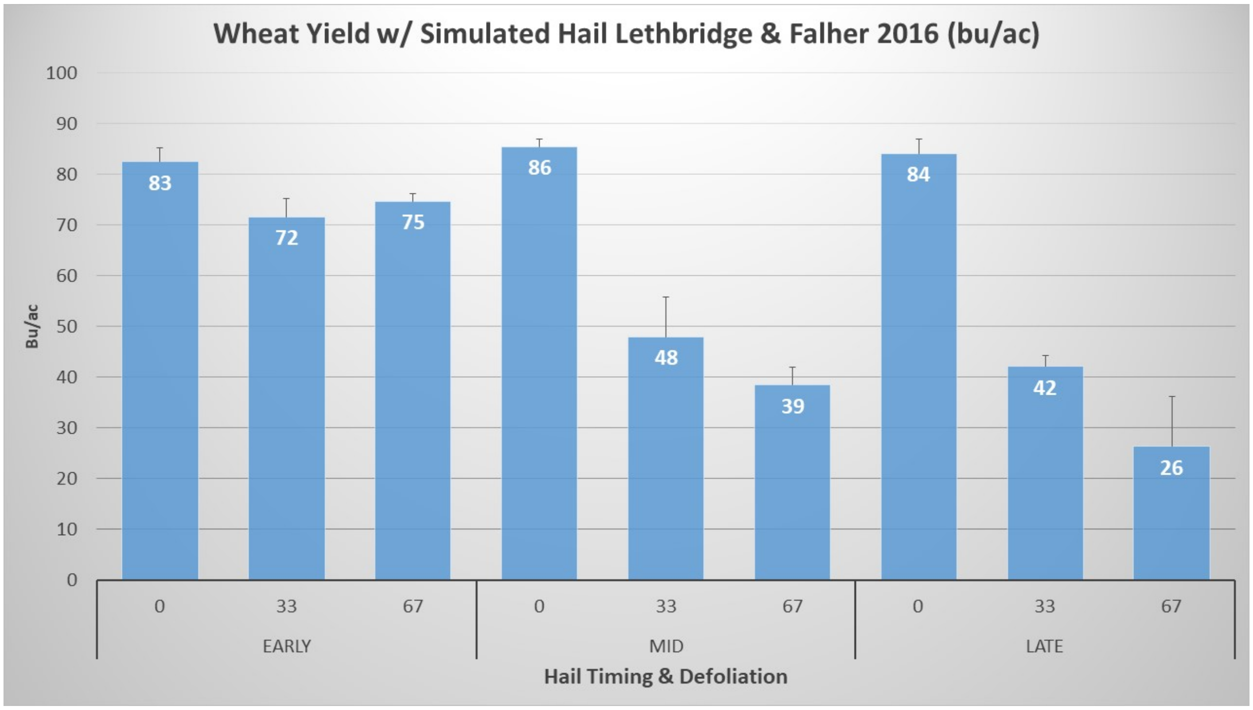

% Yield Loss with Simulated Hail Damage
July 3, 10, 20, 24 2015 p<0.0001
100
80
60
40
20
0
% loss
0%
25%
50%
75%
100%
Simulated Damage
R² = 0.8808
R² = 0.9072
R² = 0.7678
R² = 0.8222
c
c
b
a
Log. (JUL3 actual)
Log. (JUL10 actual)
Log. (Jul20 actual)
Log. (Jul24 actual)

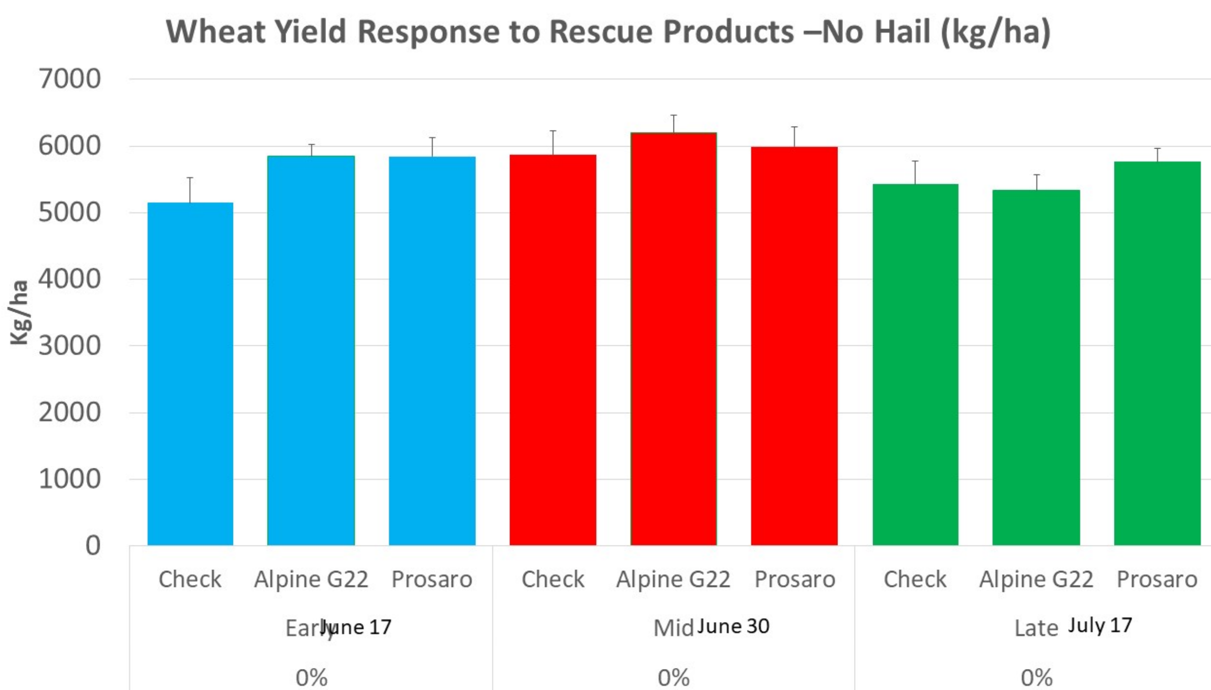

Alberta Wheat
COMMISSION
Hail Recovery Project
June 15
Light damage
June 15
Heavy damage

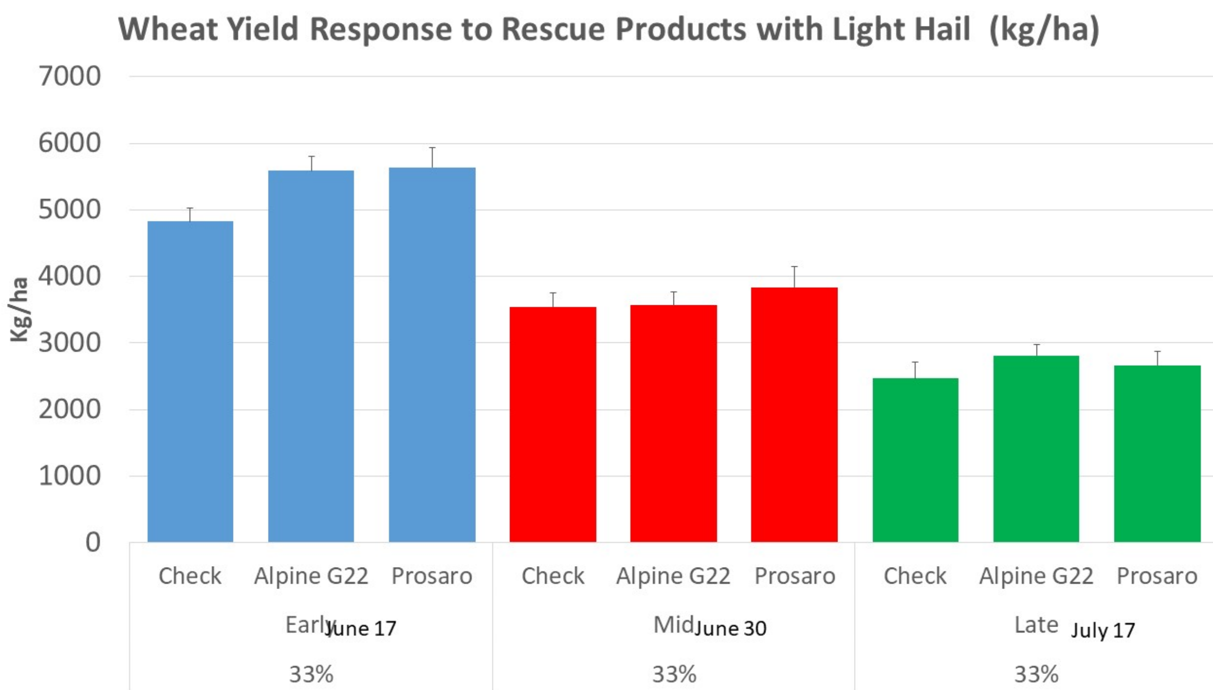


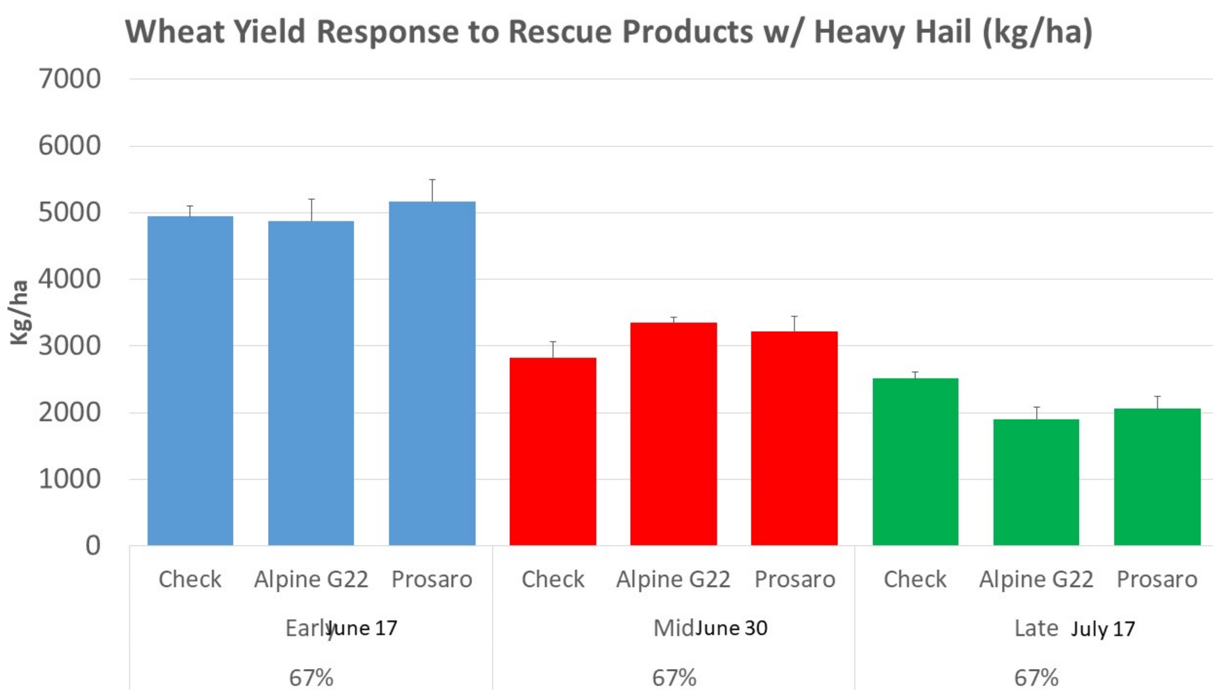
Wheat Yield w/ Simulated Hail Damage Lethbridge 2016 (kg/ha)

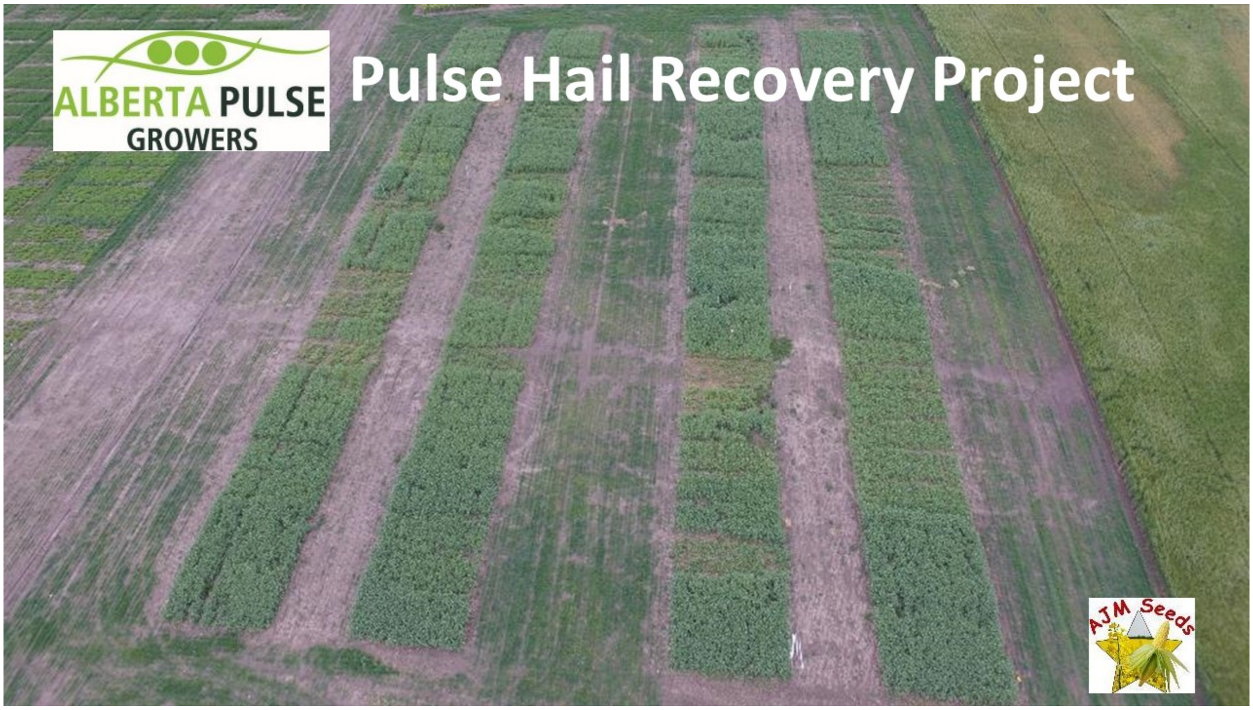



Wheat Yield w/ Simulated Hail Lethbridge & Falher 2016 (bu/ac)
100
90
80
70
60
50
40
30
20
10
0
Bu/ac
83
72
75
86
48
39
84
42
26
0
33
67
0
33
67
0
33
67
EARLY
MID
LATE
Hail Timing & Defoliation

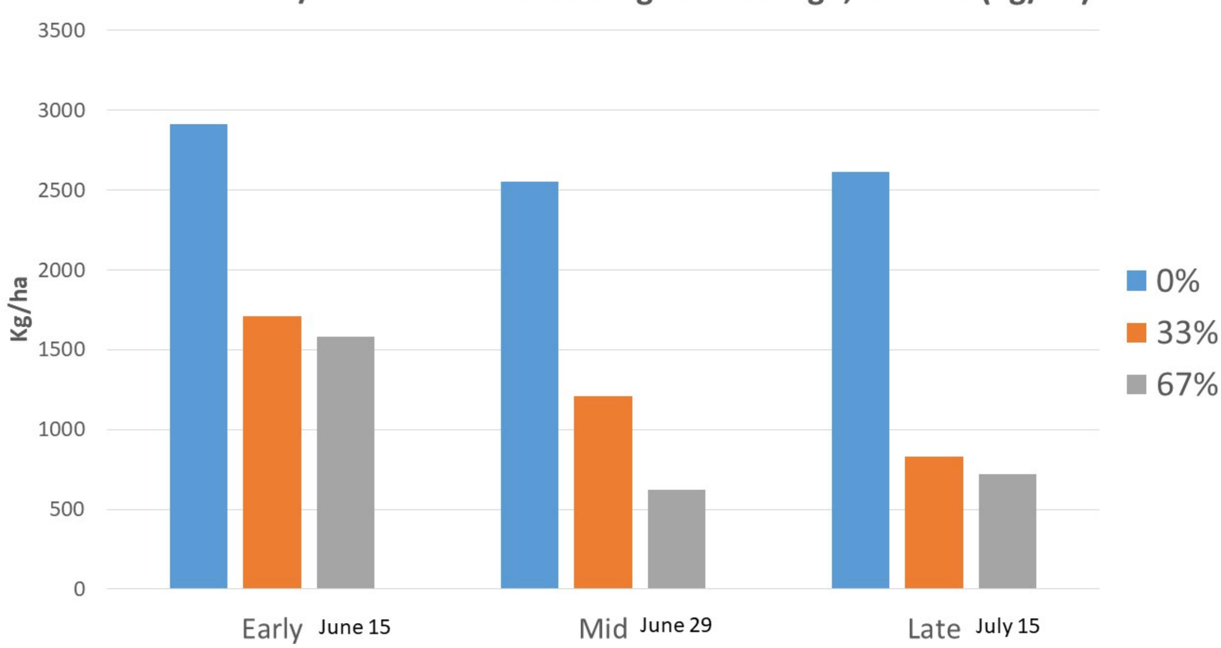

Wheat Yield Response to Rescue Products –No Hail (kg/ha)
7000
6000
5000
4000
3000
2000
1000
0
Kg/ha
Check
Alpine G22
Prosaro
Check
Alpine G22
Prosaro
Check
Alpine G22
Prosaro
Early
June 17
Mid
June 30
Late
July 17
0%
0%
0%

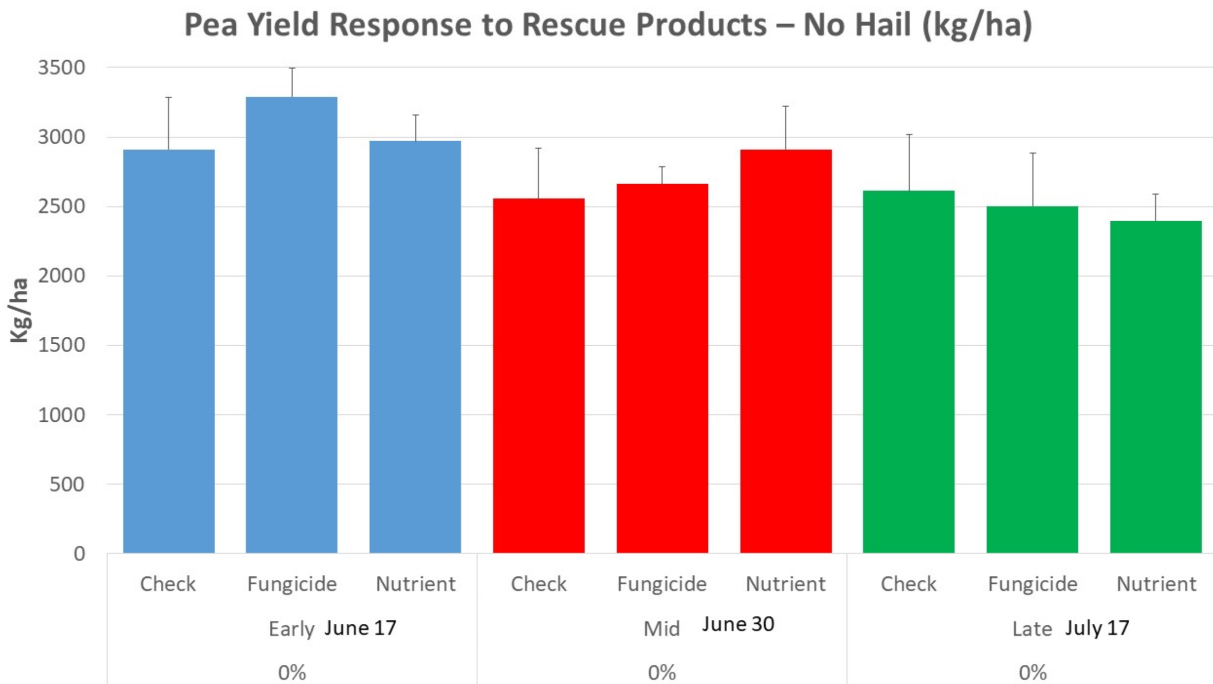

Wheat Yield Response to Rescue Products with Light Hail (kg/ha)
Kg/ha
7000
6000
5000
4000
3000
2000
1000
0
Check
Alpine G22
Prosaro
Check
Alpine G22
Prosaro
Check
Alpine G22
Prosaro
Early June 17
Mid June 30
Late July 17
33%
33%
33%


Wheat Yield Response to Rescue Products w/ Heavy 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
67%
67%
67%

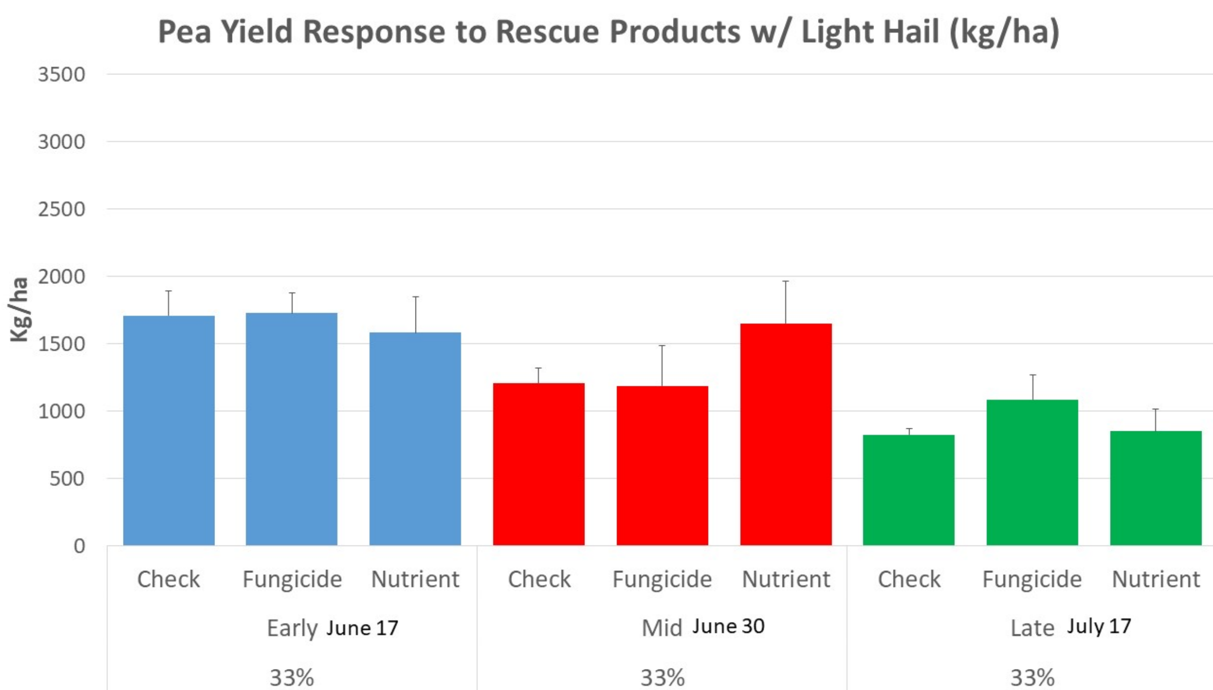


Pea Yield w/ Simulated Hail Damage Lethbridge, Alberta (kg/ha)

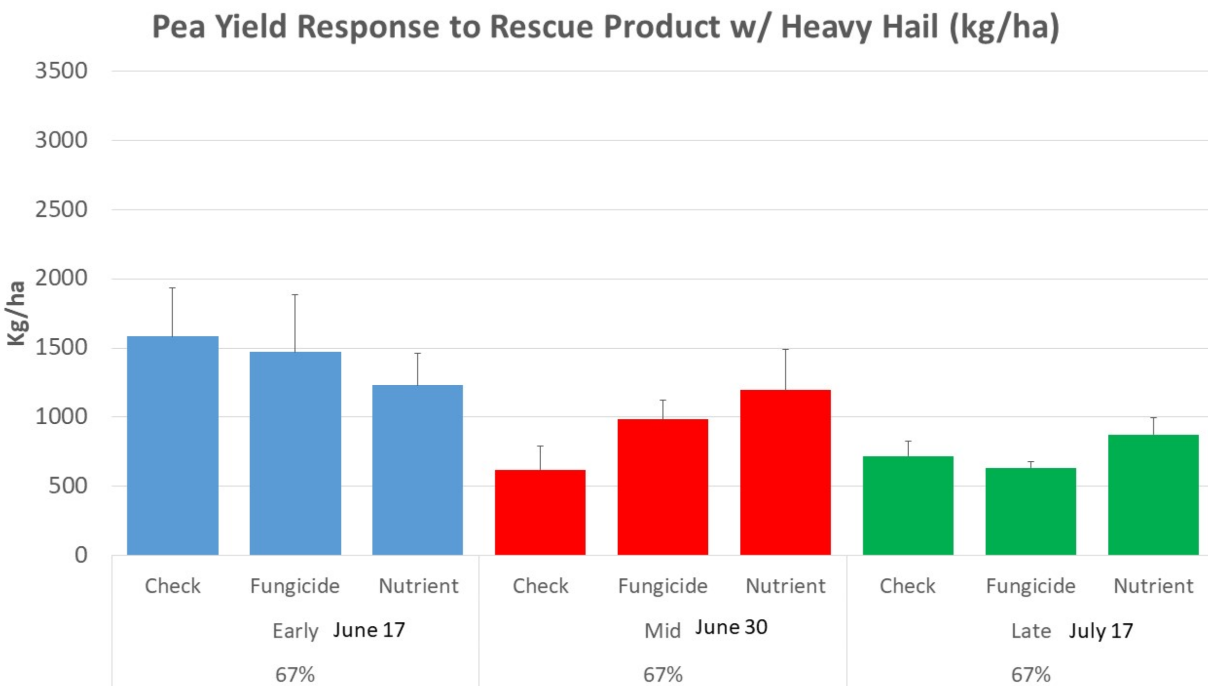


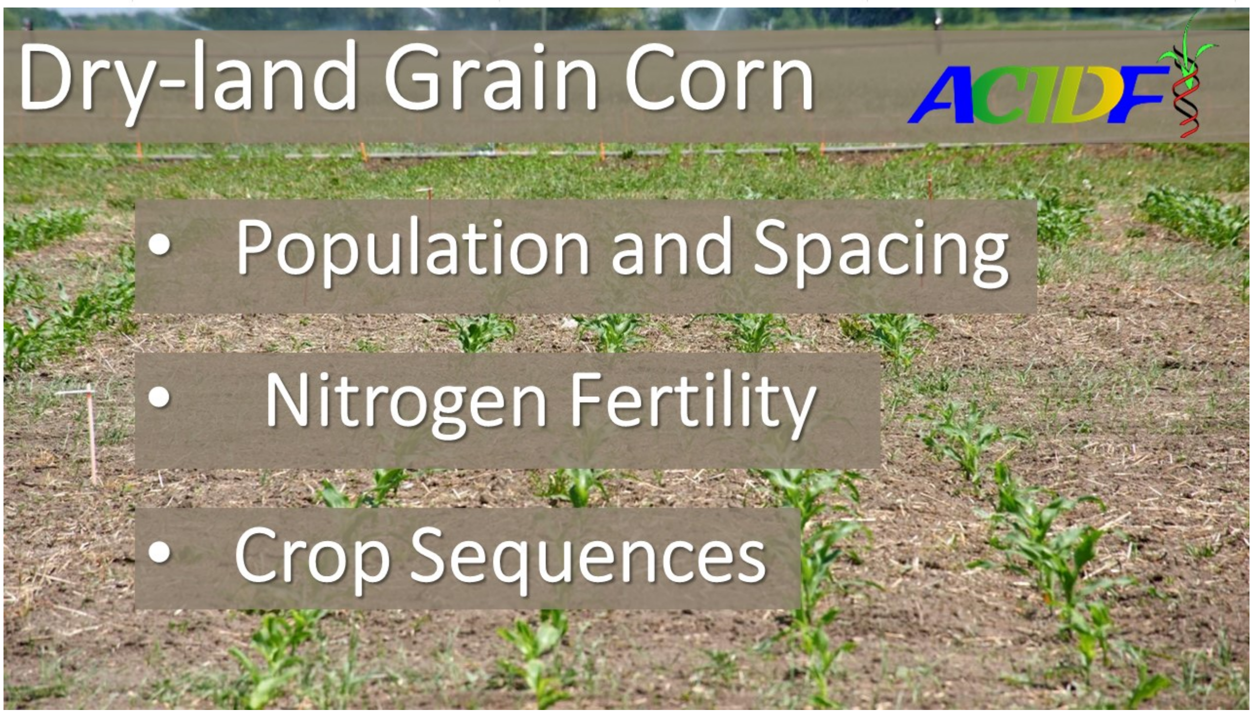


Pea Yield Response to Rescue Products – No Hail (kg/ha)
3500
3000
2500
2000
1500
1000
500
0
Kg/ha
Check
Fungicide
Nutrient
Check
Fungicide
Nutrient
Check
Fungicide
Nutrient
Early June 17
Mid June 30
Late July 17
0%
0%
0%

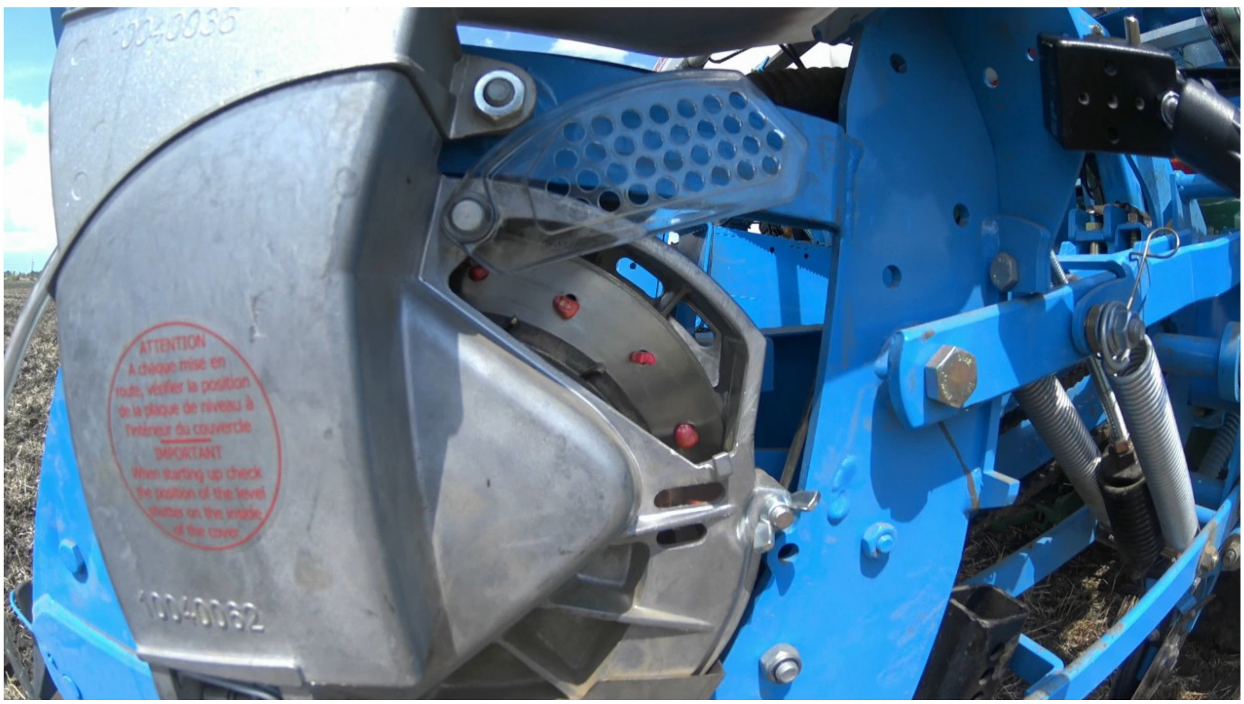


Pea Yield Response to Rescue Products w/ Light Hail (kg/ha)
3500
3000
2500
2000
1500
1000
500
0
Kg/ha
Check
Fungicide
Nutrient
Check
Fungicide
Nutrient
Check
Fungicide
Nutrient
Early June 17
Mid June 30
Late July 17
33%
33%
33%


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%

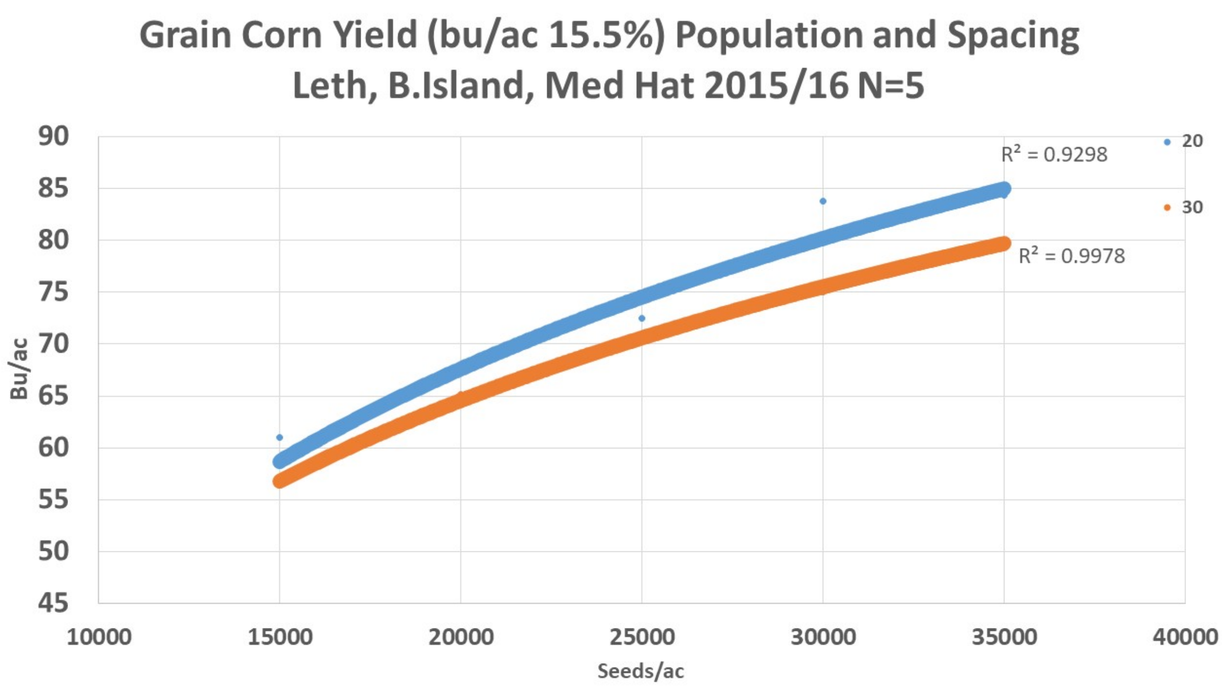

Dry-land Grain Corn
ACIDF
• Population and Spacing
• Nitrogen Fertility
• Crop Sequences


JOHN DEERE

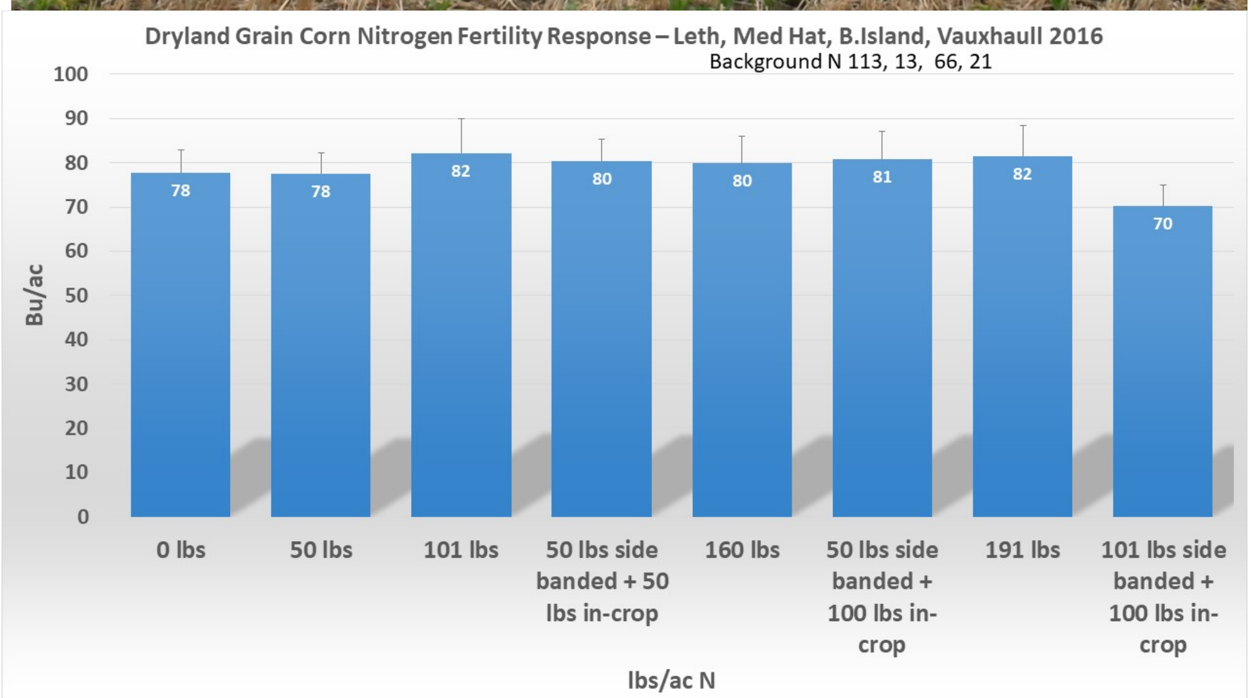

ATTENTION
IMPORTANT
10040062


MAIS STAR

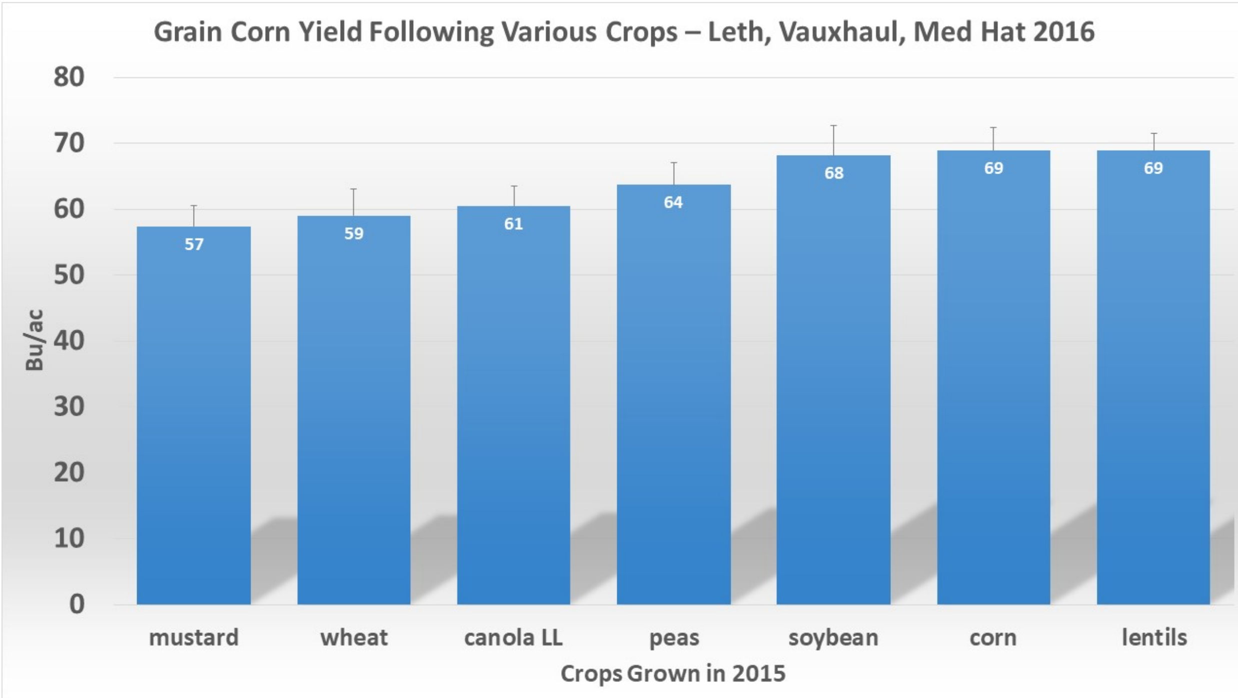

• Population and Spacing



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
R^2 = 0.9298
R^2 = 0.9978
20
30

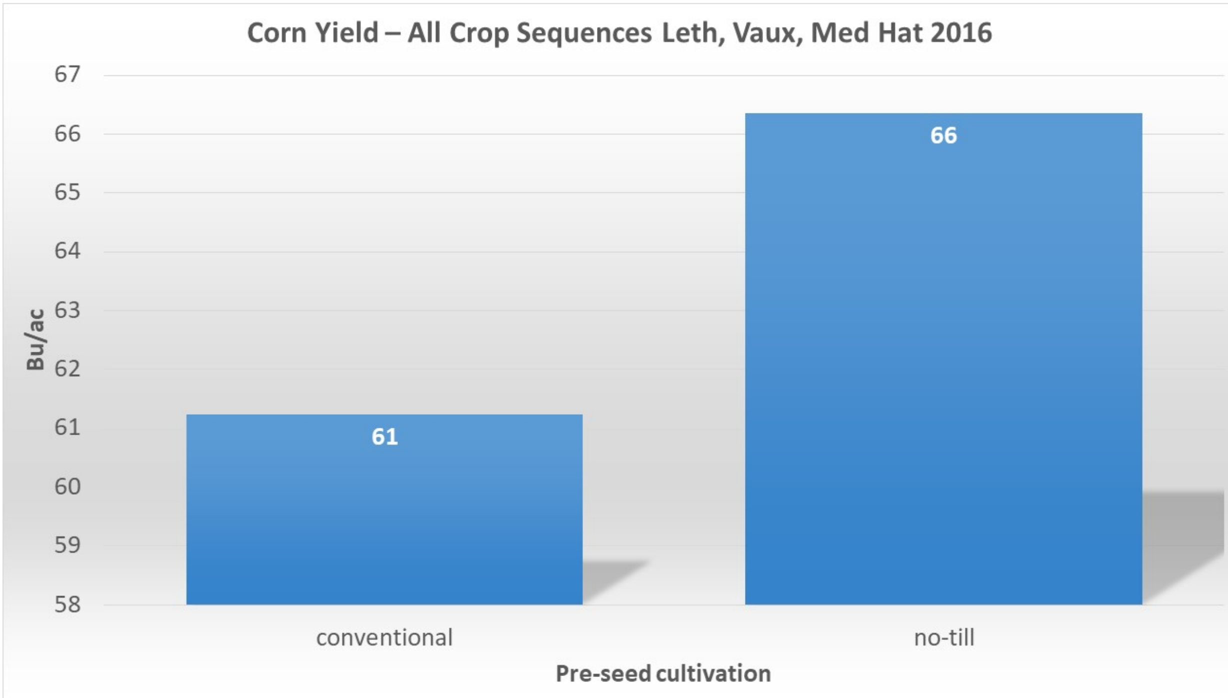

• Nitrogen Fertility

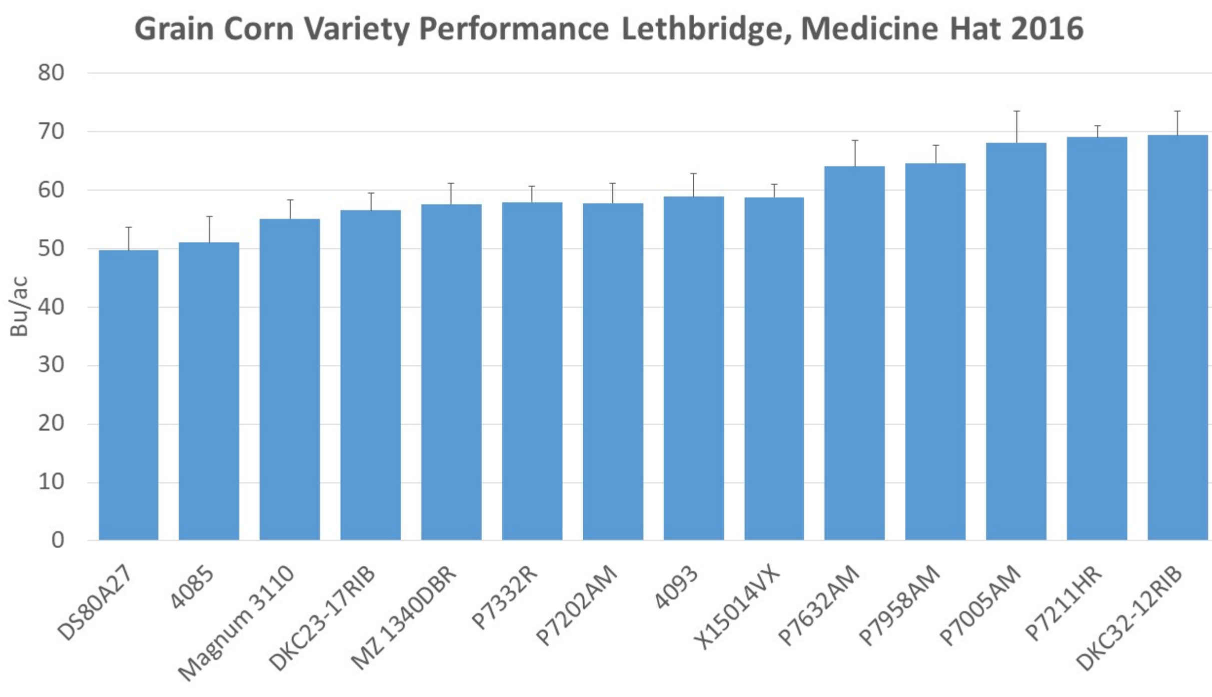

Dryland Grain Corn Nitrogen Fertility Response – Leth, Med Hat, B.Island, Vauxhaull 2016
Background N 113, 13, 66, 21
Bu/ac
100
90
80
70
60
50
40
30
20
10
0
78
78
82
80
80
81
82
70
0 lbs
50 lbs
101 lbs
50 lbs side banded + 50 lbs in-crop
160 lbs
50 lbs side banded + 100 lbs in-crop
191 lbs
101 lbs side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