DRAFT: Changes in Crop Production and Implications for Research
Summary from Online Workshops – What was heard
July 20-22, 2021

Introduction

As part of its 40th anniversary WGRF is reviewing its cross-cutting crop research funding priorities. We began in the winter of 2021 by contracting Drs. George Clayton and Stephen Morgan Jones of Amaethon to gather views on changes in crop production and the most pressing current and anticipated crop production issues affecting farmers. Farmers, agronomists, scientists and industry provided their views on the future of western Canadian field crop production in the short (5 year) and longer term (10- 20 years). This culminated in the Amaethon Report 'Survey on Future Changes in Crop Production on Prairie Farms and Implications for Research' https://wgrf.ca/special-initiatives/future-field-crop-research-needs- and-funding/.

With the aim of identifying the implications for research (research questions) associated with the issues identified in the Amaethon Report, WGRF then hosted half day Virtual Workshops on July 20th – 22nd, 2021. Since provincial Crop Commissions/Associations develop crop specific research interests and share these with WGRF through other means, crop-specific research issues were out of scope in this process. Instead, participants were asked to focus on the cross-cutting crop production issues identified in the Amaethon Report. "Cross-cutting crop production issues" were considered to be those common to at least two or more of the fifteen crops eligible for WGRF funding (barley, canaryseed, canola, chickpea, corn, fababean, flax, lentil, mustard, oats, pea, soybean, sunflower, wheat and winter cereals).

The workshops focussed on the following themes and sub-themes identified in the Amaethon Report:

July 20: Crop and Soil Management (weeds, diseases, insects, plant nutrition)
July 21: Precision Agriculture (variable rate, soil management zones, data)
July 22: Sustainability (cropping systems, diversified crops, climate change)

Each workshop consisted of a plenary session which provided an overview of the thematic areas as discussed in the Amaethon Report, and breakout discussions for each sub-theme. With the assistance of a pre-assigned moderator and note-taker, participants (see listing in Appendix A) were asked to describe the implications for research (research questions) associated with the cross-cutting crop-production issues identified in the Amaethon Report.

This document summarizes the workshop discussions for each sub-theme. It lists the *Crop Production Issues*, including those identified by the Amaethon Report, and those that arose during workshop discussions. This is followed by the *Implications for Research* as identified by the participants, which formulates the identified issues into associated research questions and

suggests the directions for agricultural research to contribute to addressing the cross-cutting issues. Note that participants were not asked to prioritize these implications, as WGRF will do this later in consultation with member organizations.

I would like to express my appreciation to the 107 participants and volunteers in WGRF's workshop series on cross-cutting crop production issues and implications for research. The following document is a draft that summarizes what was heard.

We are seeking comments on this draft document by Monday September 27th. It is also available on our website at https://wgrf.ca/wp-content/uploads/2021/08/WGRF-Research-Workshop-Summary.pdf Please email your comments to patflaten@wgrf.ca

The final version will be shared on our website and will contribute to WGRF's research priorities for cross-cutting crop production issues.

Sincerely,
Garth Patterson
Executive Director
August 31, 2021

Theme: **Crop and Soil Management**
Sub-Theme: **Plant Nutrition (2 groups)**

Crop Production Issues (from Amaethon Report and additional issues identified in workshop)

- Increased regulation of fertilizers and manure – effects on nutrient management and recommendations
- Need for increased efficiencies
- Need for verification and/or updated nutrient removal rates and fertilizer recommendations
- Soil testing and subsequent nutrient recommendation refinements and/or update for alternative management practices
    - Crop demand of high yielding crops, or in a climate change scenario
- New technologies for 4R nutrient stewardship (source, rate, placement, time)
    - Biotechnology solutions?
    - N-fixing non-legume crops, on-farm source of nutrients, plant/soil/microbe interactions
- Harnessing the power of soil microbes
- Climate change impacts
- Encouraging soil resilience
- Soil acidification
- Integration of practices
    - Crop and soil management

Implications for Research

Crop production within increased regulation of crop nutrients (manure and fertilizer)

- How do we increase nutrient efficiency further? – different chemical forms, product timing, rate and placement of fertilizer
- Regulations in some areas, such as MB with manure application, are being managed successfully, may need to adapt these practices to other localities
- How do we anticipate the issues? Surveillance, soil testing, microbial populations?
- Is there cross-over between livestock nutrition and manure management, or on-farm treatments of manure for benefit of crop production?
- Fine tune fertilizer recommendations for various local conditions and crops
- Adapt the wealth of research done in the past for today's context through new research and knowledge transfer

Need for increased nutrient use efficiencies (NUE):

- Develop tools to help identify NUE in plants
- Multidisciplinary approaches (soil science, microbial, plant architecture) to genetic improvements Important to conserve other plant traits while increasing NUE

- NUE targets and potential? Have uptake efficiencies reached a plateau? How about utilization efficiencies? Are there preferential uptake efficiencies for organic or other fertilizer options? Where can the incremental changes increase NUE?
- Are there particular cultivars which can take advantage of high N environment?
- Increasing N uptake by mixing N-fixing crops with non-fixing crops in intercropping?
- Cropping system considerations
- New or adapted crop growth models for nutrient management recommendations. Opportunities to integrate new models into APPS, IT tools for management practices and decision-making

Verification and potential update of fertilizer recommendations and nutrient removal rates:

- Many scenarios to capture in a prediction of response
- Update recommendations to reflect current yield potential and management practices (direct seeding), nutrient sources, nutrient removal rates. Need ongoing and consistent, proactive effort and capacity to update recommendations.
- Greater emphasis to be given on recommendations across the full rotation.
- Recommendations need to reflect variations in specific environmental considerations, needing long-term study over multiple sites and inclusion of multiple disciplines
- Acidification of soils – do we know how prevalent and the impacts of change of soil pH in western Canada? Is there a need for more work on liming? How does soil acidification affect NUE, crop disease and other production aspects?
- Integrate risk of range of weather considerations
- Can soil spectroscopy be used to measure the impacts on field management, zone management for digital mapping, precision agriculture applications, nutrient/water/pesticide management?
- Overall update likely needed for higher yields and different crops currently grown
- Update information to account for N-fixing potential by legumes, including a longer duration consideration (more than one year) and interactions with residue and tillage impacts
- Account for application technologies for top-dressing and split applications

Nitrogen (N):

- Breeding and selections for ammonium-tolerant lines, N use efficiency
- Mobilization of N sources within the plant
- Fertilizer source and placement options

Phosphorus (P):

- Implications of lower soil pH and P use – if soils are becoming more acidic, the P-use efficiency may be declining. Is this an issue in Western Canada and if so, how do we adapt in order to enhance P use efficiency?
- Given the finite supply of P worldwide, what are the new sources of P?
- Phosphorus accumulations and re-use in form of biochar

- Due to current direct seeding norm, P may be stranded in a shallow soil layer, therefore, should we be adapting the root architecture and management technologies to mine that P?

Soil testing:

- Further development of on-site nutrient (N, in particular) testing so as to better synchronize nutrient applications to crop use
- Is there a need to improve the P soil test?
- Testing for soil function

Plant tissue testing:

- Further development of plant tissue data to inform plant tissue testing for deficiency levels for micro and macro-nutrients

Fertilizers:

- Are slow release/coated fertilizers viable options for this region?
- Will nanotechnologies of fertilizer coatings be viable for this region?
- How has increased fertilizer use affected fertilizer use efficiencies at a landscape level?

Increasing soil resiliency:

- How to improve soil organic matter and beneficial soil microbes?
- Assess the use of tillage and its effects on the soil microbiome
- Develop and further understand short term indicators so we know we are going in the right direction when exploring and adopting new management practices
- Capture the value of soil quality work for future adaptation
- Better understanding of the relationship between soil health and nutrient use efficiencies
- Greater understanding of microbial functions in nutrient transformations and residue breakdown
- Can soil spectroscopy be used to predict microbiome, leading to no longer needing to extract and profile DNA and allowing better prediction of microbial function?

Salinity:

- How can salinity-prone areas be better utilized?
- Is breeding for saline-tolerance a viable option?

Climate change:

- If the growing season becomes hotter, drier and extended, how do we take advantage of that and how will fertilizer recommendations need to be adapted?
- Implications for the need for/pros and cons/management of cover crops?
- Implications for oil biosynthesis i.e., canola under drought conditions?

- Are there genetic or management options to maintain grain quality considering the dilution effect caused by increasing C concentration?
- Implications for the soil microbiome due to elevated CO_2?
- How do current crops and fertilizers behave differently under elevated CO_2?
- Bring together multidisciplinary teams to be predictive in approach
- Alternative fertilizer and nutrient management practices to reach lower GHG targets
- FACE (free-air carbon enrichment) projects – required for better understanding of impact of CO_2 at field-scale. Apply consistent CO_2 for predictive analysis of future environmental conditions (climate change)

Root: soil interface:

- What is the role of roots and root architecture in nutrient uptake and can roots be significantly enhanced with crop breeding and/or harnessing the root microbiome and rhizosphere dynamics?
- What crop-root rotations ('functional trait diversity') could assist with increasing nutrient use efficiencies and mining legacy nutrients stranded in different soil layers (i.e., P in shallow soil, N in deeper soil)?
- How do we replace nutrients currently harvested and exported – are there viable crop management systems which will assist with replacement of nutrients?
- Is synthetic biology an area to explore for microbiome work?
- Use a multidisciplinary approach to get a basic understanding of the soil microbiome and its functions
- Get a better understanding of free-living N fixing bacteria
- Management of cover crops and intercrops and their impact on soil microbiome, nutrient retention, N leaching and crop production

Knowledge transfer:

- Encourage soil testing
- Recommendations for nutrient management across a full crop rotation, such as development of P recommendations to account for toxicities related to narrow placement

Theme: **Crop and Soil Management**
Sub-Theme: **Insects (1 group)**

Crop Production Issues (from Amaethon Report and additional issues identified in workshop)

- Reduced or lack of availability of insecticides
    - Loss of seed treatments
    - Lack of new chemistry
- Resistance breakdown
    - Resistance reduces availability of solutions (ie. SM1 gene for midge)
    - Increasing insect pressure
- Beneficial insects/economic thresholds
- Alternative management practices
    - Biotechnology solutions
    - New technologies
- Surveillance and forecasting outbreaks
    - Climate change/ areas of adaptation
- Integration of practices
    - Next generation IPM

Implications for Research

Beneficial insects:

- Expand knowledge of the benefits of beneficial insects and the implications of the loss of beneficial insects (economic value would be useful). The information generated can be useful for a variety of purposes, including building Dynamic Action Thresholds (adding the effects of existing natural enemies to economic threshold decision-making tools)
- What is the economic benefit of shelterbelts, smaller fields, maintaining field margins and wetlands, given their importance to diverse insect populations?
- How does intercropping affect insect pests and beneficial insects? What are the economic thresholds of intercropping mixtures?
- Will self-driving field equipment lead to further reductions in field margins or will this technology facilitate smaller fields and smaller zones of management (i.e., DOT technology has potential for encouraging smaller equipment)?

Economic thresholds

- Further validate/develop existing economic thresholds for applying insecticides for the control of insect pests and as above, add beneficial insects as a factor

Surveillance and forecasting outbreaks:

- Need to expand the number of insect pests which are monitored on the prairies on a regular basis
- Need to expand the number of insects included in models for forecasting outbreaks

- Need more research in specific insect biology, behavior, impacts in order to expand the models and the monitoring of insect pests and beneficials.
- Are there automated trap technologies which could be developed or adapted to assist with monitoring insect pests and beneficials? Are smart traps effective? If they are, they could boost the surveillance program.
- Is the resolution/sampling size of current monitoring efforts of sufficient scale to avoid over- or under-reporting of issues?

Integration of practices and research:

- How much insecticide is applied which is unnecessary, how much is not applied which is necessary? (Knowledge transfer issue and scouting issue)
- What are the multi-year implications of applying particular insecticides on a single farm or field in a single year or multiple years?
- How much do insects move across multiple fields and crops – develop new tools to monitor on larger scale. What is the effect of smaller fields on insect movement?
- How do insects and control measures affect other elements of crop production, including agronomic practices (crop rotations, etc) and systems and vice versa? This level of research likely requires larger scale research and multiple research disciplines.

Alternative control technologies:

- How can RNAi be used as a new tool to control pest species?
- How well is RNAi research connected to practical application in the field? Is it ready to be 'translated' to field research and application and if it were to be, are the 'translation scientists' in place?

Knowledge transfer:

- Train agronomists and farmers to identify insects and to differentiate between beneficials (i.e., pollinators, parasitoids, beetles eating weed seeds) and pests
- Train agronomists and farmers in the use of and value of economic thresholds
- Expose scientists to the decision-making process on the farm
- Expand the reach of the Prairie Pest Monitoring Network website so that information can be easily found by more farmers and agronomists

Theme: **Crop and Soil Management**
Sub-Theme: **Weeds (2 groups)**

Crop Production Issues (from Amaethon Report and additional issues identified in workshop)

- Reduced herbicide availability
    - Loss of pre-harvest glyphosate or glyphosate in general (ie. New Brunswick)
- Herbicide resistance
    - Current/Potential weed problems (ie. Kochia, wild oat)
    - Resistance reduces herbicide availability
- New imported weeds or increased prevalence due to changing conditions
    - Proliferations of wind dispersed species across all provinces such as spring annual, winter annual cycle (e.g. Canada Thistle, sow thistle, dandelion, narrow-leaved hawksbeard)
- Alternative management practices
    - Lack of new chemistry
    - Biotechnology solutions?
    - New technologies
- Surveillance
- Integration of practices
    - Next generation IWM?

Implications for Research

Reduced herbicide availability:

- If glyphosate is a tool that is lost, we need to be ready, by developing options to potentially replace glyphosate as a tool in direct seeding and as pre-harvest application
- What is the impact of the potential loss of glyphosate on sustainability, soil conservation, agronomic practices, the environments and economics? How do alternative control options fit with the benefits of a direct seeding system?
- Perennial weeds: What is the potential for managing perennial weeds pre-harvest in patches, without glyphosate? What impact does that have on MRL's? What non-herbicide options could be adopted for managing perennial weeds in annual crops?
- How can the direct seeding system be adapted to protect efficacy of glyphosate?
- Are there alternative chemistries available elsewhere that should be considered in Western Canada?
- Given potential loss of glyphosate and other herbicides, are there new chemistries/modes of action, cultural/alternative/integrated methods or biological approaches which can be used to adapt current crop production systems?

Herbicide Resistance:

- What are the current weed and herbicide resistance problems and what are the potential herbicide resistance problems? All require continued surveillance of weeds and novel resistance: biotypes, proactive testing of high-risk weeds and situations.

- What weeds will be the largest problem in a glyphosate free system? Determine which ones we should focus on for developing alternative controls.
- Develop rapid diagnostic testing of resistance
- Develop understanding of where field resistance is happening
- Are multiple stack trait crops helpful in managing resistance?
- Develop understanding of the basics of resistance development, the evolution of resistance. This will likely need collaborations with basic sciences such as biology and genomics, etc.
- Widen the research on weeds other than wild oat and kochia, such as volunteer canola, cleavers, wild mustard, etc.
- What are the impacts of herbicide resistance on crop rotation? E.g. wild oats in oats

Alternative Management Practices, given lack of new chemistry:

- Prevention of seed bank production, management of weed seed banks without impacting the crop
- Is crop rotation diversity helping? Are we managing diverse crop rotations well?
- Do we know everything we need to know about the biology of weeds, e.g. wild oats and kochia, so as to develop methods of control?
- Are there ways to influence the viability of weed seeds to shorten their viability in the soil, or avoid viable seed production?
- Are there strategic times in the weed life cycle to control them better? Can we target alternative life stages of the weeds through crop rotations or other means?
- What mechanical controls work best, is that equipment available or does it need to be invented, and can more precise mechanical control be established, using precision AI?
- How can organic practices be adapted for mainstream crop production?
- How can insects be harnessed to control weed issues?
- What are the levels of control of weeds required to benefit the system as a whole – weighing out weed management vs weed elimination? Are there benefits to having some weeds in the system, such as benefitting soil microbiology for instance?
- What can we expect for weed management under climate change scenarios?
- Is there potential for benefits in gene editing, CRISPR in managing weeds?
- Is there potential for advancing precision technologies such as interrow tillage and spraying, electrical weeding, digital phenotyping, robotics and machine learning to identify weeds in the field?
- Could sterile pollen be used to prevent production of viable seed?
- What are the impacts of novel technologies on other aspects of the cropping system such as the crop, insects or diseases?
- Can intercrops and/or cover crops be successfully implemented in western Canada and what will the effects be on weeds and weed control options?
- What are the barriers to adoption of mechanical weed control?
- Are there opportunities to simplify integrated weed control systems?
- What are the potential applications of RNAi for weed management?

- Can we improve the competitiveness of the system, both temporally and spatially to avoid weed issues?
- Could the use of companion crops compete with/take the place of weeds?
- Could allelopathy be integrated into crop genetics to discourage weed growth?
- Are bioherbicides an option?
- For all alternative practices, including tillage, can they be adapted to retain the benefits of direct seeding, while controlling the weeds? What are the economic, environmental and agronomic impacts of adopting alternative practices?

Surveillance:

- Weed surveys have been and will continue to be a critical tool in western Canada. Are we doing enough and if not, what more do we need? Do we need more involvement and collaborations between researchers, producers and agronomists? Could 'citizen science' be adapted in a more proactive networked way?
- Would dockage at local grain collection points be useful information?
- Can methodology be improved and if changed, how do trends in time continue to be tracked? Can historical data be used to answer new questions?
- Assess the value and potentially develop DNA barcoding for managing imported seeds to more quickly identify weed species of concern
- Develop and assess remote sensing/drone capability for detecting novel resistance
- Assess priorities for weed surveillance – should it be limited to novel introductions, novel resistance, expansion of range?
- Where are the vulnerabilities to weed importation?
- Develop better understanding of selection pressure, spatial aspects of resistance within a field
- What is the best way to proactively detect novel resistance?
- Does climate change affect how surveillance should be approached?

Integration of Practices:

- Improve existing and new crop cultivar competition against weeds or crop tolerance to weeds, through weed scientist collaborations with crop breeders
- Explore possibility of identifying naturally occurring sources of weed tolerance/competitiveness/resistance to introgress into crops
- Design research to measure the cumulative effects of different methods
- Find ways to integrate weed management practices with precision technologies such as weed patch management by using increasing seeding rates, grazing, mowing in patches, to catch them prior to field-scale issue.

Knowledge Transfer:

- Practices to manage and prevent/reduce resistance development
- Better understanding of the impacts of herbicide resistance, avoiding it, and managing it

- Find ways to increase the adoption of Integrated Weed Management practices – many of the answers to avoiding herbicide resistance are already known, therefore, how to change practices with powerful messaging?

Theme: **Crop and Soil Management**
Sub-Theme: **Diseases (3 groups)**

Crop Production Issues (from Amaethon Report and additional issues identified in workshop)

- Reduced or lack of availability of fungicides
    - Varietal resistance through breeding
    - Loss of seed treatments
    - Lack of new chemistry
- Increasing disease pressure
- Resistance breakdown
    - Fungicide/bacterial resistance reduces availability of solutions
- Alternative management practices
    - Biotechnology solutions?
    - New technologies
- Surveillance
- Integration of practices
    - Next generation IPM?
- Knowledge transfer

Implications for Research

Reduced or lack of availability of fungicides:

- Need for third parties to test for efficacy in conditions of regions of western Canada
- Explore modes of action including mobilizing/leveraging local microbiome and biocontrol products
- Consider testing fungicides used in other jurisdictions, minor use evaluations
- Track the efficacy of fungicides, starting with a baseline, then proactively tracking in time
- How are fungicides affecting the soil/root microbiome and soil health? How is the microbiome impacting disease and growth stimulation?
- Should seed treatments be applied more strategically and if so, when would they be used, what will affect the decision-making matrix for this application?

Varietal resistance through breeding:

- Continue to explore genomics and genomic evolution
- Seek new sources of resistance and mycotoxin reductions via related yet genetically distant plant species and supporting breeding tools to assist in speeding up this process
- Understand mechanisms of virulence and plant resistance and transfer these mechanisms between crops
- Understand the role of crop rotation to maintain resistance
- Deeper understanding of pathogen species and plant resistance levels/mechanisms to these different species
- Ergot issues in winter cereals needs long term sustained research:

  - Needs integrated evaluation of multiple crops for ergot and other diseases which have multiple hosts
  - Transfer learnings from major to minor and minor to major crops

Understanding crop diseases:

- Understanding of population genetics and genetic evolution especially for both soil-borne and airborne pathogens
- Understanding vectors of pathogen infection and disease spread
- Understanding the effect of tillage, soil health and soil acidification on diseases
- Understanding how crop root architecture influences disease

Climate change impacts:

- How does climate change, especially temperature, impact the plant's ability to resist disease or susceptibility?
- How will climate change affect the overwintering of pathogens?

Alternative management practices:

- Integration of practices:
  - Better understanding of the suite of mechanisms (IPM: such as seed selection, scouting, fungicide use, crop rotations, crop sequences (including short and longer-term economics) and their roles and combined effect, to help farmers and agronomists with decision-making
  - Integrations of disease management with other integrated management practices
- How do new crops and management practices affect crop diseases (including intercropping, extended crop rotations, alternative crops, plant spacing considerations)
- Consideration of RNAi as an alternative; development of foliar spray-based RNAi technologies and their deployment into the plant (nanotechnology, carriers) or into the fungal pathogens to suppress growth; safety evaluation of technology
- Phenomics to identify diseases in field and spot spray via smart ag technologies.
- New biological/natural products that get activated to knock down spore load during a time span when crop is infected but not susceptible
- Biodegradable products, foliar microbial products, foliar micronutrient products – all need third party field-based verification
- Need to understand the process of useful microbial interactions if any, and the process associated with that benefit, with potential to replicate
- Are there tools from organic systems which can be used or adapted for conventional crop production?
- Technologies to extend the application window of product/fungicide efficacy
- Develop CRISPR technology to engineer plants for resistance
- Consider soil amendment strategies

Surveillance and forecasting:

- Monitoring:
    - New ways of monitoring, given trespass laws?
    - Consider role of hi-spectral/multi-spectral remote sensing technologies
    - Deep learning/machine learning to track spread of diseases across regions
    - Use of drones for scouting, monitoring for broad surveillance purpose, and for breeding tool – needs significant work to be able to differentiate between diseases and multitude of other possible plant stressors
    - Need a live platform with good functionality where farmers and agronomists as 'citizen scientists' can provide indications of disease presence
    - Smart ag tools for spreading the word that a disease has been found in a general area
    - Further integration of weather considerations in movement of spores, disease development and model development
    - Integrate pathogen genomics in the monitoring process. Being aware of race structures can be important for knowing when fungicides can be helpful, or not.
    - Model development to support advanced disease evaluations in the field
    - Develop on-farm testing, rapid testing with mobile testing kits for virulence and pathotypes
    - Develop spore trapping at an early stage and use for forecasting and shifts in pathogens
- Forecasting:
    - Forecasting the severity of risk associated with disease occurrence may be useful for encouraging strategic application of fungicides, so as to retain their efficacy when needed
- Refining risk assessment tools:
    - Requires consistent and methodical updates to reflect current tools, disease races, factors and conditions
    - Projection and diagnostic tools are important and needs further development

Knowledge transfer:

- Practices to manage and prevent/reduce resistance development
- Better communication of the impacts of fungicide and varietal resistance, avoiding it, and managing it
- Find ways to increase the adoption of Integrated Pest Management practices – many of the answers to avoiding fungicide and varietal resistance are already known, therefore, how to change practices with powerful messaging and an effective decision-making tool?
- Enhance the flow of information from scientists to farmers and vice versa for an effective 2-way communication to guide research and adoption

Theme: **Precision Agriculture**
Sub-Theme: **Data (2 groups)**

Crop Production Issues (from Amaethon Report and additional issues identified in workshop)

- Workshop notes indicate interest in some of the precision agriculture tools for the direct benefit of farmers as well as researchers wanting to utilize the technologies as research tools
- Data collection, storage, management, analysis, integration, interpretation, application
    - Data collection – how can a farmer apply it to action decisions on the farm
    - How will the farmer manage big data?
    - How can private data be accessible for research, for answering 'big questions'?
    - Is there a research approach to gaining the ability to share/merge data?
    - Proof of practice in terms of information collected and valid interpretation and value to farmers
- Sensors
    - Sensor development is in its infancy and significant development work is required.
    - Independent study required on the integration of sensor technology for the benefit of the farmer
    - Accuracy to predict nutrient requirements, variable rate of pesticides and nutrients, recognition of disease, etc. are not well understood
    - Progress will be rapid in sensor technology and farmers could potentially be overwhelmed or dependent on a third party for their management decisions.
    - Role of machine-learning and techniques
    - Link back to crop yields and profitability
- Technology and knowledge transfer

Implications for Research

Data collection and storage:

- Better understanding and tools for decision-making considering landscape and environmental variability, yield potential and nutrient management
- What is the role of cloud-based data that can benefit farmers?
- What data and data source and framework could be useful for researchers, public interest? Ideally metadata would be standardized and harmonized and avoid duplication of previous work
- Ultimate question is how to use the data to develop objective recommendations for efficient use of resources including land, inputs, management, and the data itself
- Can genomic data, agronomic data, and physiology data be integrated? Is there value? If so, what are the tools to extract the data and combine the data to become informative?
- How can data be used for practical purposes by farmers for agronomic decisions which are superior to how decisions are made without it?

- How can data be shared with researchers and for what purpose? E.g. extract data for variety specific validation on larger scale
- Is there enough resolution to the data to be valuable to farmers or researchers?
- What is the ROI to farmers in collection of data?
- Develop protocols for collection and use of data

Sensors:

- Are there sensors developed by other sectors which can be useful in the agriculture sector?
- Utility and ability to impact on-farm decision-making
- Non-destructive and low-cost, high throughput tools
- What kind of network is needed and what can be centralized? what is the benefit?
- Is the data generated by sensors of value? To whom?
- Is stationary data available and how can it be used, such as abiotic stress, soil structure
- Multispectral cameras with new algorithms to address specific problems
- Develop catalogue of spectral signatures of insects and disease of various crops leading to sensor development (to assist with economic thresholds and critical values), critical for training and validating models, goal would be to include both abiotic and biotic stresses
- Develop sensors/cameras which can detect disease at 'right' stage of disease and crop development
- Do we have enough and effective data for disease and soil management (such as GHG emissions)?
- Development of improved /new statistical models to filter noise e.g. genomic data is evolving rapidly
- Satellite use increasing rapidly – is there a method for using 'noisy data'?
- Improve weather sensors with accuracy improved, value especially for disease models depending upon temperature and humidity/moisture, irrigation scheduling
- Improved soil sensors including e.g. nutrient and moisture status, nitrous oxide and methane emissions
- Develop sensors for specific traits, plant functions under specific environments

Knowledge transfer:

- Training farmers outside of normal institutional settings, with hands on training for operation and calibration. Also an opportunity to get feedback from participants to capture gaps in knowledge and research
- Training agronomists – what are the possible conflicts of interest?
- Training and training materials for interpretation of data and types of data, requires combined expertise of data management and agronomy
- Multi-institutional approach
- All research proposals in the area of precision agriculture should describe how the new technology will be transferred to the farmers

Theme: **Precision Agriculture**
Sub-Theme: **Soil Management Zones (2 groups)**

Crop Production Issues (from Amaethon Report and additional issues identified in workshop)

- Several different methods offered to farmers
    - Are all soil management zone methods good for farmers across a wide geographic area?
    - Opportunity to gain more insight in field variability
    - Zones based on crop vs soils, which is more meaningful?
- Input predictions
    - Can soil maps and real time crop and soil management issues replace the current systems farmers employ?
- Output predictions
    - Can precision ag investment predict economic yield or farm profitability?
- Climate change impacts on soil management zones and vice versa
- Can intercropping or other cropping systems or rotations assist in managing soil management zones?
- Technology and knowledge transfer

Implications for Research

Methods of differentiating soil management zones:

- Are all methods good for farmers across a wide geographic area, in all years?
- Are management zones based on crop yield more meaningful than soil attributes, or vice versa?
- Capacity to measure seems to remain ahead of the agronomy to use that information in a meaningful way. Why is that, and what is missing? What are the measurements most important to a farmer and does that differ between farmers?
- Are complex models needed, and how many factors can one manage for in a practical way? Are complex models just creating more uncertainty, rather than more predictability as a decision-making tool in a dynamic system?
- Do sampling methods need some protocol development for consistency?
- How is weather integrated into model development?
- Given the wide variety of models used by different companies, is there a simpler system based on more collaboration rather than overlapping research and competition on the development of zones
- What is the pre-competitive space that could assist in the development of soil management zones
- Is the farmer's knowledge of the field incorporated in the development of management zones?
- Can we incorporate temporal variation into spatial variation to support the generation of soil management zones to more accurately reflect the variation?

- How can we utilize all existing data (data including a lot of temporal data) generated for variety of research purposes, for development of soil management zones?
- How would the inclusion of soil microbiome affect the definition and use of soil management zones and would that be meaningful?
- What is not already included as factors in defining soil management zones and how can they be added, and which would be meaningful? (topography, soil attributes, moisture, nutrients, carbon sequestration and GHG emissions, root zone, soil microbiome, etc.)
- What would a systems approach to the development of soil management zones look like?
- Field scale modelling with process-based models – how are/can they be utilized to advance use of soil management zones for use by producers?

Input predictions:

- Does variable rate application result in lesser inputs or better efficiency per input unit and/or improved profits?
- Field based Return on Investment research assessment in a 5-year term and accounts for more factors to account for growing season variability
- Models to account for field variability and season variability
- Develop machine learning to use data from previous year to improve model for the next year – is there a way to develop a record keeping tool for producers and ability to input into model for future crops? Preferably with open-source software.
- Create and/or support the use of current data capture and sharing technologies and services for independent testing of inputs to provide information of value to producers
- Keep up with Genetics x Environment x Management research to generate information that can help with reactive, real time interventions. Will likely need more sensor development to link to decision-making models and that will need multi-disciplinary work by engineers and agronomists and bridging of private and public interest
- What potential is there for opportunities for better pesticide management?

Output predictions:

- Further develop Profit/Loss tools and information that can be generated for soil management zone models to assist farmers in maintaining or improving yield and impact on the environment
- Consider results over 5-10 years
- Is the farmer's risk integrated in model development as decisions have to be based on risk.
- Independent research to evaluate predictability of economic yield or profitability using different models or approaches

Climate change impacts:

- May increase the need for more complex models

Knowledge transfer:

- Need to understand how to interpret data, information, and what recommendations are based on, with information that the farmer can use to manage the risk
- Ideally, incorporate video game concept to simulate different scenarios to assist in the visualization of impacts with adjustment of factors
- Can include face to face workshops, virtual platforms and should ideally include independent perspective which is seen as reliable and relatable, with opportunity for feedback and influence on research and development

Theme: **Precision Agriculture**
Sub-Theme: **Variable Rates (2 groups)**

Crop Production Issues (from Amaethon Report and additional issues identified in workshop)

- VR technology of all inputs
    - VR for nutrient, pesticides, seeding/targeted spraying on all major crops and small acreage crops
    - Connects with sensor development as discussed in Soil Management Zone-Sensors workshop
- Need for independent studies
    - Independent studies to verify manufacturer recommendations over diverse geographic areas
- Weather prediction
- Verification of ROI
    - ROI over diverse geographic areas in a systems approach
- Technology and knowledge transfer

Implications for Research

VR technology of all inputs:

- Assess ways of getting direct comparisons of treatments in a VR application – designate control and test strips within existing defined zones of a field
- Weed control strategies – test patch treatments, green on green technology, green on brown technology. Need an understanding of weed patch dynamics.
- VR seeding:
    - changing the ratio of crop in an intercrop system according to zone
    - changing rates of seed of single crop and variety or different varieties according to expected yield potential zone
- Fungicide applications – since lower rates for some fungicides may increase the risk of resistance development (this is a risk with most pesticides, whether considering herbicides, fungicides or insecticides), test patch treatment with on/off strategy. Perhaps also test on/off strategy vs rate reduction and the effect on development of fungicide resistance
- Variable rate fertilizer applications:
    - Short term moisture (less predictable) and long-term soil attributes (more known) or historical yield maps best used as basis for decision-making? N is most common nutrient managed this way, what about other nutrients?
- Could use of soil pH maps be useful in assessing risk of pesticide carryover and decisions associated with pesticide applications?
- Need for independent studies – research needed for development and testing of algorithms which predict nutrient needs, disease pressure, etc.
- Need for research that is more holistic or integrated approach to VR, i.e., multiple aspect/inputs assessed together rather than one component assessed at a time

- Can combined record over time of input applications per field or farm provide evidence of sustainability? Is there value in studying the impacts in longer term, across the cropping system that farmers use?
- Mapping based on pre-determined zones or based on sensor data – how to interpret and apply to VRT, especially for real-time application decisions such as pesticides?
- Basic research in biology, soil science, agronomy, etc. is needed as the underpinning of VR technology applications
- How can maps be updated, revised, and fine-tuned from year to year based on new conditions and needs, without losing the value of a single year's experience?

Need for independent studies:

- Independent studies to verify manufacturer recommendations over diverse geographic areas
- Is precision agriculture sustainable? How does public perception align with actual results?

Weather prediction:

- Weather is a critical factor in predicting yield potential and many risks and responses to inputs. Need to have risks associated with forecasting responses in the Prairie environment

Verification of ROI

- ROI over diverse geographic areas in a systems approach
- Can these new technologies be used to account for differences in abiotic conditions to ensure appropriate rates and applications are used?
- Cost/benefit analysis for all of these technologies and applications, perhaps especially at the proof-of-concept stage
- Assess benefits to time management, which may not often be included in metrics

Tech transfer:

- Several good tools already in use such as websites, Twitter, videos, interviews, podcasts, face to face meetings, online workshops, in field discussions, demonstrations
- Enhance the opportunities for farmers and researchers to interact
- Some of what is intended to be applied research needs to be better designed to be adoptable before it is funded. Ask the question 'if the research objectives are successfully accomplished, what will be adoptable'?

Theme: **Sustainability**
Sub-Theme: **Climate Change (3 groups)**

Crop Production Issues (from Amaethon Report and additional issues identified in workshop)

- Surveillance
    - Understanding and defining changing pathotypes, species and new area of adaptation
- Abiotic stresses
    - Holistic, multi-disciplinary integrated approach (GxExM) to adapt to severe weather
- Soil C capture/GHG emissions
    - Rapid methods to assess soil C capture under different crops
    - Cropping system assessments of GHG
- Weather forecasting
    - Improve in-season forecasting of weather affecting pesticide use and nutrient management
- Technology and knowledge transfer
    - Advocacy of sustainability through Technology transfer

Implications for Research

Surveillance:

- Develop understanding and modelling of/for the potential for changes in crop and cropping system adaptability and ranges over time
- Gain a broader understanding of the spatial and temporal components, how climate change affects pests (insects, diseases and weeds) in the region and local areas: microclimates, proximity to land masses, atmospheric changes, changes in vegetative coverage, past pest pressures and past pesticide use
- Assess the demands for nutrients due to expanded cropping season and crops grown
- Identify and understand the key factors driving pest invasions, habitat change
- Advanced forecasting and warnings for weather, weather risks, pest risks
- Cataloguing of insects (spectral signatures) for model development and predictions
- Explore new data capture and management systems

Abiotic stresses and Tools or technology to address climate change issues:

- Need fundamental understanding of the response of crops, cropping systems, nutrient use to climate change and increased CO2 levels in diverse agro-ecological zones. Create alternatives, test and adapt as needed.
- Impact of CO2 and temperature changes on soil organic matter mineralization, greenhouse gas emissions, soil microbes, N fixation, all aspects of C and N cycling. Also consider how synchronizes through the cropping season and crop growth
- Improve and adapt crop physiology models to changes in precipitation, temperature and growing season

- Compile and collate, validate and enhance multiple modelling studies to provide practical recommendations about what this means for agriculture on the prairies
- Develop Stress Vulnerability maps to visually show vulnerability to a system to climate-change related to stress
- Apply expected changes to climate to breeding efforts to provide adapted crops
- Better understanding of both mitigation and adaptation to climate change (e.g. water management, soil carbon, retention of wetlands, soil C capture, GHG emissions
- Regional level models developed and verified for feedbacks of CO2 (Free-Air Carbon dioxide Enrichment (FACE) studies), temperature, and moisture and their impacts on water use efficiency and soil moisture
- Roles and interaction of agriculture with natural landscapes (i.e., forests, agroforestry) and impacts on climate change. How do trees impact crop and livestock production?
- How does climate change impact at the farm level and how does a farmer or region or sector respond and prepare? Translate national scale to regional and local scales (research and modelling for extreme weather events – droughts, floods)
- Further development of crops with tolerance to salinity
- Using physiological markers for selection (carbon and oxygen isotopes for example)
- Linking Genome-Wide Association Studies (GWAS), genomics and phenomics selection
- Need information on how to practically use available water supplies throughout the growing season
- Develop ways to assess seedbank return under given weather patterns in particular regions
- Continue to develop an understanding of basic phenology of pests and crops
- Understanding of the interaction between cropping systems and livestock systems and how they impact/mitigate climate change

Soil C capture/GHG emissions:

- Develop rapid methods to assess C capture in different soil depths, remote sensing to correlate with soil measurements
- Can variable rate technologies help to maximize carbon capture and minimize emissions?
- Assess the role of cropping systems and individual annual and perennial crops regarding GHG emissions and carbon sequestration
- Improve measurement of dynamic systems at the farm level
- Develop tools to assist with selecting traits for C capture in different crops
- Get a better understanding of offset and permanence of soil C
- Develop better protocols to understand the value of C in soils

Weather forecasting:

- Improve understanding of weather patterns and improved accuracy
- Better prediction modelling for crop diseases for affordable, real-time risk assessments, forecasting and decision-making

- Develop better weather alerts and predictive tools for extreme weather events, specifically for agriculture. Prior to seeding for cropping decisions, and within season for benefit of disease and insect risks and spraying decisions

Knowledge transfer:

- Develop better weather alerts and predictive tools for extreme weather events, specifically for agriculture. Prior to seeding for cropping decisions, and within season for benefit of disease and insect risks and spraying decisions
- Real-time pest risk alerts
- Improve communication strategies re. defining and understanding climate change, the impacts and implications (risks and benefits, concrete choices) to farmers
- Better connection between researchers and end-users
- Engage youth in regenerative agriculture and technology, encouraging youth and indigenous community to develop and utilize solutions

Theme: **Sustainability**
Sub-Theme: **Cropping Systems (3 groups)**

Crop Production Issues (from Amaethon Report and additional issues identified in workshop)

- Conservation – maintain benefits, problem-solve
    - Conservation tillage/organic systems as regenerative ag solutions
- Soil Health – impact of tillage, soil microbes and nutrient availability
    - Soil/plant/air continuum to facilitate soil health
- Reduction/alternative pesticides
    - Alternatives to pesticides/targeted spraying as alternatives to reverting back to tillage
- Cover crops/Intercrops
    - Understanding suitable Cover crops/Intercrops for profitability and diversify cropping systems
- Regenerative Agriculture – integration of all practices that increase profitability
- Technology and knowledge transfer
    - Advocacy of sustainability through TT

Implications for Research

Conservation:

- Quantify the impacts of different cropping systems (including organic agriculture) in terms of C input and sequestration, e.g. green manure over several years, grazing crop residues with livestock, cover crops
- What is the impact of water on sustainability?
- How does tillage affect microbial profile and C?
- Life cycle analysis to assess energy balance and C
- Quantify effects of conservation tillage within a holistic approach
- What are the potential issues with conservation tillage in terms of water quality or soil fertility, etc and how to improve? E.g. weed management, management of heavy residues, challenges of wet conditions, links between conservation tillage and insect pest life cycles
- What are the cross-infection risks for plant pathogens in crop rotations or systems?
- How does zero-till help with water retention within current crop rotation in drier soil zones?
- Quantify crop rotation effects on microbial diversity, building on work already done
- Can tillage address herbicide resistance issues? What are the impacts of tillage on newer crop rotations or specific phases of a crop rotation? What kind of tillage practices are most beneficial and least harmful and for what purpose?
- Strategic tillage in zero till systems – what is the 'strategy' part of strategic tillage? How much tillage can we 'get away with'? e.g. depth, speed, residue impacts, soil movement

- How to apply conservation practices in a wet soil zone where extensive tillage and row cropping is the norm?
- Assess the impact of occasional tillage within an essentially zero-tillage system – what are the impacts (within a long-term study)? How can the research done during the transition from conventional tillage to conventional direct seeding assist with assessing the effects of strategic tillage on pests, soil quality, soil microbes, nutrient cycling, etc.?
- Develop concerted effort to use and adapt best practices of regenerative agriculture, conventional agriculture and organic practices. E.g. develop organic friendly strategies for using conservation tillage or reducing tillage by using mulches or cover crops. One cropping system may benefit from adopting pieces of another.
- What non-chemical options are available for pre-seeding weed control?

Soil health:

- How do we quantify soil health? How do management practices affect soil health?
- Potential for improving soil health of marginal lands?
- Soil acidification – if highly stratified, is it missed and, what are the unique effects on plant stress, microbial communities, pest resistance. Is liming necessary and if used, what are its effect on crop disease, nutrient cycling, soil health?
- How is soil health linked to productivity and profitability? (profitability will drive practice adoption, just as direct seeding did)
- What are the impacts of current chemical input production systems on soil health? What are the effects of other production systems on soil health including green manures, cover crops, intercrops, diverse crop rotations, etc.
- Are soil amendments effective for increasing soil health?
- How does nutrient cycling affect soil health?
- How does tillage affect soil health?
- Develop, adapt and assess tools for measuring soil health over the short term

Reduction/alternative pesticides and practices to avoid tillage as solution to pest problems:

- Economic assessments of all practices
- To control weeds, what are the alternatives to reverting back to tillage
- Is there potential for no-till organic system?
- Develop bioherbicides, biocontrol agents as tools easily adapted on the farm
- Incorporation of biological control or livestock into our cropping system for pest control
- Assess cultural practices such as delayed seeding and ploughing, harvest or post-harvest season strategies for weed control
- Assess use of trap crops, perimeter trap crops, strip tillage, strip farming, pollination/beneficial insect habitat borders
- Consider alternative life stages for targeting weed and insect management
- Consider particular intercropping crop combinations to reduce insect pests
- Quantify what a beneficial insect can do
- Better mapping capability for patch management and spot spraying

- Assess the effect of insects on weed seeds
- Assess the effect of radiation of weeds
- Variable rate seeding in terms of weed competition
- RNAi technology in pesticide development
    - Proof of effectiveness, transfer of technology from lab to field, fate of molecules, target high priority pests first, cost effective, unintended effects such as soil health?
- Can CRISPR technology be used as a tool to address resistance development concerns?

Cover crops/intercrops:

- Development and understanding of suitable cover crops and intercrops for profitability and diversification of cropping systems
- Comprehensive assessment across Western Canada to show what certain cover crops (could even include native species or perennial grains) do for soil and crop systems
- Timing of cover crop and intercrop for nutrient management (including carbon sequestration and greenhouse gas emissions) within and between growing seasons
- What is the correct method and timing for termination of cover crops for best impact?
- Potential for cover crops and intercrops for weed, disease and insect management
- How does intercropping affect crop rotations? Replace, enhance? Is there a long-term utility of intercropping vs monoculture within a rotation? Compare intercropping to a diverse rotation. How do the benefits hold up over time under changing environments?
- What is the feasibility for cover cropping in short growing seasons of low moisture? Are there cover crops with low moisture use, which would still have value?
- Research on intercropping for long-term solution to address market access issue on farming practices to reduce pesticides or other inputs/restriction on certain inputs e.g. EU
- What is the impact of intercropping on C sequestration at a field scale?
- What combinations of crops fit well together as intercrops or cover crops for different environments, then what are the seeding rates, and placements, cultivars? Why do they work (this could assist with identifying other potential intercropping strategies)?
- Screening and breeding of optimal varieties for intercropping
- Breeding of legumes to transfer more N to companion crops
- Impact of intercropping on the microbial profile
- Harvestability of intercrops – equipment, sorting, storage
- Assess plant spatial designs such as alternate rows, mixed rows
- Intercrop mixtures for silage

Regenerative agriculture:

- Develop a clear/scientific definition of regenerative agriculture and certification that will be widely adopted
- Consider the nature, role and utility of regenerative agriculture in relation to current prairie agriculture practices and issues.

- Need more cropping systems management studies to measure sustainability, profitability, GHG emissions and include marginal lands
- Practical approaches that can be adopted by farmers?
- What is the impact of land ownership on the adoption of regenerative agriculture?

Knowledge transfer:

- Researchers need to have knowledge of on-farm practices as foundation for building research programs
- Participatory approach can be useful for informing research and vice versa
- May need greater TT for communicating what has been accomplished with direct seeding, particularly for those who have started to farm recently
- Opportunity for communicating soil health in terms of profitable/stable/sustainable soils
- TT, including demonstrations, useful for showing the practical aspects of intercropping and cover crops, including identification of risks and applied to diverse regions
- Create awareness about environmentally friendly solutions and impacts for the reduction of chemicals use, increased use of alternative pest control options
- Increase the TT for interpretation of product claims and sales tactics
- BMP's for implementation of increased crop diversity
- Consider the development of a cropping rotation/sequence calculator based on research as a tool for producers to change parameters to easily compare hypothetical scenarios

Theme: **Sustainability**
Sub-Theme: **Diversified Crops (2 groups)**

Crop Production Issues (from Amaethon Report and additional issues identified in workshop)

- Small acreage crops
    - Define areas of adaptation of crops with less than 2M acres
    - Improved agronomy of small acreage crops
- New winter crops
    - Potential for winter crops like durum wheat, canola, pea and possibly the expansion of winter wheat
- Integration into crop rotation and conservation tillage systems
    - Ideas to incorporate and expand existing rotations.
- Technology and knowledge transfer
    - Advocacy of sustainability through TT

Implications for Research

Small acreage crops:

- What are the pesticide options available for use in minor crops?
- Basic understanding of pathology, genetic diversity, crop rotation opportunities
- Develop dual purpose crops for use as grain and forage
- Are there annual crops which could become profitable perennial crops associated with a deep root system, having climate change effect due to low equipment use, having economic and sustainability value?
- Economic thresholds for insect pests, identification of both pests and beneficials
- Crop nutrition needs
- Use for buffer zones to support system resiliency
- Drought/heat/cold tolerance
- Root microbiome benefits
- Analysis for supporting new crops and systems to include crop economic value, fit with changing climate, ability to predict climate change and weather
- Economic analysis
- Germplasm development:
    - Application of genomics, agronomy and pre-breeding for integration of traits
    - Drought and flood, cold and heat tolerant varieties
    - Hybrid development to increase resiliency to abiotic stresses
    - CRISPR for trait development (e.g. increase in seed size)/MAS/genomic selection
    - Pesticide tolerance
    - Using mutagenesis as a breeding tool
    - Address end-user quality issues

New winter crops:

- Identify barriers to growing winter crops and direct research towards those barriers

- Breeding to adapt crops to survive prairie conditions and various regions within
- Explore possibilities to grow winter crops to improve soil health and/or economics
- Economic analysis
- Develop new tools for increasing efficiency in adaptation of new traits in new crops, likely using genomics, phenomics and pathology research
- How to resource and conduct research most efficiently to address the full package needed by farmers for growing new and minor crops?

Integration into crop rotation and conservation tillage systems:

- Identify barriers to extending rotations, direct $ and TT to address those barriers
- Is there an opportunity to intercrop major crops with minor crops or intercrop multiple minor crops?
- Address issues such as residue management for crops such as flax

Knowledge transfer:

- More collaboration between researchers and private and public agronomists, producers to correctly diagnose issues
- Advocacy of evidence-based sustainability and resiliency through use of diverse crops

Appendix A. Workshop Participant List

Ahmed Lasisi	AAFC
Alison Nelson	AAFC
Axel Diederichsen	AAFC
Barbara Cade-Menun	AAFC
Bifang Cheng	AAFC
Breanne Tidemann	AAFC
Bruce McArthur	AAFC
Charles Geddes	AAFC
Curtis Cavers	AAFC
Fardausi Akhter	AAFC
Felicitas Katepa-Mupondwa	AAFC
Francois Eudes	AAFC
Haben Asgedom Tedla	AAFC
Haley Catton	AAFC
Henry de Gooijer	AAFC
Holly Mayer	AAFC
Hossein Borhan	AAFC
Jatinder Sangha	AAFC
Jennifer Otani	AAFC
Johanne Kristjanson	AAFC
Joyce Boye	AAFC
Keith Hanson	AAFC
Kelly Seymour	AAFC
Keshav Singh	AAFC
Kevin Floate	AAFC
Kui Liu	AAFC
Meghan Vankosky	AAFC
Mervin St. Luce	AAFC
Michelle Hubbard	AAFC
Mohammad Khakbazan	AAFC
Myriam R. Fernandez	AAFC
Nicholas Larkan	AAFC
Prabhath Lokuruge	AAFC
Raja Ragupathy	AAFC
Raju Soolanayakanahally	AAFC
Ramona Mohr	AAFC
Reynald Lemke	AAFC
Sally Vail	AAFC
Samia Berraies	AAFC
Shaun Cook	AAFC

Shaun Sharpe	AAFC
Sima Vyas	AAFC
Steve Robinson	AAFC
Taras Lychuk	AAFC
Kelly Turkington	AAFC
Tony Yang	AAFC
Tyler Wist	AAFC
Vern Baron	AAFC
Xiben Wang	AAFC
Yuefang Ruan	AAFC
Jagroop Kahlon	AB Pulse Growers
David Simbo	AB Wheat and Barley
Jeremy Boychyn	AB Wheat and Barley
Kelly Chambers	Alberta Seed Growers
George Clayton	Amaethon Ag Solutions
Stephen Morgan Jones	Amaethon Ag Solutions
Nasima Junejo	Battle River Research
Khalil Ahmed	Battle River Research
Gina Feist	Brewing and Malting Barley Research Institute
Doug Miller	Canadian Seed Growers Association
Cosmin Badea	Canterra
Glenda Clezy	Federated Co-operatives Ltd
Chris Neeser	Government of Alberta
John Heard	Government of Manitoba
Abimfoluwa Olaleye	Government of Saskatchewan
Danielle Stephens	Government of Saskatchewan
Danny Petty	Indian Head Agricultural Research Foundation
Thom Weir	Indian Head Agricultural Research Foundation
Gursahib Singh	Irrigation Crop Diversification Corporation
Krishanthi D Vithanage	Mackenzie Applied Research Association
Lori-Ann Kaminski	MB Crop Alliance
Doug Martin	MB Crop Alliance
Daryl Domitruk	MB Pulse Growers
Cathy Holtslander	National Farmers Union
Katelyn Gaetz	PAMI
Lee Anne Murphy	Pest Surveillance Initiative (PSI)
Shawna Mathieson	Prairie Oat Growers Association
Nancy Tout	Results Driven Agricultural Research
Doug Heath	SaskCanola
Miki Miheguli	SaskCanola
Wayne Thompson	SaskFlax
Ron DePauw	SeCan

Greg Sundquist	SK Flax
Michelle Beaith	SK Flax
Patricia Lung	SK Flax
Allison Fletcher	SK Pulse
Blair Goldade	SK Wheat
Carmen Prang	SK Wheat
Haley Tetreault	SK Wheat
Sushmita Nandy	SK Wheat
Allen Terry	Syngenta
Boyd Mori	University of Alberta
Linda Gorim	University of Alberta
Maya Evenden	University of Alberta
Stanford F. Blade	University of Alberta
Samuel Robinson	University of Calgary
Michele Konschuh	University of Lethbridge
Alejandro C. Costamagna	University of Manitoba
Annemieke Farenhorst	University of Manitoba
Curt McCartney	University of Manitoba
Martin Scanlon	University of Manitoba
Robert Gulden	University of Manitoba
Steve Shirtliffe	University of Saskatchewan
Bobbi Helgason	University of Saskatchewan
Eric Johnson	University of Saskatchewan
Maryse Bourgault	University of Saskatchewan
Randy Kutcher	University of Saskatchewan