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Full Research Project Final Report

- This report must be a stand-alone report, *i.e.,* must be complete in and of itself. Scientific articles or other publications cannot be substituted for the report.
- One electronic copy and one signed original copy are to be forwarded to the lead funding agency on or before the due date as per the investment agreement.
- A detailed, signed income and expenditure statement incurred during the entire funding period of the project must be submitted along with this report. Revenues should be identified by funder, if applicable. Expenditures should be classified into the following categories: personnel; travel; capital assets; supplies; communication, dissemination and linkage; and overhead (if applicable).
- For any questions regarding the preparation and submission of this report, please contact ACIDF

Section A: Project overview

1. Project number: 2015F007R
2. Project title: Developing Agronomic Knowledge and Management Skills for Grain Corn Production in Alberta
3. Research team leader: Ken Coles
4. Research team leader's organisation: Farming Smarter
5. Project start date (yyyy/mm/dd): 2015/04/01
6. Project completion date (yyyy/mm/dd): 2017/12/31
7. Project final report date (yyyy/mm/dd): 2018/01/31

Section B: Non-technical summary (max 1 page)

Provide a summary of the project results which could be used by the funders for communication to industry stakeholders (e.g., producers, processors, retailers, extension personnel, etc.) and/or *the general public. This summary should give a brief background as to why the project was carried out, what were the principal outcomes and key messages, how these outcomes and key messages will advance the agricultural sector, how they will impact industry stakeholders and/or consumers, and what are the economic benefits for the industry.*

Farming Smarter studied grain corn agronomy in southern Alberta for three years (2015-2017). These rain-fed locations included Lethbridge in dark brown soils zone, Vauxhall, Bow Island and Medicine Hat, all in the brown soils zone. The 2015 and 2017 growing seasons were abnormal with very little precipitation and extreme heat, while the 2016 season was close to long term averages. Long term accumulated corn heat units (CHU) increase from west to east (2150-2415 CHU's), and were above average (2291-2894). (Appendix 2, Table 1, 2 & 3).

As corn production increases across the prairies, the main project goal is to deliver an unbiased evaluation of agronomic practices that will assist producers in making the most profitable production choices. To do this, we established a plant population versus row spacing (n=8), a nitrogen fertility (n=8), a rotation/ crop sequence (n=6) and a variety study (n=5) (Appendix 1, Table 1).

Study 1: Plant Population and Row Spacing

The population and spacing study showed that narrow rows (20") and high seeding rates (35,000 seeds/ac) produced maximum corn yields. Corn yields were 9% higher when seeded on 20" spacing vs 30" spacing. Generally, yield increases linearly with increasing plant population (Appendix 3, Table 1). Days to tassel, silk and maturity were one day longer from highest to lowest seeding rates (35,000 seeds/ac vs 15,000 seeds/ac), but did not noticeably effect maturity.

Study 2: Nitrogen Fertility Requirements

Nitrogen fertilizer had little effect on corn yield. Comparing total available nitrogen (soil available + fertilizer) versus corn yield showed very little response between 50lbs/ac and 200 lbs/ac. Below 50 lbs/ac and above 200 lbs/ac, there was a small yield decrease. Higher nitrogen rates also increased days to tassel, silk and maturity by approximately one day (Appendix 3, Table 2).

Study 3. Tillage system and crop rotation impacts to corn production

This study did not show a significant yield difference between pre-plant tillage and direct seeding. However, corn emergence in the conventional system was 99% and only 84% in the no-till plots. This is caused by hair-pinning and issues with residue from the previous crop. Better residue management at harvest; properly adjusted residue managers during planting and following a low residue crop could address these issues. For instance, grain corn yielded highest following pulse crops (as well as corn), when direct seeded. Further research may facilitate adapting planters to zero-tillage and prove the value of rain-fed corn production in southern Alberta.

Study 4: Variety maturity rating performance
Studies 1-3 used the variety with lowest available heat unit rating. This study sought to roughly evaluate varieties from various companies with various maturity ratings. There was a 250 kg/ha increase in average yield by going from a 2000 CHU variety to a 2500 CHU variety (appendix 3, figure 13). However, yields of different varieties at each CHU could vary as much as 1000 kg/ha (appendix 3, tables 5-9), making comparisons at various heat units difficult. Days to tassel, silk and maturity were all lengthened with increased CHU rating (figure 14), but not enough to cause problems for harvest. The date of the first frost (-2°C) ranged from September 17 to October 24 (table 10) usually leaving adequate time for maturity. Industry experts warn that most seed companies use differing methods in assigning CHU ratings; which this data set makes apparent. The intent of this study was not to aid in variety selection, but to determine if there is opportunity for higher yields.

Section C: Project details

1. Project team (max ½ page)
Describe the contribution of each member of the R&D team to the functioning of the project. Also describe any changes to the team which occurred over the course of the project.

Ken Coles of Farming Smarter led the project and supervised sites in Lethbridge and Medicine Hat, AB. (Technical staff: Mike Gretzinger, Jamie Puchinger, Toby Mandel, and Lewis Baarda). Dr. Brian Beres of Agriculture Agri-Food Canada supervised a site in Vauxhall, AB (Technical staff: Steven Simmill, Ryan Dyck, Warren Taylor) and Dr. Manjula Bandara supervised a site in Bow Island (Technical staff: Art Kruger). Farming Smarter seeded and harvested the Lethbridge, Bow Island and Medicine Hat locations. Dr. Beres' crew harvested the Vauxhall site in 2016 and 2017. Advisors included Nicole Rasmussen from Pioneer in Lethbridge, AB; Gary Csoff from Monsanto for equipment advice, seed selection, treatment lists, and agronomy resources. All contributed to developing the protocols and data collection.

2. Background (max 1 page)
Describe the project background and include the related scientific and development work that has been completed to date by your team and/or others.

Corn is the most widely grown grain crop in the world and the third most valuable in Canada (Statistics Canada 2015). Despite relatively higher input costs, corn has high yield potential and thus higher potential returns. Major barriers to growing corn in Alberta include a short growing season, low nitrogen availability in soil, and low precipitation. However, grain corn acres are on an upward trend in Alberta. This is largely due to increasingly favorable growing conditions for grain corn in Alberta, specifically: increasing temperature, precipitation, and length of growing season. This is compounded by the availability of earlier maturing and consistent yielding grain corn varieties. Recent, heavy investments from major seed companies in the development of short season, early maturing grain corn varieties for Alberta and Saskatchewan offer Alberta crop farmers a huge opportunity. For example, Monsanto Canada announced a $100 million investment over the next 10 years to develop corn hybrids with earlier relative maturities under a grain corn expansion project. Additionally, DuPont Pioneer established a new multi-million-dollar research facility in Lethbridge, Alberta, to develop ultra-early corn hybrids for Western Canada.

While seed companies focus on breeding new varieties, farmers need proven agronomic practices to successfully integrate corn into common cropping systems and rotations in the area. To this end, Farming Smarter, in collaboration with ACIDF, AAFC (Agri-Food and Agriculture Canada) and Alberta Agriculture, initiated four corn agronomy studies with locations across southern Alberta for three growing seasons (2015 - 2017). The main objective of this project was to determine best management practices for rain-fed grain corn production. The opportunity is two-fold in that it provides a new profitable crop option for producers and helps sustain and strengthen the competitiveness of Alberta's feed and livestock sectors.

3. Objectives and deliverables (max 1 page)

State what the original objective(s) and expected deliverable(s) of the project were. Also describe any modifications to the objective(s) and deliverable(s) which occurred over the course of the project.

The goal of this research project was to discover optimal agronomic practices that would financially and environmentally warrant the integration of grain corn into producers' crop rotations in southern Alberta. The project ran for three years (2015-2017) with trials in Lethbridge, Medicine Hat, Vauxhall and Bow Island. The following agronomic parameters were observed: a) fertility, variety, plant population and row spacing and crop sequencing to find optimal growing conditions for grain corn on rain fed land in southern Alberta.
Overall project objectives include an unbiased assessment of state-of-the-art corn production technology for adaptation and development of BMPs for successful, efficient and profitable grain corn production in the province.

Study Objectives are to:

- Evaluate the yield potential of short season grain corn hybrids under dryland conditions
- Adapt & optimize soil fertility and nutrient management strategies (e.g., corn varieties recommended for the area, expected yield goals, soil types, site-specific levels of plant nutrients, crop rotations and irrigated or dryland)
- Create a cumulative report outlining optimal agronomic management practices of grain corn production specifically for the Southern Alberta growing region
- Disperse knowledge to the public through field days, conferences, new articles and reports.

Deliverables:

- A comprehensive report outlining the best agronomic practices for producers to use in cropping systems to aid in the growth of grain corn in southern Alberta

- Facilitating hands on application of knowledge through educational workshops such as field days
- Widespread dispersal of knowledge to producers, industry developers, and consumers through conferences, presentations, and news/magazine articles

4. Research design and methodology (max 4 pages)

Describe and summarise the project design, methodology and methods of laboratory and statistical analysis that were used to carry out the project. Please provide sufficient detail to determine the experimental and statistical validity of the work and give reference to relevant literature where appropriate. For ease of evaluation, please structure this section according to the objectives cited above.

The study design aimed to find the ideal plant population, row spacing, fertility, crop sequence and tillage requirements for growing dryland grain corn in southern Alberta.

Experimental Design

The trials in Lethbridge, Medicine Hat, and Bow Island were small plots (4 rows x 6m long) and the trials in Vauxhall were medium sized plots (4 rows x m 20 m long). Guard rows seeded on the outside rows prevented edge effects, and, in final years following industry recommendations, the study added buffers seeded around the entire trial. Seeding dates are listed in Appendix 1, Table 1.

The field trials took place over three growing seasons (2015-2017) at four locations (study dependent) that represent southern Alberta's soils and growing conditions. Site years for each study are listed in Appendix 1, Table 2.

Site Information, Maintenance and Preparation:

Environmental

Long term accumulated corn heat units (CHU) increase from west to east (2150-2415 CHU's). Normal rainfall for Lethbridge is 256 mm, Bow Island 217mm, Vauxhall 212mm, Medicine Hat 219mm (Appendix 2, Table 1, 2 & 3).

Soil Background

Lethbridge is in the dark brown soil zone, while Vauxhall, Bow Island and Medicine Hat are all in the brown soil zone. The soil gets gradually sandier and has lower organic matter west to east. The sites were under continuous cropping and seeded onto wheat stubble (Appendix 2, Table 4).

Variety

The earliest maturing corn variety available was chosen for studies 1-3 (Pioneer P7332R, 2050 CHU).

Seeding and fertilizer application

The Fertility, Population and Spacing, and Sequencing trials were seeded using a 4 row Monosem vacuum planter. The rows in all trials were 30" apart and seeded at 20,000 seeds/ac (except the Population and Spacing study).

Soil samples prior to seeding in April to determined soil fertility and forecast fertility needs. Site preference for the fertility trial went to sites with low soil nitrogen less than 30 lbs/ac. The other trials were mid-row banded with 46-0-0 nitrogen fertilizer at seeding to achieve 150 lbs/ac total available nitrogen (Appendix 1, Table 3). Three gallons/ac 10-34-0 liquid ammonium phosphate was applied with the seed.

The variety trials used a custom built two-row, three-point hitch gravity planter for seeding. Urea (46-0-0) and ammonium phosphate (11-52-0) granular fertilizer was banded three inches deep perpendicular to the rows before seeding.

In the fertility trial, in-crop N applications of 28-0-0 UAN were made using a CO2 sprayer with streamer bars and drop tubing on a hand built 2m boom with 20" and 30" row spacing. We targeted the V4-V6 growth stage of corn an inch from each seed row.

Technicians made herbicide applications with UTV sprayers. The applied glyphosate (1 L/ac) and Aim (29.2 mL/ac) as a pre-seed burndown. To control weeds, they sprayed trials with glyphosate (1 L/ac) at the 2-leaf stage and again at the 4-6 leaf stage. One of the timings was tank mixed with topramezone (15 mL/ac) to help control volunteer glyphosate tolerant canola.

Harvest Management

Technicians harvested the plots using a 2013 Wintersteiger Classic plot combine with a 1.5 m corn head. It collected and weighed grain samples using calibrated on-board balance and moisture sensors and a test weight chamber.

Study Description

Study 1. Plant Population and Row Spacing

<u>Objective</u>: To examine the effect of row spacing and plant population on the performance of grain corn on dryland conditions. Study locations included Lethbridge, Bow Island, and Medicine Hat from 2015 until 2017 (Appendix 1, Table 2).
<u>Factor 1</u>: Row spacing (inch) – 2 (20", 30")
<u>Factor 2</u>: Plant population – 5 (15000, 20000, 25000, 30000, 35000 seeds/ac)
<u>Factor 3</u>: Locations – 3
<u>Treatments</u>: 2 x 5 x 3 locations x 3 years = 90 treatments
<u>Plot Design</u>: Randomized split plots, 4 reps

Study 2. Nitrogen Fertility Requirements

Objective: To investigate the effect of nitrogen fertilizers on the performance of grain corn under dryland conditions. Trial locations included Lethbridge, Bow Island, and Medicine Hat from 2016 until 2017 (Appendix 1, Table 2).

Factor 1: Fertilizer – 8 (5 N rates: 0lbs, 50lbs, 101lbs, 160lbs, 191lbs, 50 lbs side banded + 50 lbs in crop, 50 lbs side banded + 100 lbs in crop, 100 lbs side banded +100 lbs in crop).
Factor 2: Locations – 4
Treatments: 8 x 4 locations x 2 years = 64 treatments
Plot design: RCBD, 4 reps

Study 3. Tillage system and crop rotation impacts to corn production
Objective: To evaluate the effects of tillage and grain corn crop rotations with major crops grown in the region under dryland conditions. Study locations included Lethbridge, Vauxhall and Medicine Hat from 2016- 2017 (Appendix 1, Table 2).

Factor 1: Previous crop – 7 (wheat, soybean, peas, lentils, mustard, canola, corn)
Factor 2: Tillage – 2 (Zero till, and Conventional Till)
Factor 3: Locations – 3
Treatments: 7 x 2 x 3 location x 3 years = 126 treatments
Plot Design: Randomized split plot design, 4 reps

Study 4. Variety maturity rating performance
Objective: To observe maturity and yield of corn varieties with varying CHU ratings. Study locations included Lethbridge and Medicine Hat (2016-2017 and in Lethbridge only in 2015).
Factor 1: Varieties (number of varieties varied from year to year).
Factor 2: Location –2 (Lethbridge and Medicine Hat for 2016 and 2017, Lethbridge only in 2015)
Treatments: TBD by year and seed available
Plot Design: RCBD, 4 reps

Data Collection
1. Plant counts – count rows 2 & 3
2. Days to tassel/anthesis VT [male] (10% of plants have a tassel)
3. Days to silk R1 [female] (50% of plants have silk aka mid-silk)
4. Maturity date (at physiological maturity)
5. Plant height (at physiological maturity)
6. Straw breakage (lodging)
7. Moisture
8. Test weight
9. Yield
10. Corn heat units (CHU)
11. Pictures (1x UAV mid-end of season)

The study retained its objectives, anticipated outcomes, and project design/methodology from the original proposal. The data was analyzed using SAS proc mixed.

5. Results, discussion and conclusions (max 8 pages)

Present the project results and discuss their implications. Discuss any variance between expected targets and those achieved. Highlight the innovative, unique nature of the new knowledge generated. Describe implications of this knowledge for the advancement of agricultural science. For ease of evaluation, please structure this section according to the objectives cited above.

NB: Tables, graphs, manuscripts, etc., may be included as appendices to this report.

A relatively late funding approval for this project made for an exciting field season in 2015. Fortunately, with kind assistance from Mr. Gary Csoff of Monsanto, we were able to plant two population and spacing trials in Lethbridge and Medicine Hat. A borrowed corn plot planter from AAFC, allowed us to seed a variety trial in the same locations, and precursor crops in Lethbridge, Vauxhall and Medicine Hat for the crop sequencing study. We established all trials despite a very dry and hot year, and some emergency irrigation in Medicine Hat.

All locations experienced widespread drought that surpassed the normal long- term precipitation and temperatures. The average precipitation was approximately 35% less than normal long-term conditions. Corn heat units were on average 6% greater than normal conditions (Appendix 2, Table 1). Despite a very dry and hot season, corn growth was surprisingly good and we harvested all trials.

During this season, Farming Smarter purchased a grain corn header for our plot combine, a four row Monosem planter and a custom built two row plot planter. This equipment aided harvest in all years and seeding the 2016 and 2017 trials.

Spring rains in 2016 lead to slightly later than normal seeding dates (May 26-29) (appendix 1, table1.) All trials had good emergence and flourished with average to high rainfall (4-66% above normal) and higher than normal heat (normal – 9% above). (Appendix 2 table 1-3).

Good spring moisture in 2017 allowed for perfect establishment (May 3-19). However, no appreciable precipitation came after June 10 resulting in an extreme drought (42-64% of normal) and very high heat unit accumulation (8-12% above normal). Nevertheless, the corn performed surprisingly well and all trials achieved reasonable yields.

Study 1. Plant Population and Row Spacing

Results

Grain corn yield was 9% higher when seeding on narrower 20” rows vs wider 30” rows (P=0.01, Appendix 3 Table 1). Yield increased with increasing seeding rates (15,000 to 35,000seeds/ac) on 20" and 30" row spacing (P=0.01). Surprisingly, maximum yield did not materialize with the highest tested seed rate. Row spacing and seeding rates affected grain yield independently of one another (P=0.57). The plots seeded on 30” spacing had 10% lower emergence (P=0.01), delayed tasselling (P=0.18), silk (P=0.01) and maturity (P = 0.23) by approximately one day and were on average 4cm taller (P=0.01) than the 20" spacing. The lowest seeding rate had 17% higher emergence (P = 0.01) and delayed tasselling (P = 0.01), silk (P = 0.01), and maturity (P = 0.14) by one day compared to the highest seeding rate. Seeding rate did not affect height (P=0.86) (Appendix 3, Table 1).

Discussion

Dr. Dwayne Beck (personal communication, 2014) initially suggested that 20" spacing and 20,000 seeds/ac might be optimal for rain-fed corn in southern Alberta. However, our data showed yield increased up to 35,000 seeds/ac. The highest average yield came from 20" rows with 30,000 seeds/ac.

Often, plant population and row spacing affect the success of grain corn yield and percent emergence (Pederson and Lauer, 2002). Corn plants compete for resources such as light, water and nutrients because of extensive root systems and tall canopy (Caratti et al., 2016). The assumption that a lower plant population would yield better with reduced water availability was not supported by this study. It is likely that due to our short growing season, a higher population is required to optimize canopy closure by the June solstice. This may also be why narrower rows prove beneficial.

In the Midwestern states, producers obtained more uniform plant distributions and decreased seedling mortality by narrowing row width and increasing plant population (Jeschke, n.d., Pederson and Lauer, 2002). Narrow rows also to maximize yields by allowing the crop canopy to capture 95% or more photosynthetically active radiation (PAR) more efficiently than 30" row spacing (Jeschke, n.d., Andrade et al., 2002). In 1994, a study concluded that corn on 20" and 10" rows out yielded 30" row spacing by 7.2% (Porter et al, 2013).

We found that grain corn grown on 20" row spacing yielded 9% higher than grain corn grown on 30" row spacing (Appendix 3, Figure 1). While the yield response of row width was independent of plant population we still suspect an interaction. Row spacing does not maximize plant population. A similar study, in Minnesota, (Porter et al., 2013) found that plant population did not change when planting in row widths less than 30" wide. To maximize yield, we recommend producers seed dryland grain corn on narrower rows (20") at higher seeding rates (30,000 +seeds/ac).

Trial 2. Nitrogen Fertility Requirements

Results

Despite overall low soil test nitrogen, we had limited corn response to nitrogen fertilizer. Corn yields were between 5006 – 5215 kg/ha, except the "100lbs N at seeding + 100 lbs N in crop" treatment that yielded significantly lower at 4428 kg/ha (P = 0.02, n = 6) The 0 nitrogen check yielded 4885 kg/ha. Very high nitrogen rates reduced plant height by almost 10cm (P=0.04, Appendix 3, Figure 4), increased days to silk (P<0.0001), tassel (P<0.0001) one day and maturity (P<0.0001) by three days (Appendix 3, Figures 5-7).

Discussion

The growth of corn in arid regions is limited by the amount of water and nitrogen available (Shapiro & Wortmann, 2006). When these two elements simultaneously occur in a growing system optimum crop growth and productivity can result. But, when available nitrogen is greater than available moisture, nitrogen uptake decreases (Pandey et al., 1999). This study showed that dryland grain corn had limited response to nitrogen clearly demonstrating that water was the limiting factor. To better compare total available N across site years, we plotted the percent of maximum yield vs soil available N added with the fertilizer N (Appendix 3, Figure 2). Optimal yield occurred in cases where total available nitrogen from the soil combined with nitrogen applied at seeding was between 50 kg/ha and 200 kg/ha. When nitrogen rates were too high, plant height decreased by almost 10cm. Days to tassel, silk and maturity were all delayed with increased fertilizer by making stalks too green and weak; therefore, causing stalks to take additional time to dry down (Gov. of Manitoba, 2018).

The findings suggest that optimum total nitrogen requirements for rain-fed grain corn in southern Alberta would be between 50-200 lbs/ac.

Trial 3. Tillage System and Crop Rotation

Results

Corn planted on tilled land allowed for near perfect emergence (99%) whereas corn direct seeded into existing stubble had an emergence of 83% (Appendix 3, Table 3). Yield was not impacted by low emergence on zero till (4160 kg/ha) and, in fact, increased versus tilled land (4010 kg/ha). We require more site years to increase our confidence in our result for yield ($P=0.07$) (Appendix 3, Table 4).

The previous crop impacted the emergence of corn ($P=0.08$) and its yield ($p<0.01$ $n=4$) in zero till, but had no effect when using a pre-seed tillage operation ($P=0.62$) (Appendix 3, Table 3). Corn grown after lentils had the highest emergence of 100%. Peas, soybean, wheat and canola emergence was 86%, 84%, 84% and 82% respectively. Zero-till corn on corn residue had only 68% emergence. However, high emergence did not necessarily indicate high yields in zero till, as wheat (4085 kg/ha), mustard (3762 kg/ha) and canola (3616 kg/ha) plots yielded significantly lower than corn plots (4357 kg/ha) (Appendix 3, Figure 8).

The previous crop did not affect the corn height in either the conventional ($P=0.57$) or zero till ($P=0.43$) (Appendix 3, Table 3). Residue, in conventional treatments, did not affect days to tassel ($P=0.66$) whereas it lengthened days to silk in corn after canola and mustard ($P<0.01$). Residue in zero-till treatments had a significant effect on days to tassel ($P<0.01$) and days to silk ($P<0.01$). Canola and mustard residue elongated days to maturity in zero till.

Discussion

There was no effect on yield in corn grown on different crop residues in conventionally tilled plots. This is because conventional tillage controls residue from previous crops in addition to aerating the soil (Statistics Canada, 2015). The drawback of conventional tillage is the loss of water, soil erosion and cost of operation (Statistics Canada, 2015). Dry and windy conditions in southern Alberta cause farmers to seek soil management tools such as zero tillage. We found that grain corn yielded similarly on both conventional and zero till. Zero tillage conserves soil moisture and creates a low amount of soil disturbance, but does not control residue (Statistics Canada, 2015). Zero till yielded an average of 150 kg/ha higher, likely due to the hot and dry conditions in two of the three sites years when water conservation was crucial. Corn in zero till plots produced significantly different yields depending on the type of crop residue, whereas corn in conventional tillage showed little effect. Pulse crops such as peas, lentils and soybeans yielded the highest corn in both conventional and zero till. This is due to the nitrogen fixing properties of pulse crops in addition to low amounts of crop residue. Zero till yields were equal or greater to conventional till yields in every residue treatment except canola and mustard (Appendix 3, Table 3). Canola and mustard are non-mycorrhizal crops; therefore, fewer mycorrhizal associations can form with corn the following year (The Western Producer, 2004). This often results in reduced nutrient uptake (especially phosphorus) by corn that can result in lower yields (The Western Producer, 2004). Conventionally tilled plots did not demonstrate this effect as strongly as zero till.

Cultivation to control residue affects the quality of crop emergence. In our study, zero till received no management of residue and we cultivated conventionally tilled treatments to manage residue. The average emergence of cultivated plots was 99%. Cultivation creates a uniform seed bed for emergence and it was not surprising that the previous residue did not cause a significant difference between the percent emergence or the yield (avg. 4010 kg/ha) the following year. The zero-till plots averaged 84% emergence and showed a significant reduction in emergence due to the various residue left on the plots. Corn following corn on zero till was also among the highest yielding treatments, despite only 68% emergence in the spring. We do not recommend continuous cropping of corn because it can lead to higher disease prevalence. Also, because conventionally tilled plots were more successful at emergence (avg. 99%) than zero-tilled plots (avg. = 84%), it makes the comparison between the two more difficult. Given the dry growing conditions for much of the study, we observed that the no-till plots were much more vigorous and able to compensate with larger cobs. If we were to install floating residue cleaners, or manage the residue differently before seeding in the no-till plots, we are confident we could see comparable if not greater emergence and yield than we would in the cultivated plots.

To better to maximize yield, using zero till, we recommend that producers incorporate the use of floating residue managers in contrast to rigid residue managers. We suggest that further studies on floating residue managers and perhaps modified strip tillage would benefit agronomic practices.

Trial 4. Variety Performance

Results

Corn variety heat unit ratings did not strongly correlate with higher yields. There was a small increase in average yield with increasing corn heat units (CHU) in Lethbridge 2015 and 2016, but a decrease in yield with increasing CHU in Medicine Hat 2016 and 2017 (Appendix 3, Figures 9-12). There was a slight increase in average yield as CHU increased, but only by 250 kg/ha (Appendix 3, Figure 13). In comparison, differences in yield occurred as high as 1000 kg/ha for some varieties of the same heat unit rating. The majority of varieties (27/41) tested yielded between 3000-4000kg/ha regardless of CHU; which were between 2000 and 2500. Days to tassel (3 days), silk (4 days) and maturity (4 days) were all lengthened for all site years as CHU increased, but still varied more between varieties of the same heat unit, than between the low heat unit and high heat unit varieties (Appendix 3, Table 5-9). The date of the first frost (-2°C) was not until the first week of October for all site years of the study and did not interrupt maturity. (Appendix 3, Table 10).

Discussion

The study selected variety trials to showcase the range in seed potential traits available to farmers. We chose to use seed from the corn committee trials (irrigated) for ease of seed selection. The varieties chosen changed yearly as seed from industry became more available and made amalgamation of the data difficult; which is why we chose to present the varieties based on CHU.

In order to better see the yield response to heat units, we removed the Lethbridge 2017 site, because they were seeded later and grain yields were only approximately 25% of the other site years due to drought. We saw a slight increase in yield, days to tassel, silk and maturity as CHU increased; which is what we would expect. However, the variation in results at each CHU was far greater than the range of results from low to high CHU. This means some low CHU varieties had better yields than high CHU varieties and vice-versa. This could be confounded by the fact that individual companies have different methods of calculating heat units. So a 2050 CHU variety from one company might actually mature the same as a 2200 CHU variety from another. We were also above average CHU for the duration of this study (Appendix 2, Table 1-3). We suggest all producers growing grain corn develop a good relationship with a local retail agronomist to select for varieties known to yield well in their area and contain disease and pest resistance traits.

Conclusion

During this study, we evaluated agronomic practices that will assist producers in making the most profitable production choices such as population and spacing, fertility, crop sequencing and residue management and variety. Despite less than ideal growing conditions during this study, grain corn still produced yields that can benefit producers under irregular southern Alberta dryland conditions. We recommend that producers seed dryland grain corn on narrower rows (20”) at higher seeding rates (30,000 +seeds/ac) targeting between 50-200 lbs/ac available nitrogen for grain corn production. If using zero till, we recommend that producers manage crop residue by either raking away excess, sequencing after a low residue crops like lentils or use floating residue managers at seeding. Producers should choose a variety of grain corn based on local area average CHU to maximize yield potential. Further research might evaluate proper residue management to optimize the yield potential of zero till grain corn. Also, it could evaluate if nitrogen is more essential in the growth of grain corn under irrigated conditions.

6. Literature cited

Provide complete reference information for all literature cited throughout the report.

Andrade, F. H., P. Calviño, A. Cirilo, and P. Barbieri. 2002. Yield responses to narrow rows depend on increased radiation interception. Agron. J. 94:975-980.

Berry JA, Björkman O. Photosynthetic response and adaptation to temperature in higher plants. Annu Rev Plant Physiol. 1980; 31:491–543.

Caratti, F., Lamego, F., Silva, J., Garcia, J., & Agostinetto, D. (2016). Partitioning of Competition for Resources Between Soybean and Corn as Competitor Plant. Planta Daninha,34(4), 657-666. doi:10.1590/s0100-83582016340400005

Government of Alberta, Alberta Agriculture and Forestry, Policy and Environment, Environmental Stewardship Division, Engineering and Climate Services, Agrometeorological Applications and Modelling. (2017). Current and Historical Alberta Weather Station Data Viewer. Retrieved Dec. & Jan., 2017/2018, from https://agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp
https://agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp

Government of Manitoba. (2018). Agriculture Corn Trouble-Shooting. Retrieved January 2018, from https://www.gov.mb.ca/agriculture/crops/production/grain-corn/print,corn-trouble-shooting.html

Jeschke, M. (n.d.). Is the Future of Corn Production in Narrow Rows? Retrieved January 2018, from https://www.pioneer.com/home/site/us/agronomy/corn-production-narrow-rows/https://www.pioneer.com/home/site/us/agronomy/corn-production-narrow-rows/https://www.pioneer.com/home/site/us/agronomy/corn-production-narrow-rows/https://www.pioneer.com/home/site/us/agronomy/corn-production-narrow-rows/

Jordan, H., K. Laird, and D. Ferguson. 1950. Growth rates and nutrient uptake by corn in a fertilizer-spacing experiment. Agron. J. 42: 261–268.

Oba H, Tawaraya K, Wagatsuma T. Inhibition of presymbiotic hyphal growth of the mycorrhizal fungus Gigaspora margarita by root exudates of Lupinus spp. Soil Sci Plant Nutr 2002;48:117–20.

Pandey, R., Maranville, J., & Chetima, M. (1999). Deficit irrigation and nitrogen effects on maize in a Sahelian environment II. Shoot growth, nitrogen uptake and water extraction. Agricultural Water Management, 46(2000), 15-27. Retrieved January 2018, from https://pdfs.semanticscholar.org/ecb9/413d485e7af56d9aaf877711ad40927dbc2a.pdf.

Pedersen, P., and J.G. Lauer. 2002. Influence of rotation sequence and tillage system on the optimum plant population for corn and on soybean at post-optimal planting dates. Agron. J. 94:968–974.

Porter, P., Hicks, D., Lueschen, W., Ford, J., Warnes, D., & Hoverstad, T. (2013). Corn Response to Row Width and Plant Population in the Northern Corn Belt. Journal of Production Agriculture Abstract - Research, 10(2), 293-300. doi: doi:10.2134/jpa1997.0293

Shapiro & Wortmann. 2006. Corn response to nitrogen rate, row spacing, and plant density in eastern Nebraska. Agro. J. 98: 529.

Statistics Canada. (2015). Conventional tillage: How conventional is it? Retrieved January 23, 2018, from http://www.statcan.gc.ca/pub/16-002-x/2008003/article/10688-eng.htm

Statistics Canada. (2015). Corn: Canada's third most valuable crop. Retrieved Januar 23, 2018, from http://www.statcan.gc.ca/pub/96-325-x/2014001/article/11913-eng.htm#a1

The Western Producer. (2004). Mycorrhizae can unlock plants' potential - Organic Matters. Retrieved January 16, 2018, from https://www.producer.com/2004/07/mycorrhizae-can-unlock-plants-potential-organic-matters/

7. Benefits to the industry (max 1 page; respond to sections *a)* and *b)* separately)

a) Describe the impact of the project results on Alberta's agriculture and food industry (results achieved and potential short-term, medium-term and long-term outcomes).

This project generated knowledge of corn agronomics and crop management that will help southern Alberta crop producer adopt this crop into rotations. Local producer questions prior to the study included: Can I make money growing grain corn? Will it survive/reach maturity? Can I grow it on dryland? Can I use conventional equipment such as air drills? How do I fit this into my rotation? What's the ideal row spacing/fertilizer rates and many more?

Our research allows us to answer many of these questions and provide recommendations to producers currently growing or wanting to grow grain corn. It supports the production of dryland grain corn in southern Alberta, however cautions that extreme drought conditions may significantly impact yields. It also supports production in a zero-till system with equal or better success than a conventional system. Data indicates that fertilizer requirements for dryland grain corn are not as high as previously thought, versus an irrigated crop. Farming Smarter will recommend using a higher seeding rate and narrower row spacing than producers may currently use.

We increased producer awareness, agronomic knowledge and management skills for grain corn production in southern Alberta and identified issues that will require further study.

b) Quantify the potential economic impact of the project results (*e.g.,* cost-benefit analysis, potential size of market, improvement in efficiency, etc.).

In 2017, Alberta growers planted 60,000 acres of grain corn, an increase of 140% over acres grown in 2016. Compared to agronomic practices for growing irrigated corn: Seeding on 20” rows at 35,000 seeds/ac (93 bu/ac) vs 30” rows at 20,000 seeds/ac (74 bu/ac) increased yield a total of 19bu/ac or 26%. Fertilizing to a total of 100lbs/ac total N instead of 150 lbs/ac total N would save $11/ac in fertilizer costs. Growing grain corn in a no-till system, on pulse stubble would give an additional 7% in yield, compared to growing under conventional tillage in a field previously seeded to corn. Choosing a high yielding variety could also improve yield as much as 25% (3000kg/ha vs 4000kg/ha). The grand total of these savings is estimated to be:

Yield 60,000ac X 19 bu/ac increase @ $4/bu = $3.02 million additional yield
Fertilizer 60,000ac X $11/ac savings = $6.60 million savings
Stubble/system 60,000ac X 19 bu/ac X 7% @ $4/bu= $4.88 million additional yield
Variety 60,000 ac X 19 bu/ac X 25% @ $4/bu = $5.70 million additional yield

By following these recommendations, there is a potential for dryland grain corn producers to earn an additional $20.2 million dollars per year.

8. Contribution to training of highly qualified personnel (max ½ page)

Specify the number of highly qualified personnel (*e.g.*, students, post-doctoral fellows, technicians, research associates, etc.) who were involved in the project.

Farming Smarter (15)
AAFC (8)
Alberta Agriculture (6)
Monsanto (2)
Pioneer (2)

9. Knowledge transfer/technology transfer/commercialisation (max 1 page)

Describe how the project results were communicated to the scientific community, to industry stakeholders, and to the general public. Organise according to the following categories as applicable:

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

None yet.

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

This project resulted in the publication of seven magazine articles in Farming Smarter magazine that goes to 10,000 rural addresses and unlimited digital users. We had three news posts on the front page of the website that averages 49,344 page views per year. These posts also automatically Tweet to almost 5,000 followers. There were 12 presentations at conferences, meetings and workshops, and seven videos published for the Farming Smarter Video Library and YouTube channel that has over 1000 views and over 121 hours watched.

Farming Smarter has an established and successful extension program that ensures producers and agricultural stakeholders in Alberta have access to unbiased, innovative farm business knowledge. Our strategy incorporates Farming Smarter magazine, a monthly E-newsletter, our website, YouTube Channel, in-person events, media relations and social media. Last year Farming Smarter reached over 3.5 million people through all these outlets and provides a value of $864 million to the industry.

Magazine Articles (most recent first)

1. Dry Soil Hampers Corn, Farming Smarter Magazine, Fall 2017, page 24. https://issuu.com/fbcpublishing/docs/1710272131106fff57471f324c4cb68dd648a2d0c60f
2. Grain Corn Offers Opportunity, Sarah Redekop, Farming Smarter Magazine, Fall 2017, page 27. https://issuu.com/fbcpublishing/docs/171027213110-6fff57471f324c4cb68dd648a2d0c60f
3. Learning in the Field at Farming Smarter, Farming Smarter Magazine, Spring 2017, page 11. https://issuu.com/fbcpublishing/docs/170301003255-494701e6c3c64202b1a4a0d4bfeb0de0
4. Dryland Grain Corn can fit Prairie Rotations, Lee Hart, Farming Smarter Magazine, Spring 2017. Page 24 - https://issuu.com/fbcpublishing/docs/170301003255-494701e6c3c64202b1a4a0d4bfeb0de0
5. Grain Corn Project Surprises Researchers, Alexis Kienlen, Farming Smarter Magazine, Spring 2016, page 26. https://issuu.com/fbcpublishing/docs/160310163257-dc93dfb285ea4380a7d401167cd3878f/26
6. Alberta Crop Industry Development Fund (ACIDF), Kristi Cox, Farming Smarter Magazine, Fall 2015, pg 12. https://issuu.com/fbcpublishing/docs/151027192208-b348df3e6f2c4134bd5a2873324d18fe
7. Corn on Deck for Rotations, Helen McMenamin, Farming Smarter Magazine, Spring 2015, pg 8- 9. http://issuu.com/fbcpublishing/docs/150306174601-0b49c294569d49099b92c3a7dc8ff215/1?e=2726637/11898433

News Post (most recent first)

1. Higher Seeding Rate Helps Grain Corn, Barb Glen, The Western Producer—2017. https://www.farmingsmarter.com/wp-content/files/2018/01/WP-Higher-seeding-rate-helps-grain-corn.pdf
2. Farming Smarter brings Innovation Together, Tim Kalinowski, Medicine Hat News—July 7, 2017. https://www.farmingsmarter.com/wp-content/files/2012/10/MHN-Farming-Smarter-brings-innovation-together.pdf
3. Cypress County impress in Medicine Hat, Farming Smarter – July 14, 2016. http://www.farmingsmarter.com/farming-smarter-cypress-county-impress-medicine-hat/

c) Scientific presentations (e.g., posters, talks, seminars, workshops, etc.)
d) Industry-oriented presentations (e.g., posters, talks, seminars, workshops, etc.)

Presentations (most recent first)

1. Farming Smarter Conference, Lethbridge, December 5, 2017
2. Farming Smarter Conference, Medicine Hat, October 26, 2017
3. Medicine Hat Field Day, Cypress Field site, July 6, 2017
4. Lethbridge Plot Hop, FS Dryland, June 8, 2017
5. Planter Clinic, Farming Smarter shop, March 7, 2017
6. Stamp Seeds Workshop, Enchant, December 16, 2016
7. South Country Co-op training webinar, December 14, 2016
8. Farming Smarter Conference, Medicine Hat, December 7-8, 2016
9. Lethbridge Rachel Harder tour, Lethbridge area, August 31, 2016
10. College Student Tour, Lethbridge field site, September 6, 14, 20 & 27, 2016
11. South Country Co-op training day, Lethbridge field site, July 19, 2016
12. Medicine Hat Field Day, Cypress field site, July 14, 2016
13. Medicine Hat Workshop, Medicine Hat Lodge, October 22, 2015

e) Media activities (e.g., radio, television, internet, etc.)
Videos (most recent first)

1. Kenny Crack Corn, Ken Coles, Lethbridge Farming Smarter Conference- December 5, 2017: https://youtu.be/ZE2VWwv8FYw
2. Planting Cornola, Ken Coles, Cypress Farming Smarter Conference- October 26, 2017: https://youtu.be/OV2WHVOW6GA
3. Precision Planting Corn in Southern Alberta, Ken Coles, 2017 Cypress Field Day- July 6, 2017: https://youtu.be/Mj8qGYauFJU

4. Using a Precision Planter to Plant Canola, Corn and Wheat, Ken Coles, Field School 2017-
   June 27-29, 2017: https://youtu.be/3YlX6hfYVOg
5. Growing Grain Corn in Southern Alberta, Ken Coles, 2017 June Plot Hop- June 8, 2017: https://youtu.be/eTBSx_q5U7o
6. Cornucopia, Ken Coles, 2016 Cypress Conference- Dec 6: https://youtu.be/Akd7Ycs8f4g
7. Grain Corn Agronomy for Southern Alberta, Lloyd van Eeden Petersman, 2016 Cypress Field Day- July 14, 2016: https://youtu.be/O4D9HAJh_Vw
8. Dryland Corn Update, Ken Coles, 2015 Medicine Hat Workshop – October 22, 2015: https://www.youtube.com/watch?v=4tewRkbuJP4

f) Any commercialisation activities or patents

No

N.B.: Any publications and/or presentations should acknowledge the contribution of each of the funders of the project.

Section D: Project resources

1. **Statement of revenues and expenditures:**
   a) **In a separate document certified by the organisation's accountant or other senior executive officer, provide a detailed listing of all cash revenues to the project and expenditures of project cash funds.** Revenues should be identified by funder, if applicable. Expenditures should be classified into the following categories: personnel; travel; capital assets; supplies; communication, dissemination and linkage; and overhead (if applicable).

Reporting period	Source	Type	Personnel	Travel	Capital Assets	Supplies	CDL*	Other	Total
Year 1	ACIDF	Budgeted	$34,735.00	$1,085.00	$39,376.00	$3,799.00	$2,770.00	$11,885.00	$93,650.00
Dates: 2015/04/01		Spent	$34,735.00	$1,085.00	$39,376.00	$3,799.00	$2,770.00	$11,885.00	$93,650.00
to 2016/03/31	Gov't	Cash							$0.00
		In-kind							$0.00
	Industry	Cash	$6,450.00	$200.00	$0.00	$750.00	$1,400.00	$1,200.00	$10,000.00
		In-kind	$22,441.00	$690.00	$0.00	$2,417.00	$1,381.00	$7,596.00	$34,525.00
Total Spent for Period 1			**$63,626.00**	**$1,975.00**	**$39,376.00**	**$6,966.00**	**$5,551.00**	**$20,681.00**	**$138,175.00**
Year 2	ACIDF	Budgeted	$52,367.00	$1,637.00	$0.00	$23,645.00	$4,176.00	$14,850.00	$96,675.00
Dates: 2016/04/01		Spent	$52,367.00	$1,637.00	$0.00	$23,645.00	$4,176.00	$14,850.00	$96,675.00
to 2017/03/31	Gov't	Cash							$0.00
		In-kind							$0.00
	Industry	Cash	$6,450.00	$200.00	$0.00	$1,950.00	$1,400.00	$0.00	$10,000.00
		In-kind	$50,034.00	$1,538.00	$0.00	$5,388.00	$3,079.00	$16,936.00	$76,975.00
Total Spent for Period 2			**$108,851.00**	**$3,375.00**	**$0.00**	**$30,983.00**	**$8,655.00**	**$31,786.00**	**$183,650.00**
Year 3	ACIDF	Budgeted	$52,367.00	$1,637.00	$0.00	$23,645.00	$4,176.00	$14,850.00	$96,675.00
Dates: 2017/04/01		Spent	$52,367.00	$1,637.00	$0.00	$23,645.00	$4,176.00	$14,850.00	$96,675.00
to 2017/12/31	Gov't	Cash							$0.00
		In-kind							$0.00
	Industry	Cash	$6,450.00	$200.00	$0.00	$1,950.00	$1,400.00	$0.00	$10,000.00
		In-kind	$50,034.00	$1,538.00	$0.00	$5,388.00	$3,079.00	$16,936.00	$76,975.00
Total Spent for Period 3			**$108,851.00**	**$3,375.00**	**$0.00**	**$30,983.00**	**$8,655.00**	**$31,786.00**	**$183,650.00**
Period 4	AFC	Budgeted							$0.00
Dates: yyyy/mm/dd		Spent							$0.00
to yyyy/mm/dd	Gov't	Cash							$0.00
		In-kind							$0.00
	Industry	Cash							$0.00
		In-kind							$0.00
Total Spent for Period 4			**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
Period 5	AFC	Budgeted							$0.00
Dates: yyyy/mm/dd		Spent							$0.00
to yyyy/mm/dd	Gov't	Cash							$0.00
		In-kind							$0.00
	Industry	Cash							$0.00
		In-kind							$0.00
Total Spent for Period 5			**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
CUMULATIVE AFC CASH SPENT			$139,469.00	$4,359.00	$39,376.00	$51,089.00	$11,122.00	$41,585.00	$287,000.00

***Communication, Dissemination, and Linkage**

b) Provide a justification of project expenditures and discuss any major variance (*i.e.*, ± 10%) from the budget approved by the funder(s).

2. Resources:

Provide a list of all external cash and in-kind resources which were contributed to the project.

Total resources contributed to the project		
Source	**Amount**	**Percentage of total project cost**
Funders	$287,000	57%
Other government sources: Cash		%
Other government sources: In-kind		%
Industry: Cash	$30,000	6%
Industry: In-kind	$188,475	37%
Total Project Cost		**100%**

External resources (additional rows may be added if necessary)		
Government sources		
Name (only approved abbreviations please)	**Amount cash**	**Amount in-kind**
ACIDF	$287,000	$0
Industry sources		
Name (only approved abbreviations please)	**Amount cash**	**Amount in-kind**
DuPont Pioneer	$30,000	$0
Farming Smarter	$0	$76,975

Section E: The next steps (max 2 pages)

Describe what further work if any needs to be done.

a) Is new research required to deal with issues and opportunities that the project raised or discovered but were not dealt with within the current project?

We need further research in crop sequencing. The emergence differences with different residues on the zero till plots surprised us. We believe that because moisture is a limiting factor and zero till offers better moisture retention, research into different residue management options can benefit grain corn production in southern Alberta.

John Deere Corp acquired Monosem and will likely develop new seeding equipment as corn and soybeans move west across the prairies.

Earlier studies demonstrated that corn production in rain fed conditions is feasible in southern Alberta. However, many questions remain regarding optimum planting systems, seeding date and hybrid maturity classes that would give consistently high yields. While it may be tempting to use intensive tillage, it is important to maintain a conservation tillage approach to prevent erosion and maintain soil health. Strip tillage refers to the practice of tilling a 6-8-inch-wide area for each row of corn. This practice would maintain good overall ground cover, while providing better seed-to-soil contact, warmer temperatures, and reduced N immobilization. Ontario and USA widely use strip tillage for corn production, but we have little experience with it in our region.

Corn stalks are larger and tend to break down slower than many other crop residues. Excessive corn residue can reduce emergence, growth and yield of some following crops depending on environmental conditions. Crop residue could be addressed with complete stubble burying, vertical-tillage, strip-tillage, flail mowing, and stubble bailing, but we need more research in this region to determine best management practices.

b) Is there related work that needs to be undertaken to continue advancement of the project technology or practice?

In the variety trial, we discovered a large range in yields based on variety and location. Currently, private companies submit varieties for testing through the Alberta Corn Committee irrigated trials, but there are no trials that we know of comparing varieties under dryland conditions in southern Alberta. It would be worth correlating our dryland results to irrigated results to see if the varieties yield the same way.

c) Did the project identify any new technology or practice that needs to be developed?

Residue managers for vacuum planters would improve zero-till operation in general.

d) What suggestions do you have that increase commercial use of results by farmers and/or companies.

These may be:

1. commercial uptake.

2. further research toward commercial use.

3. extension and information disbursement.

Wide scale adoption will require several components and need to be a step wise process. On farm risk management is usually a critical issue that needs to be addresses. Most important would be the development of more commercial data for grain corn in order to properly insure crops with regional data. Good baselines are critical to help farmer manage the risk in growing a new crop with variable climate patterns.

Continued knowledge transfer will facilitate the adoption of best management practices however, appropriate equipment development and adaptation will be critical in order to achieve optimum yields. This includes narrow row implements with the ability to deal with residue in zero-tillage systems and grain carts to administer appropriate fertilizers in a one pass seeding operation. Grain corn headers that can harvest narrow rows and grain dryers will also be important for success.

Clearly defined markets beyond just being a feed stock will also be important.

Section F: Research Team Signatures and Employers' Approval

The team leader and an authorised representative from his/her organisation of employment MUST sign this form.

Research team members and an authorised representative from their organisation(s) of employment MUST also sign this form.

By signing as representatives of the research team leader's employing organisation and/or the research team member's(s') employing organisation(s), the undersigned hereby acknowledge submission of the information contained in this final report to the funder(s).

Team Leader's Organisation

Team Leader	
Name: Ken Coles	Title/Organisation: General Manager, Farming Smarter
Signature:	Date: January 29, 2018
Team Leader's Employer's Approval	
Name: Doug Brodoway	Title/Organisation: Chairman, Farming Smarter
Signature:	Date: January 24, 2018

Research Team Members (add more lines as needed)

1. Team Member	
Name:	Title/Organisation:
Signature:	Date:
Team Member's Employer's Approval	
Name:	Title/Organisation:
Signature:	Date:

2. Team Member	
Name:	Title/Organisation:
Signature:	Date:

Team Member's Employer's Approval	
Name:	**Title/Organisation:**
Signature:	**Date:**