Assessment of current and future needs for entomological extension in agriculture in Alberta

by

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Abstract

Recent changes to the structure of agricultural extension in Alberta have raised concerns about the effectiveness and efficiency of the system. There is a need to evaluate the effectiveness of the current agricultural extension system to identify opportunities for growth and collaboration. Extension professionals need to understand the priorities of producers, the effectiveness of different extension efforts, and the best modes of communication for efficient exchange of information and technology. This project uses scientific surveys targeted at producers and extension professionals to better understand their priorities, needs, and preferences for entomological information, as well as the pest management issues and opportunities they face. The cost and the loss of chemical controls were identified as the worst pest management issues, while extension issues were viewed as less severe to both producers and extension professionals. In addition to expected pest control priorities, producers also valued conservation of beneficial insects. Producers trusted both traditional communication methods and digital ones but use and trust of resources were not always aligned. Extension professionals reported that funding, accessibility, and coordination of extension efforts were the biggest barriers to extension in the province. Results of this project provide insights into potential opportunities to improve extension in Alberta. In addition, a visual map of online entomology extension efforts in Alberta was created to help extension users find information they need.

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Table of Contents

List of tables

List of figures

Chapter 1: Introduction

Background

Agricultural extension is a system of knowledge and technology exchange among individuals involved in the industry, ranging from researchers to producers and everyone facilitating the communication. Extension involves planning, demonstration, adoption, and evaluation of communication activities (RDAR 2022b). It highlights two-way communication between researchers and producers to effectively and efficiently share information that will help improve agricultural practices (Anderson & Feder 2007; Izukanne 2014; Milburn et al. 2010). In Canada and internationally, extension is also known as "knowledge and technology transfer", "knowledge and innovation brokering", "technology adoption", among others. (Chowdhury & Odame 2013; RDAR 2022b).

Extension supports the agricultural industry by connecting research to practical application in the hands of producers, and effectively drives agricultural productivity (Warsame 2015). Extension directed activities keep producers and agricultural associations up to date with changes and opportunities within the agriculture industry and potential operational impacts of these changes (Izukanne 2014, ASB 2023). Extension increases the rate at which producers adopt newly developed best management practices and innovations (Warsame 2015; Liu et al. 2018; Dhehibi 2020, RDAR 2022a), and is especially important in an extension effort's early stages when perceived risk is high (Anderson & Feder 2007). Extension services address a variety of producer needs such as: technical information for production systems, production and environmental management information, and farm business management and marketing (BC Agriculture & Food Climate Action Initiative 2016). These services can come in the form of newsletters, field tours, informational bulletins from government agencies, grower commodity

group communities, among others. In addition to providing knowledge exchange, extension activities connect producers with the agricultural community, which helps individual producers and the local food system as a whole (Sanders et al. 2021). As such, agricultural extension is a key pillar that supports the agricultural industry.

A robust extension system provides resilience to the farming community and supports producers in times of change and challenge (AIC 2017; Davis 2020; Madonna et al. 2023). The Canadian Prairies face critical risks associated with climate change, since this region is warming at a rate second only to the Arctic (Laforge et al. 2021). Climate change-related challenges include increased risk of drought, range expansion of insect pests, and adoption of different agricultural practices (Laforge et al. 2021). Alberta has previously demonstrated resilience and ecological values in times of change by prioritizing soil health through the adoption of zero tillage practices in the 1970's (Laforge et al. 2021; Spencer & McConnell 2021). Extension supports changes in production practices, which continue to evolve with the advent of new technologies that are accessible and affordable to producers (Chowdhury & Odame 2013; Norton & Alwang 2020; Spencer & McConnell 2021).

Most extension approaches across North America are based on the Boone et al. (1971) model of extension, a Program Development Model based on five main components: 1) needs assessment and understanding of community values, 2) involvement of leaders linking institutions to the public, 3) program design and implementation based on needs, 4) program evaluation and assessment, and 5) incorporation of feedback from evaluation to future extension (Franz 2015; Knapp 2021). The use of this model creates improved outcomes for extension activities by emphasizing factors such as the goals and intentions of the program, and the provision of documentation to evaluate and create accountability. By facilitating the evaluation

of programs by extension workers, Program Development Models help provide a framework for replicating a successful program.

Modern extension programs value reciprocal communication between producers and extension workers (Cooke 2017; Illingworth 2017). Dialogue and engagement in extension creates long-lasting impacts on the participants. Two-way communication allows extension professionals to learn the needs of the community, address barriers in understanding, and understand the priorities of the end users of the information Scientists and extension experts are no longer only a source of information to producers, but are engaged in conversations with stakeholders and the public.. It is crucial to understand the needs of producers and consumers so that research addresses knowledge gaps and is accountable to stakeholders (Burroughs 2000; Chowdhury & Odame 2013; Hollmann et al. 2022). Recent research on public engagement during scientific endeavors, however, demonstrates that promotion of active public participation in scientific programs is difficult (Wu 2019).

Extension in Canada has historically been the domain of the provinces, without federal government directives, but agricultural extension theory and practice in the country are in a period of change (Brewin et al. 2022; Chowdhury & Odame 2013; Gill 1996). In the past, provincial and regional extension agents supported local extension providers. A shift to specialized farming combined with provincial budgetary constraints, led to provincial extension providers being lost to attrition (Anderson & Feder 2007; AIC 2017; Dika 2021; Knapp 2021). The federal government's role in extension is limited and focuses on training through job creation programs and technology transfer (Gill 1996). There is some extension done federally via programs and publications by Agriculture and Agri-Food Canada and the associated Prairie Pest Monitoring Network, the Canadian Broadcasting Corporation (Brewin et al. 2022).

Provincial and federal governments increasingly allocate financial support in agriculture to research projects with high return on investments, and extension programs that have fewer tangible outcomes, may receive less funding (Anderson & Feder 2007; Brewin et al. 2022).

Agricultural extension in Alberta

Agriculture is a vital industry to Alberta's economy. It functions to supply nutritious food to the region and thereby improve human health (Baffoe et al. 2021). In 2022, the agricultural sector in Alberta contributed $10.2 billion to the provincial GDP, which is 3.1% of the total GDP (Statistics Canada 2023). Alberta is a driver of agricultural production in the country, as one of three Prairie Provinces in which most of Canada's arable land lies (Brewin et al. 2022; St. Pierre & McComb 2023). Alberta's agricultural industry is globally competitive, with beef exports to the USA and wheat and canola products reaching overseas markets (Chen 2020).

Agricultural extension in Alberta has decentralized over time, as advisory services have shifted towards business-oriented systems (Anderson & Feder 2007; AIC 2017; Brewin et al. 2022; RDAR 2022b). Extension delivery is transforming partly due to increased reliance on technology for online information sources (Gosselin 2009; Laforge et al. 2021; Spencer & McConnell 2021). Players in the Albertan agricultural extension system, such as private agronomists, service and product providers, and various producer organizations fill extension gaps left by the withdrawal of the province from the extension system. The increased diversity of extension providers in Alberta results in a "pluralistic extension system", in which extension services come from public and private providers with multiple funding streams (Burner et al. 2009). The role of government in this type of agricultural extension system shifts towards research funding and dissemination, food safety, and implementation of environmental programs (Anderson & Feder 2007; Brewin et al. 2022). The Results Driven Agriculture Research board

(RDAR) primarily handles research funding while Alberta's Insect Pest Monitoring Network and Applied Research Associations take on other extension roles in the province.

Challenges and opportunities in extension in Alberta

Privatization of extension services provides opportunities for producer-led extension efforts to diversify services and can spread costs amongst multiple players in the industry (Anderson & Feder 2007; Dika 2021; Warsame 2015). Coordination of agricultural advisory services, however, can be complex and potentially more expensive for users (Warsame 2015; Pensupar & Oo 2015). Producers may find free extension information less accessible in a privatized system (Brewin et al. 2022; Chowdhury & Odame 2013; Liu et al. 2018). The wide variety of extension providers creates multiple sources for information without a consistent delivery method, which can make it difficult for end users to discern relevant content. The private sector is also limited in its capacity to apply agricultural reforms (Mangheni 2016).

In response to the loss of public extension agents, many producers rely on information from private corporations, which can result in recommendations that maximize company profits rather than supporting the best interest of the client (Krell et al. 2016; Laforge et al. 2021). Producers may doubt the authenticity of the information from companies that sell the recommended product or service (Anderson & Feder 2007). These concerns may be the reason that private consulting may be gaining momentum in Alberta. Producers in Alberta can rely on impartial information provided by non-profit organizations, agricultural service boards, research associations, and commodity boards (Anderson & Feder 2007; AIC 2017; ASB 2023; Brewin et al. 2022). These organizations cooperate on behalf of producers with government and academic partners, such as through contracted extension strategies, to fund and implement research that focuses on knowledge translation (Anderson & Feder 2007).

The decentralization of Alberta's agricultural extension system has resulted in the loss of important extension efforts and opportunities. Communication and implementation of programs was done across the province in the former public extension system (Knapp 2021; RDAR 2022b). Important figures in entomology extension who assimilated information from across the regions are no longer associated with the provincial government. Loss of these key players also results in loss of information and networks. Extension professionals are often the first point of contact to identify new issues as they interact with producers and commodity stakeholders to identify research gaps (AIC 2017; Davis 2020; Issa 2023; Nettle et al. 2022). In a decentralized extension system, there is no obligation to communicate or work together so response to disruptive changes may be difficult for the agricultural community (AIC 2017; Gill 1996; Laforge et al. 2021). With the changing ecosystem of extension in Alberta, and lack of centralized leadership, an assessment of the habits, needs, and preferences of producers in terms of extension usage are needed to help inform future extension efforts (Knapp 2021).

The multitude of recent changes to the Alberta agricultural extension system has sparked a conversation to examine current extension efforts and the response of producers to these efforts in Alberta. Specific issues discussed at a meeting of the RDAR board with agricultural working groups in 2021 included the need for tools and a coordinated effort to disseminate information to producers, and an understanding of producer needs and learning preferences (Knapp 2021), due to a lack of effective feedback mechanisms to Alberta Agriculture (Gosselin 2009). Increased support and collaboration between extension organizations to establish links with producers is needed to learn the priorities and the challenges that producers face, and to develop tools and modes of communication preferred by producers.

Data collection using surveys

In an effort to understand the current entomological extension system in Alberta, I developed, administered, and analyzed scientific surveys to provide insight into the future direction of entomological extension efforts in agriculture. Surveys provide a standardized method to collect information from a target population to make inferences about a larger population using statistical estimates (McDonald 2021; Yahng, 2017). Correlations found in survey results identify the relatedness of behaviours or attitudes to each other and to factors such as demographic data of the sampled population. Surveys obtain information about people's experiences and provide insight into gaps in their knowledge. Surveys are used extensively in agricultural extension efforts throughout North America (Roberts & Rao 2012; Warsame 2015; Halbritter et al. 2021; Hollmann et al. 2022), and by organizations in Alberta. Organizations such as crop commodity commissions and the Prairie Pest Monitoring Network survey producers about their needs and knowledge in target subject areas (Rollins et al. 2018; Alberta Grains 2019; Alberta Pulse Growers 2020; PPMN 2022; Strydhorst 2020). The survey questionnaires that I developed in this project investigated the views of agricultural producers on the most important issues related to entomological extension and their perspectives on current agricultural extension efforts. The surveys also explored the modes of effective communication to understand the extension material that is used most. The scientific surveys developed in this project not only shed light on potential issues within the entomological extension system in Alberta, but can also be used as a template for the development and refinement of future extension efforts within the province as well as for extension efforts in related fields such as disease and weed management, and agronomy.

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Chapter 2: What's bugging you? A survey of producer perspectives on entomology extension in agriculture in Alberta, Canada

Introduction

Extension services and activities provide critical support for agricultural regions through knowledge exchange and education that improves the well-being of producers and strengthens the regional agriculture system (AIC 2017; Baffoe et al. 2021; RDAR 2022a). Extension services drive productivity and adoption of innovation among producers by bridging the communication gap between researchers and the end-users (Anderson & Feder 2007). Effective extension also provides resilience to agricultural systems during times of change or difficulty (Izukanne 2014; Davis 2020; Madonna et al. 2023).

The province of Alberta, Canada is one of the three Prairie Provinces in which the majority of arable land in the country drives agricultural production (Brewin et al. 2022; St. Pierre & McComb 2023). In Alberta's agricultural industry, extension activities often follow a series of three basic steps (Knapp 2021, RDAR 2021) that is similar to the Program Development Model (Franz 2015) of agricultural extension. The first step is to understand producer needs, determine knowledge and skill gaps, and identify priorities of the target audience. Once needs are identified, extension programs are developed that help producers meet those needs with appropriate information and resources. The extension program is not a single effort or one-time project but includes all activities conducted by extension professionals and end users. These activities include planning, program development, and administration across multiple projects (Franz 2015; RDAR 2022b). After an extension program is in place, it should be evaluated to determine the success of the program and identify potential improvements to ensure long-term success (Burroughs 2000; Zall et al. 2004). Program Development Models (Franz 2015) create improved extension outcomes through emphasis on the goals and intentions

of the program followed by evaluation of the program to create accountability (Anderson & Feder 2007). A program evaluated as successful can act as a template for future extension programs.

In Alberta, the role of the provincial government in the provision of public agricultural extension services has consistently been reduced over the past few decades. While Alberta's agricultural sector contributes significantly to the province's GDP and invests in research and development, the provincial government plays little role in agricultural extension. Continual change in agricultural extension in Alberta has called the future trajectory of extension in the province into question (RDAR 2022a 2022b; Spencer & McConnell 2021). Agricultural extension in Alberta is now primarily provided by industry groups such as commodity associations and product or service providers, with an increasing role of private agronomists (AIC 2017; ASB 2023; Brewin et al. 2022). This is in contrast to other Prairie Provinces, where the provincial government takes a leading role in agricultural extension (AIC 2017). In similar farming regions in the United States of America (USA) there is a cooperative extension system that works closely with land-grant universities to provide local extension in each state (AIC 2017; Norton & Alwang 2020; USDA 2022). While collaboration between public and private sectors is common in research, partnering on extension efforts is rare (Krell et al. 2016). As Alberta's extension system continues to become more privatized, opportunities for collaboration and coordination of extension efforts become rarer, and extension efforts are less likely to be standardized or effectively maintained (Warsame 2015; Pensupar & Oo 2015). This has been recognized in recent discussions among key players in Alberta's agricultural system that focused on the challenges facing extension in the province (Knapp 2021). Alberta agriculture would

benefit from an investigation of the extension ecosystem to identify producer needs and extension preferences, opportunities for collaboration, and potential paths for improvement.

This study uses scientific survey questionnaires administered online and at in-person events to agricultural producers within the province of Alberta over a five-month period. The survey aims to gather information from producers on current pest issues, the use of entomology extension material, and producer perspectives on the different modes of extension in the province. Survey results and demographic parameters are analyzed to identify patterns among respondents and inform discussions about potential paths and obstacles to improve the effectiveness of extension efforts in Alberta.

Objectives

1. Determine the entomological extension material currently used by producers in Alberta.
2. Assess the preference for mode and method of knowledge exchange of producers in Alberta.
3. Determine important current and future entomological issues facing producers in Alberta.
4. Analyze methods to streamline and create collaborative entomology extension efforts in Alberta.

Survey design and methodology

Survey design

Factors considered in the survey were entomological issues facing producers, the availability of extension information and what resources and extension material are trusted and used by producers. Data elements related to these factors (Table 1.1) were designed and associated with measurable aspects. For instance, to assess agricultural practices used by producers in response to entomological issues, the survey included aspects such as insect pest control measures used, percentage of farm area with chemical pesticides and fertilizers, and the

prioritized values in pest control implementation. These measurable aspects were used to design the questions appearing in the survey. Supplemental figures are in Appendix A, and a copy of the survey is in Appendix B.

The survey questionnaire was created with simple questions that were designed to be as easy as possible to answer. In multiple choice and multiple response questions, all potential answers were included so that respondents were unlikely to need to use the 'Other' option to write a response. The number of questions that required writing or typing out an answer was limited (n=5 of 76) and few open-ended questions (n=3 of 76) were used in the survey. Closed-ended questions limit the information provided by respondents but take less time to answer than open-ended questions and are easier to analyze (Cowles & Nelson 2019; McDonald 2021; Issa 2023).

Questions posed using a Likert-scale such as "always, often, sometimes, rarely, never" were used extensively in the survey (n= 53 of 76) to explore the views and opinions of producers without requiring respondents to recall specific information. For instance, a respondent may have difficulty recalling exactly how often they use a particular extension tool, but can compare its use to other extension tools using a Likert-scale. It is important that the scale operates at a continuum of roughly equal intervals to give respondents a clear idea of the degree of each ranking (Pearse 2011). All Likert-scale questions are considered independently as part of a larger Likert-scale question group.

Question order was also considered in the development of the survey. Survey design guidelines (Gallhofer & Saris 2007; Gideon 2012) dictate question order to optimize the experience of respondents and increase the number of completed surveys. Difficult or sensitive questions are placed near the end to avoid "scaring off" respondents. In this survey, a question on

the size and location of farmland appeared later in the survey since respondents may be hesitant to share this information. General questions preceded specific ones to provide context, and questions were grouped based on topic (Table 1.2). Demographic questions were placed at the end of the questionnaire to prevent loss of engagement. A variety of demographic data were collected, which included personal information about the respondents as well as farm operation information.

Another consideration in survey design is the mode in which the survey is conducted. The mode of survey delivery impacts not only the number of survey respondents but also the nature of the responses (Baghal 2017; Cowles & Nelson 2019). The survey administrator's tone of voice or rapport with the respondent can impact in-person or phone surveys (Issa 2023). Online and paper surveys require careful visual design to avoid inclusion of graphics and images that influence the respondents' view on a given topic. Online and paper surveys can be more efficient at reaching a larger number of respondents, and for this reason were used in this study.

The surveys were created online on the SurveyMonkey® platform (http://www.surveymonkey.com) to be shared electronically, and a printable version of the surveys was created for administration at various in-person producer events. The two different survey versions limit the chance of sample bias due to the mode of communication and as a result increase the number of survey responders (Sakshaug et al. 2019). The online survey platform also streamlines data analysis as downloaded responses are easily converted into formats for in-depth analysis.

A project "brand" was developed to convey professionalism and recognition to encourage recruitment of respondents (Illingworth 2017). The survey brand included the creation of a logo (Fig. 1.6) and style for project recognition in promotional material, contact emails, and the

survey itself. The branding was also used in the creation of gift items provided to respondents at in-person events (Fig. 1.7).

The minimum sample size required for reliable survey results was calculated using the following equation (Gideon 2012):

$X = 0.25 / (\text{margin of error} / \text{z-score})^2$

minimum sample size = (X * target population size) / (X + target population size – 1)

The 2021 census provides the most recent publicly available data on the number of agricultural producers in Alberta, as 57 200 farm operators (owners, tenants, or hired managers of agricultural operations) (Statistics Canada 2022). To achieve survey results with a confidence level of 95% (α=.05) and a margin of error of 5%, a minimum of 382 participants is required.

Pretesting

Once the survey was developed, it was reviewed by the project team, which includes members with expertise in agricultural entomology, extension and survey design. Interviews using pre-determined questions about the survey content were conducted over Zoom and Google Meet with several extension entomologists to identify missing or confusing information. Additionally, the former agricultural provincial entomologist (Scott Meers) was consulted to review the survey and he provided helpful feedback and information on extension issues in the province.

To further ensure the clarify of language and comprehension of response options, the survey was pretested through interviews with a small group of agricultural producers (n=4) recruited through personal and professional contacts. These interviews were conducted individually using a “think-aloud protocol” whereby respondents were encouraged to voice their thoughts while completing the survey to uncover any confusing questions (Ericsson 2003; Wolcott & Lobczowski 2021). In the pre-test interviews, another set of open-ended questions

(some spontaneous and some predetermined) was asked after respondents completed the survey. Interviews with open-ended questions provide detail and explanation useful to survey design (Cowles & Nelson 2019; Issa 2023). The pre-test interviews were not recorded to ensure privacy, but detailed notes were taken on responses.

Survey administration and data collection

Prior to administration of the survey, the project was approved by the Research Ethics Board (REB) at the University of Alberta (study ID: Pro00126163) to ensure the safety, security, and privacy of participants in the project. A reference number for the ethics approval was included in the survey (Appendix B). Survey administration used a combined web-based (n=141) and in-person approach (n=193) based on a convenience sampling model in which sampling is not random or systematic, but designed to obtain responses in a way that is easy for the researcher (Gideon 2012; Gallhofer & Saris 2007). The convenience sampling methods used included attendance at in-person agricultural events (n=9) to solicit response to the hard-copy survey (Appendix B) and promotion of the online survey. The survey was promoted, and participants were recruited through email contacts, online publications, and in-person promotion at events such as research expositions and conferences (Table 1.3). In-person events were especially helpful at targeting special interest farming groups, such as Hutterite colonies, that use less online communication. In person events were identified with the research team and were selected based on timing, cost, and the number of producers at the event. Direct email recruitment for the survey also occurred, but was limited to forage seed producers, greenhouse operators, and other farms with contact information easily available online (Table 1.3). The survey was available online from 1 January- 31 May 2023. Paper surveys collected were entered into the SurveyMonkey platform to convert them into the same format as the electronic surveys.

Many respondents left the email section blank when filling out paper surveys, so these respondents were given an identifier based on where they filled out the survey.

The objectives and goals of the study were clearly outlined with the survey promotional material, and at the beginning of the questionnaires to recruit the greatest number of producer respondents possible. In-person events made use of promotional material to increase visibility and recognizability of the project, and to offer compensation with gifts. At each event, a table was set up with signage outlining the project, paper copies of the surveys, a submission box, and gift items. Gifts included stickers and pins created for the project that featured elements of the Alberta flag on the back of a coccinellid beetle (a beneficial insect), as well as hats with the survey logo and name embroidered on the front (Fig. 1.7). These gifts provided incentive for producers to complete the survey without the need for a vested interest to support research on agricultural extension.

Statistical analyses

Data collected through the questionnaire were "cleaned" prior to analysis. Submissions that were predominantly incomplete, as well as duplicates, and submissions from individuals outside of the target audience (producers whose farms were outside of Alberta) were removed. Data cleanup also included: coding numerical responses for consistency, conversion of ordinal variables (such as Likert-scale responses, age, cost ranges, etc.) into numerical responses, and conversion of farm locations into one of 5 regions used by Alberta's Agriculture Service Boards (Government of Alberta 2023). Binary response variables (yes/no) were coded into numerical responses (0 and 1) to allow correlations to be measured. In the demographic data, only male and female genders were considered because other genders formed less than 1% of respondents. Responses such as 'I don't know' or 'Prefer not to answer' were considered as missing variables for analyses unless non-response rates were being measured. The number of responses selected

in questions that permitted multiple responses was used as count data in addition to the response variables. Data cleaned in Microsoft Excel were uploaded to the survey analysis program Jamovi (The Jamovi Project 2023), where questions were labelled and grouped, and variables programmed as ordinal, nominal, or continuous.

Nominal data were visualized using descriptive statistics. A Kruskal Wallis test compared differences in responses across variables such as demographics to determine if responses to one question influence responses to another question (α=0.05). This test is used to handle the non-normal data common in survey data (Ostertagová et al. 2014). Pearson correlation heatmaps were used to reveal the strength and direction of relationships in the data (Cohen 1977). An example of a heatmap can be found in Figure A1.1. Correlation heatmaps were also used to identify additional patterns in the data between individual questions. A summary of tests performed can be found in Table A1.1 (Appendix A). For analyses that involved extension resources, they were categorized into print, in-person, and online resources. Print and in-person resources were pooled. E-newsletters provided by organizations were considered print.

Survey evaluation

Upon completion of data collection, surveys must be evaluated to detect potential response problems and identify issues that may have impacted the data collected. Survey evaluation assesses the survey's validity, reliability, and item non-response (Gideon 2012; Gallhofer & Saris 2007; Tsang et al. 2017; Issa 2023). Item non-response is the proportion of responses to a given question that were left blank or skipped by the respondents. Questions skipped by >5% of respondents are flagged for further investigation (Cohen 1977). Questions may be skipped by respondents if they are too long or complicated, if they are irrelevant to the respondent, or if they ask for sensitive information. Item non-response is shown in questions that

are skipped systematically in a pattern. Only questions that should have been filled out by all respondents were considered for this error, as not all questions apply to all respondents.

Survey reliability reflects the consistency of response measurements and survey results. As it was not possible to retest the same population using the same survey, internal consistency within the data (Tsang et al. 2017) was measured. Cronbach's α was used to evaluate scale reliability for groups of questions within the survey. This metric examines the strength of the relationship between a group of questions, such as a set of individual question within a Likert-scale question group (Gallhofer & Saris 2007; Gideon 2012*)*. Cronbach's α compares the amount of shared variance among questions within a group. Questions that reliably measure the same item have a high degree of covariance. This measure can be considered as the average correlation coefficient and reveals the strength of relatedness for a group of questions. The closer Cronbach's α is to 1, the higher the degree of covariance between the questions, and a number above 0.6 is considered acceptable for a set of questions that aim to measure the same factor (Cohen 1977). Item-rest correlations are subsequently used to identify responses to questions that behave differently from others in the group and provide information on the discriminatory power of the survey questions. Values below R^2=0.2 indicate a low correlation in responses to one question compared to other questions in the group.

Survey validity is the ability of the survey to measure the tested factors accurately (Gideon 2012; Gallhofer & Saris 2007; Tsang et al. 2017). Confirmation of construct validity, or the degree of competency for a group of questions to test a desired factor (i.e. constructs), promotes confidence in survey interpretation. Relationship strength and direction were examined using Pearson correlation matrices (Cohen 1977). Validity can be tested by looking for sampling errors, or discrepancies between values in the sample compared to the target population (Murphy

& Davidshofer 1988; Tsang et al. 2017). Data collected in these surveys were compared to data from the 2021 Census of Agriculture (Statistics Canada 2022b) to identify sampling error and evaluate the presence of a selection bias in the survey that might be expected based on the convenience sampling approach used in this study. Producer demographic variables as well as information on farm types and inputs were compared between the two data sets. The total membership numbers for crop and livestock commissions were also used to evaluate the percentage of members that replied to the survey. A χ^2 goodness of fit test was used to compare survey data of nominal and ordinal variables to population data, and a one-sample t-test was used to compare average farm size (α=0.05).

Finally, 200 respondents that input their email information were contacted after the survey period in an attempt to get general feedback from producers regarding the quality of the survey. In addition to an evaluation of the survey, the outlook for extension in Alberta was explored, to further identify issues in the extension system and potential paths for improvement.

Results

Survey administration

Over the five-month survey period, a total of 334 surveys were collected, of which 300 were usable after data cleanup and removal of respondents outside the target audience. The number of respondents is just below the minimum sample size for a 95% confidence level estimate of the target population, but is a large enough for a 90% confidence level estimate (α=.1).

Demographic data

Most farms managed by respondents in the survey ranged between 400-2,500 hectares (988-6,178 acres), with the average farm size being 1518 hectares (3751 acres) ($\bar{x}$=15.2 Km^2, SE=19.8). The most common crops grown by respondents were canola and barley, followed

closely by wheat (each grown by 75-80% of respondents), while dry field peas, alfalfa forage, other forage, and oats were also commonly farmed (between 28-45%) (Table A1.2). Most Albertan farms have synthetic fertilizer and insecticide inputs that cover an average of 83% of total farm area. While most producers used insecticide on ≥75% of their fields, farms that used insecticide on ≤25% of their fields were also relatively common, especially in the case of smaller farms.

A large portion of respondents (78%) have some post-secondary education such as a Bachelor's degree or technical diploma (Fig. A1.2). A large portion (57%) of respondents had > 20 years of farming experience (Fig. A1.3), and many (85%) come from multigenerational farms. Alberta has the highest proportion of multigenerational farm operations in Canada (Liu et al. 2018; Rollins et al. 2018; St. Pierre & McComb 2023). Multigenerational producers are more likely to adopt practices that benefit the farm and surrounding environment because of their long-term connection to the land. Multigenerational farmers grow a larger variety of crops ($p=0.004$), are associated with more crop commissions ($p=0.019$), use a greater variety of control measures ($p<0.001$), and came from larger farms ($p=0.001$) than non-multigenerational farms. Since non-multigenerational farms made up a small proportion of the sample, further sampling to confirm these relationships is warranted.

Use of extension material by producers

The use of entomology extension materials by producers was primarily evaluated through a Likert-scale question (Question #20, Fig. 1.1). Alberta's Crop Protection Guide (a.k.a. The Blue Book) as well as peers are the sources of information used most often by producers, with 36.2% and 44.2% of producers reporting monthly use of these resources, respectively. Extension information was rarely obtained from online or in-person short courses and Applied Research Associations, as 64.6% and 62% of producers reported using these sources less than once a year.

Private agronomists and scientific publications are also used infrequently, with 42.9% and 54.8% of producers reporting that they use these sources less than once a year. Social media as well as audiovisual resources (podcasts, radio, and webinars) are commonly used by some respondents (31.6%), but many respondents report never using these sources (22.9%).

The Kruskal Wallis test an association of the use of some materials with demographic variables. Older respondents were less likely to get entomology information from social media ($p=0.002$) and fellow producers ($p=0.018$) than younger respondents. Respondents that identified as female were more likely to use social media for extension information than those who identified as male ($p=0.03$). Male respondents hired private agronomists more often than female respondents ($p=0.014$). Respondents from multigenerational farms were likely to obtain entomological extension information from Alberta's Crop Protection Guide ($p=0.008$), crop commissions ($p=0.011$), private agronomists ($p=0.024$), and in-person events ($p=0.008$). Respondents associated with multiple crop commissions used 7 of the 15 extension resources more frequently than those associated with ≤1 commission (all p-values <0.05). The number of pest control tactics and alternative pest control methods used by producers was positively associated with extension material use. Strong correlations ($R^2>0.4$) occurred in respondents' answers based on the type of resource (print/in-person vs. online sources of information) (Table A1.4). Cronbach's α for question 20 was 0.86, and all item-rest correlations were above $R^2=0.2$, signifying that response options are answered similarly and the question reliably measures the use of extension material.

Question #16 (Appendix B) asked about resources used by producers to find information about alternative pest management tactics, such as drone surveys or intercropping. The most common sources of alternative information were agricultural conferences and events (47.4%)

and agronomist newsletters (38.4%), with social networking, private agronomists, and private companies also providing this type of information (29-33%) (Fig. A1.4). Use of scientific publications by respondents was marginally correlated with the number of sources used to gain alternative information (R^2=0.29). Similarly, the number of alternative pest control methods used by respondents was correlated with use of scientific publications by respondents (R^2=0.32).

Producer preferences for extension material

Question #19 (Appendix B) assessed producer preferences and trust of different sources of extension information (Fig. 1.2). Producers reported that they were likely to adopt a management practice if it was recommended by Alberta's Crop Protection Guide (73.9%), speakers at events (65.5%), private agronomists (65.5%), crop commissions (62.5%), and agronomist newsletters (62.2%). In contrast, producers were unlikely to adopt tactics recommended by social media (46.4%) and audiovisual material (podcasts/radio/webinars) (36.2%).

The Kruskal Wallis test identified demographic variables that impacted producer responses about extension preference. Age of respondents impacted the perceived trust of pest control products and services provided by private companies, as younger respondents were less likely to implement recommendations from private companies than older respondents (p=0.022). Similarly, years of farming experience influenced the perceived trust of agronomist newsletters, as individuals with less experience were less likely to implement recommendations in newsletters (p=0.005). The number of alternative pest control tactics used by respondents was significantly associated with the perceived trust of Alberta's Crop Protection Guide, as respondents who used more tactics reported less trust in the guide (p=0.027). Notably, the relative trust levels reported for social media and for speakers at agricultural events in question #19 were correlated with other variables in this question (7 and 10 respectively). Cronbach's α

for question #19 was 0.97, and all item-rest correlations were above R^2=0.2. When question #19 was compared to question #20 regarding frequency of use of extension resources, 12 response options overlap. Of these 12 overlapping response options, 4 of them have high correlations above R^2=0.3, and another 6 have relatively high correlations above R^2=0.25.

Current issues in entomology and extension

The most common insect pests managed by respondents were flea beetles (69%) followed by cutworms (53%), lygus bugs (50.8%), and grasshoppers (46.6%) (Table 1.4). Producers rated the same top four insects as the most commonly treated with foliar insecticide over the past three years at the time of the survey. Producers reported use of insecticide seed treatments to manage flea beetles (82%), cutworms (41.9%), wireworms (32.9%) and pea leaf weevils (12%). Producers identified pests primarily through field observations (90%), scouting reports from agronomists (43.2%), sweep net sampling (39.7%), and word of mouth (34.7%) (Fig. A1.5).

Question #11 and #15 (Appendix B) inquired about pest management tactics used by respondents over the last 3 years at the time of the survey. Producers reported use of synthetic fertilizers and pesticides on an average of 83.25% of farm area, and foliar insecticide spray coverage over an average of 30.1% of farm area. The most common pest control tactics employed by respondents were crop rotation (74.8%), insecticide-treated seed (61.7%), foliar insecticides (49.7%), and resistant crop varieties (47.6%) (Fig. A1.6). Question #15 (Appendix B) evaluated use of alternative pest management tactics and reported that maintaining habitat for natural enemies (22.4%), new-to-market insecticides (20.5%), followed by residue removal (15%) were the most commonly used alternative tactics.

Question #17 (Appendix B) used a Likert-scale to evaluate respondent opinions on pest management issues (Fig. 1.3). Major pest management issues most often reported are ‘the loss of chemical control options’ (34.75%), ‘the cost of insect pest control’ (31.2%) and ‘the severity of

damage from insect pests' (27.1%). Other pest management issues were reported as only a minor concern by respondents, including unfamiliar insects (65.1%) and damage (57.9%), as well as 'a lack of hands-on practical training' (58.9%). Cronbach's α for question #17 was 0.8, and all item-rest correlations were above R^2=0.2. Potential answers to question #17 (Appendix B) were highly correlated. 'The decision to implement controls' was correlated with' the decision of which control to use' (R^2=0.61) and 'the loss of chemical control options' (R^2=0.48). There were also strong correlations between the response options of 'new insects in the crop' as well as 'unfamiliar damage' (R^2=0.54), and between 'the ability to monitor insect pests' and 'the severity of damage from pests' (R^2=0.48).

Older respondents saw 'the severity of pest damage' as a lesser issue (p=0.04), and 'the cost of pest control' as a more important issue (p=0.036). Respondent's with a higher education level saw 'the severity of damage' (p=0.04), and cost (p=0.024) as lesser issues, and 'the loss of chemical control options' (p=0.019) as more important. Farm location affected respondent opinions on 'the severity of crop pest damage' (p=0.008) and 'whether to implement pest controls' (p<0.001). 'The number of control tactics used over the past 3 years' and 'use of managed pollinators' by respondents influenced responses about 'loss of chemical control options' (p=0.009 and p=0.016 respectively).

In question #18 (Appendix B) producers were asked about priorities in the implementation of pest control tactics (Fig. 1.4). The 'effectiveness of control methods' was rated as very important by 82% of respondents, followed by 'economic thresholds' (64.6%), and 'preventing harm to beneficials' (59.1%). Factors that were not considered as affecting the selection of pest management tactics included 'pest controls implemented on neighbouring farms' (26.9%), 'forecast maps' (24.4%), and 'farm visits from agronomists' (22.9%). There

were no significant correlations between response options in question #18. Cronbach's α for this question was 0.67, and all item-rest correlations were above R^2=0.2. The Kruskal Wallis test showed that older producers were more concerned with 'preventing harm to beneficials' (p=0.003), 'the loss of control options' (p=0.002), and 'using forecast maps' (p=0.009) than younger producers when considering the adoption of pest management tactics.

In question #21 (Appendix B), producers were queried about the severity of potential problems in entomological extension (Fig. A1.7). Response options rated as major concerns for many respondents included 'the reliability of forecast maps' (24.2%), and the challenge of 'adopting new technology or farming practices for insect control' (23.4%). Interestingly, 'the cost of reliable extension resources' was not rated as a major concern by any respondents. All response options in question #21 had high correlations except for the response option about 'adopting new control practices'. Cronbach's α for this question was 0.8, and all item-rest correlations were above R^2=0.2. While no demographic variables significantly impacted answers to this question, 'the number of crop commissions in which respondents were involved' was associated with an increased frustration with 'accessing forecast maps' (p=0.009), 'understanding forecast maps' (p<0.001), and 'understanding general entomology extension information' (p=0.029).

Question #22 (Appendix B), positioned near the end of the survey gave producers an opportunity to provide additional open-ended comments about insect issues and entomological extension in Alberta. A total of 38 responses were received by producers and tagged to fit into any of 10 categories, with more than one tag applied if comments fit into multiple categories (Fig. 1.5).

Survey evaluation

Non-response replies throughout the survey were generally less than 5%, apart from a few questions (Table A1.6). Likert-scale questions were the type of question most often skipped by respondents. All response options throughout all five Likert-scale question groups were skipped by at least 5% of respondents. Other questions skipped by a large portion of respondents included 'the cost of treating fields for insect pests' (33.7% skipped), 'percentage of field treated with synthetic fertilizer or pesticide' (9.3% skipped) and the size of the farm (6% skipped).

The reliability of the questions to measure the desired factors was independently reported for questions above using Cronbach's α, most of which were >0.7, and item-rest correlations, all of which were $R^2 \geq 0.2$. This indicates that the potential responses consistently measured the same factor in the respondents, such as the level of trust of information sources. Expected alignments between related questions were also used to validate the survey. For instance, the complexity of the farming system in terms of the number of crops grown had a positive relationship with the number of controls used ($R^2=0.44$), as well as respondent familiarity with ($R^2=0.35$) and use of ($R^2=0.28$) alternative control methods. Similarly, respondents dealing with more types of pests were familiar with ($R^2=0.36$) and used ($R^2=0.52$) a greater variety of control methods. Respondents who used a variety of pest control tactics were more likely to be familiar with ($R^2=0.5$) and use ($R^2=0.48$) alternative control methods, and to obtain alternative pest control information from a number of sources ($R^2=0.44$). Similarly, the relationship between pest management cost per unit area and the issue of pest management cost were correlated ($R^2=0.36$). Concern about the loss of chemical control options was correlated with the challenge of deciding to implement controls ($R^2=0.58$), while familiarity with alternative pest management tactics was correlated to their usage ($R^2=0.45$) and the number of extension information sources ($R^2=0.51$) used to obtain that information. Additionally, the respondent's location ($p=0.002$) and the amount

of foliar insecticide coverage applied by producers ($p=0.042$) was affected by whether or not producers used managed pollinators, consistent with previous findings that show lower pesticide use in farms with pollinators (Bloom et al. 2021).

External validation of the survey through comparison of survey responses to data from crop commissions and from the 2021 census, showed that a higher proportion of members of smaller crop commissions (<500 members) replied to the survey than members of large commissions (Table A1.3). Some large crop commissions had strong response rates including Alberta Pulse Growers (2.1%), Alberta Grains (1.1%), and Alberta Canola Producers Commission (1.2%). Our survey showed that more respondents farmed all crops compared to those reported in the agricultural census (Table A1.2).

Comparison with data from the 2021 Census of Agriculture (Statistics Canada 2022b) showed that the survey captured a larger proportion of male producers ($\chi^2=15.1$, df=1, $p<0.001$), and a much larger proportion of younger respondents ($\chi^2=84.8$, df=2, $p<0.001$) than expected from census data. The average farm size reported by survey respondents of 1518 hectares, was much larger than the average farm size of 479 hectares ($t=8.83$, df=281, $p<0.001$) reported in the census. Respondents reported significantly higher rates of foliar insecticide application ($\chi^2=796$, df=1, $p<0.001$) and use of insecticide-treated seed ($\chi^2=177$, df=1, $p<0.001$) than in census data. Significantly more survey respondents came from multigenerational farms (85%) than those who declared to have a written or verbal succession plan on the census (39%) ($\chi^2=262$, df=1, $p<0.001$).

Only three people replied out of 200 survey respondents contacted via email for survey feedback, and no issues with the survey were reported.

Discussion

This project was the first scientific survey of its scale to quantitatively evaluate the perspectives of producers on entomological extension in agriculture in Alberta. The survey was administered widely at in-person events and promoted online (Table 1.3), but the target sample size of 382 was not quite reached, so the confidence of survey findings being representative of the target population is at 90 instead of 95%. The study revealed that extension use patterns by producers is not always aligned with their perceived level of trust. As producers have a tendency to use the same type of extension material, digital extension tools may be greatly underutilized by some producers. Cost of pest management, along with the loss of chemical control options, are major entomological issues, while access to and reliability of extension resources are some of the biggest challenges in extension in the province.

Demographic data

Survey respondents were well educated and experienced in agriculture (Fig. A1.2), a common trait for farmers in developed countries (Mangheni 2016). As many producers reported being from multigenerational farms, they may gain significant agricultural experience at a young age. Multigenerational farms are generally large, long-standing operations that support complex farming systems. Farms owned by survey respondents were larger ($\bar{x}$=1518 hectares) than those reported in the 2021 Agricultural Census ($\bar{x}$=479 hectares) (Statistics Canada 2022a). It is possible that operators of small farms attend fewer agricultural trade shows and events due to a lack of capital or time, and the potential benefits of attendance may not offset the costs of travel or lost work (Liu et al. 2018; Norton & Alwang 2020). Large farms use third-party extension services for pest management more than small farms, and private extension can be difficult to access for low-income farmers (Anderson & Feder 2007; Brewin et al. 2022; Mangheni 2016; Norton & Alwang 2020). Large farms are also more likely to implement best management

practices than small farms, as they are willing to invest in new technology and have more resources (Liu et al. 2018; Rollins et al. 2018). Average farm size on the Canadian Prairies has tripled in the last 50 years (Laforge et al. 2021), but this pattern is less strong in Alberta (St. Pierre & McComb 2023). Farms in the survey sample may be more representative of average farm sizes in the future.

The survey captures a larger proportion of crop producers than livestock farmers compared to the populations of these farmers in Alberta's agriculture system (Table A1.2). Crop producers were the target demographic considered in survey development, since most pest management extension in Alberta focuses on crop pests. As insect pests of crops are more damaging than the nuisance insects associated with livestock in Alberta, crop producers may have stronger opinions and more experience with insect pest management than livestock farmers and be more likely to respond to the survey.

Use and preference of extension material by producers

Producers commonly use a wide variety of extension material to obtain entomology information, though the frequency of use varies by resource (Fig. 1.1). Convenience and trust in the Alberta Crop Protection Guide results in significant use of this extension resource. Interestingly, this resource is no longer maintained by the provincial government, but is a shared publication produced by several crop commissions in Alberta (Alberta Blue Book 2023). Similarly, producers seek information from peers, as it is convenient and efficient during the busy growing season to reach out to neighbours about pest management issues. Peers were more commonly consulted by young producers. Peers are trusted resources, as many producers will only adopt innovations after learning about the experience of others (AIC 2017; Liu et al. 2018; Marantidou 2011).

Survey results revealed that some extension information sources are underutilized by producers, including short courses and information from Applied Research Associations, which may be due to a lack of entomology extension material from these sources. Other sources may be underused due to a lack of access. Private agronomists charge producers and not all producers can afford to pay for this service. Scientific publications typically target academic audiences and can be costly for those without access to academic libraries (Hirst 2003). Social media and audiovisual resources were heavily used to obtain entomology extension information by some respondents but seldom used by others. Online resources are more widely used by younger respondents, which agrees with findings of previous studies (Guiry et al., 2012). Demographic variables such as age, gender, and economic standing, often impact user's preferences and experiences with extension (Giulivi et al. 2023; Marantidou et al. 2011; Norton & Alwang 2020). The consistency in the preferred mode of extension delivery expressed by respondents is reflected in the number of significant correlations for print and in-person material or online resources (Table A1.4). These correlations were especially strong for individuals using technology, highlighting the dependance on these types of resources by some respondents. My findings suggest that extension providers should use both online and either print or in-person material to effectively reach a wide target audience (Chowdhury & Odame 2013; AIC 2017; Cooke et al. 2017; Illingworth 2017; Nettle et al. 2022). Additionally, separation of producers into clusters to target and analyze extension efforts may improve the reach of extension efforts with a narrow scope (Marantidou et al. 2011).

The willingness of producers to adopt new pest management practices and products will drive long term changes in the industry (Giulivi et al. 2023; RDAR 2022a). Extension providers need to understand producer perspectives and needs to develop effective extension programs.

Due to the increased familiarity with online tools, we expected producers would prefer electronic forms of extension over other information resources. Many of these electronic communication channels, however, including social media, audiovisual material, and digital tools are either underutilized or viewed as untrustworthy sources of information by producers. Respondents to a *Wheat Extension Survey* conducted by Alberta Grains (Strydhorst 2020) also rated social media as untrustworthy, and users of social media often promote solutions with weak evidence of effectiveness (Labarthe et al. 2012). The potential for digital media as an effective extension tool is not yet widely recognized by producers and could use additional promotion and support to increase its use (AIC 2017). Digital technology aligns with producers' needs for timely and efficient knowledge transfer and supports interactions that can build networks and communities (Anderson & Feder 2007; Chowdhury & Odame 2013; Liu et al. 2018; Madonna et al. 2023; Rollins et al. 2018). Digital tools also lower barriers to the spread of information and can grow their reach at a low cost (Giulivi et al. 2023; Norton & Alwang 2020). More advanced digital tools for collaboration and knowledge transfer are available since the COVID-19 pandemic, but the full potential of these tools to support entomological agricultural extension has not been reached.

Despite the growth of digital media, traditional sources of information, such as peers, agronomist newsletters, and agricultural events are still preferred by many producers (Fig. 1.2), and face-to-face programs still make up the bulk of many public extension budgets in North America (Norton & Alwang 2020). Peers are considered highly trustworthy as they are familiar to producers (AAFC 2022a; AIC 2017; T. Liu et al. 2018). Albertans in general trust farmers more than other professionals including scientists, university researchers, and public servants (CCFI 2022). Another discrepancy between the two surveys was the trust held in information

provided by private agronomists. Respondents of my survey ranked private agronomists as highly trusted, whereas in the *Wheat Extension Survey* they did not rank among the most-trusted sources of information. Grower preference for mode of extension information requires additional research to understand the discrepancies between these two surveys. Low trust ratings of professional agronomists in the *Wheat Extension Survey* could be linked to infrequent use, and high variation in the use of private agronomists was evident in my survey. Significant correlations among the levels of trust for similar types of sources (Table A1.5) was revealed in our study.

Respondents to my survey trust extension materials that they use frequently. The exception to this finding includes scientific publications and short courses as sources of information. Respondents found these extension resources to be relatively trustworthy but did not use them often. Interestingly, scientific publications ranked as least trusted among the traditional extension resources. Respondents of the *Wheat Extension Survey* (Strydhorst 2020) however, ranked scientific publications as highly trustworthy. There is potential to increase the exposure of these sources of information, but that will require removal of access barriers to these sources through open access publication. Social media is ranked as relatively untrustworthy, but a significant proportion of respondents use it regularly. Use of social media by extension professionals may alleviate the negative public perception of social media and make it a more trusted resource for producers (Brewin et al. 2022; Chowdhury & Odame 2013). Social media can be a beneficial tool for agricultural extension since it amplifies messages from other media, enables collaboration in content, is free to access, and allows creativity in the delivery of information (Chowdhury & Odame 2013; Madonna et al. 2023; Norton & Alwang 2020). Additionally, social media allows users to contest and challenge information and permits

individual voices to be heard. The lack of background checks and information verification on social media, however, erodes the value of the content.

Trusted sources of agricultural information differ among stakeholders in Alberta according to RDAR's report from their extension task force (RDAR 2022b). In my survey, the Cronbach's α value was especially high for the Likert-scale question measuring relative trust, indicating that respondents either found sources very trustworthy or untrustworthy. Public trust of different players within the agriculture system varies with age, and older Canadians have a higher level of trust (CCFI 2022). In my study, the level of trust of extension information sources correlated positively with the age or experience of the respondent, and this correlation was particularly strong for trust of private agronomists and agronomist newsletters. Non-demographic variables were also correlated with trust levels in our survey results. Respondents with low trust of Alberta's Crop Protection Guide use more alternative pest control tactics.

Current issues in entomology and extension

The survey revealed producer perspectives on the most common entomological issues in Albertan agriculture. Insect pests monitored and controlled by respondents over the past 3 years (Table 1.4) align with insect pest population levels in Alberta, reported by the Western Committee on Crop Pests in 2022 (Barkley 2022). Most survey respondents could identify target pests through field observations and sweep net sampling. Most producers report unfamiliar insects and damage as only a minor concern and seek help with identification from peers (Fig. A1.5). Agronomists were revealed as an important resource for insect identification and on-site pest monitoring. Location impacted response to pest management issues, which highlights the need for local extension information (Gosselin 2009; Labarthe et al. 2012; Sanders et al. 2021; Brewin et al. 2022).

Respondents report high synthetic chemical inputs, with higher application rates of foliar insecticides and seed treatments than shown in census data (Statistics Canada 2022a). This discrepancy may result from higher representation of livestock producers in the census data than in our survey. Livestock producers may farm hay and forage as feed, but this has low insecticidal inputs as the crop is not for human consumption.

The cost of insect pest management, and the loss in crop value from insect pest damage were ranked as highly problematic by respondents of my survey (Fig. 1.3). Farm management costs have been increasing due to the rising input costs over the past two decades (AAFC 2022a; CCFI 2022; Laforge et al. 2021). The number of Canadian producers that rate input costs as the worst issue they face has more than doubled in the last five years (AAFC 2022a). Cost is also a barrier to the adoption of innovative practices, especially when coupled with the risk and uncertainty of new technologies (Liu et al. 2018).

Unfamiliar insects and damage were rarely reported as an issue by respondents. This finding could indicate that invasive or rare insect pests and the associated damage are infrequently encountered in Alberta. Alternatively, information on new threats may be quickly and effectively disseminated to producers through current extension sources, such as beneficial insect identification information provided by Field Heroes (https://fieldheroes.ca). Lack of hands-on training in insect identification was not a major concern of survey respondents. Producers from multigenerational farms (82%) likely receive “in house” training from experienced family members. Those producers who reported an issue in identification of unfamiliar insects also had issues with unfamiliar damage, and monitoring for insect pests.

The loss of chemical control options was the response option most frequently rated as a major concern by respondents of the survey (Fig. 1.3). Although Canadian farmers still use some

insecticides that have been banned in other regions, such as neonicotinoids (Government of Canada 2020), recent bans on the use of chlorpyrifos (Pest Management Regulatory Agency 2020; Schulte 2021), and severe restrictions in lambda-cyhalothrin (ex. Matador®) (Aldrich 2023; Pest Management Regulatory Agency 2021)use impair the pest control options available for producers. Correlations in the survey data suggest that loss of chemical controls make pest management decisions more challenging for producers. The loss of chemical controls was generally a bigger issue for producers who use managed pollinators, potentially due to a desire for more insecticide options not harmful to pollinators. Producers who use a greater variety of control measures are less concerned about the loss of chemical control options.

Effectiveness of pest control tactics is the top priority of producers when implementing pest control measures (Fig. 1.4). Albertan producers, however, are also visibly conscious stewards of the environment (CCFI 2022). Respondents prioritized extension input from economic thresholds and harm prevention to beneficial insects over the cost of control measures. This environmentally conscious outlook may be associated with the recent increase in extension efforts to promote knowledge on beneficial insects. Older respondents were more concerned about beneficial insects and were more likely to use forecast maps than younger respondents, but were also more challenged by the loss of chemical control options.

Entomology extension issues were considered as moderately important by most respondents of the survey (Fig. A1.7). Insect forecast maps that help producers monitor and prepare for insect pest issues are regularly used by ~20% of respondents. The reliability of forecast maps, however, in local areas was identified as a major extension issue by respondents, a common issue with forecast maps (Crimmins et al. 2020; Liu et al. 2022; Prasad & Prabhakar 2012). Since many common insect pests have highly variable populations, the issue of local map

reliability may not be easily solved for some insect pests (AAFC 2023). New technologies may enhance monitoring and improve pest forecasts (Kanwal et al. 2022; Liu et al. 2022), but producers need support to implement these systems (AAFC 2022a). Interestingly, neither access to nor the cost of extension information was rated as a major concern to producers in the survey. Cost of extension in a pluralistic system can be high due to a lack of economies of scale and the incentive of profit, though it would be low compared to input costs (Pensupar & Oo 2015; Norton & Alwang 2020). Access to extension may be a minor concern since the advent of digital tools that facilitate communication (AIC 2017; Brewin et al. 2022; Chowdhury & Odame 2013; Norton & Alwang 2020).

Open-ended comments on the entomological extension system in Alberta provided by producers offered suggestions to improve specific pest management or extension issues, and identified gaps in the available knowledge (Fig. 1.5). The loss of the provincial agricultural extension system was a common concern for respondents. Respondents recognized the need for objective and unbiased entomological extension information provided by more extension professionals, a drawback of private extension systems (Labarthe et al. 2012; Krell et al. 2016; Mangheni 2016). Respondents report that the current reliance on volunteers and a small number of paid professionals to do all insect pest forecasting for the whole province is unsustainable, though these are less costly than other approaches (Rollins et al. 2018). Extension workers in Alberta regularly volunteer for extension initiatives in their local communities, and often depend heavily on local volunteers for assistance in delivery (Gosselin 2009). The comments of respondents also showed that entomology information needs to be more accessible, more up-to-date, and more in-depth. Respondents had issues finding information on economic thresholds and pest forecasts.

Outlook on extension in Alberta

Increased coordination among agricultural groups will strengthen the extension system in Alberta. Increased collaboration can streamline extension efforts to prevent overlap, reduce costs, allow information to be more widely promoted, and increase the efficiency and adoption of new practices and technologies (Anderson & Feder 2007; Krell et al. 2016; Warsame 2016; Yang & Ou 2022). The lack of coordination within the province has resulted in a lack of collaboration between extension workers and policymakers (Gosselin 2009). Survey respondents acknowledge that the growth and maintenance of an information network is key to effective extension (RDAR 2022a).

Producers value timely and accurate information, so information should be made easily accessible to promote beneficial management practices (Anderson & Feder 2007; Krell et al. 2016; Liu et al. 2018). Collaborations increase distribution of extension material and save time, effort, and resources spent on the development of extension material (Krell et al. 2016; Illingworth 2017). Increased collaboration could result in an extension system in Alberta with better coordination of activities and increased networking among players, which could streamline the search for information by producers (RDAR 2022a). The formation of an organized and coordinated extension system to give producers easier access to current agricultural extension resources is a recognized path for improvement to Alberta's extension system (ASB 2023). Coordination would reduce competition among extension service providers and improve the effectiveness of information exchange (ASB 2023). A reformed extension system in Alberta needs to align with government climate goals (Hollmann et al. 2022) and adapt to emerging challenges and future transformations to agri-food systems caused by changes in technology and consumer demands (Milburn et al. 2010; Yang & Ou 2022; AAFC 2022a; Brewin et al. 2022). Coordination of extension efforts requires farmer empowerment and training for extension

professionals to build system resilience to face these changes (Huber 2017; Davis 2020; Madonna et al. 2023). Extension professionals need on-going training and incentives for professional development (Yang & Ou 2022). This would require a clear framework to analyze extension performance and recognize professional development opportunities (Davis 2020).

Organization of entomology extension in Alberta may result in a template for coordination of agricultural extension more broadly in the province. Entomological information can be found in a narrow range of resources provided by a small group of experts. Restructuring of the system over time has made it challenging to identify extension providers and responsibilities. For instance, The Association of Alberta Agricultural Fieldmen (AAAF) have taken on programs on behalf of Agriculture Service Boards that were formerly handled by extension staff (Gosselin 2009). Multiple survey respondents recommended reinstatement of a provincial insect specialist who could assimilate current research and production information related to insect pests and work with agrologists to disseminate this information. While current government-affiliated organizations like the Alberta Insect Pest Monitoring Network (https://www.alberta.ca/alberta-insect-pest-monitoring-network) and the Prairie Pest Monitoring Network (https://prairiepest.ca) effectively disseminate this information, the scale may be too broad for the specific needs of producers (Anderson & Feder 2007; Gosselin 2009). Coordination of extension efforts is necessary in Alberta as there are many private and public extension sources currently providing information to producers without a coherent extension plan (AIC 2017; Gosselin 2009).

The coordination of extension efforts in Alberta could be spearheaded by the Agriculture Service Boards (ASB's; https://agriculturalserviceboards.com), which, when adequately funded, are well-positioned to deliver extension in local counties across the province (ASB 2023). These

boards advise both municipal and provincial governments on agricultural issues and policies. Agriculture Service Board staff possess generalist knowledge and can disseminate information gained by experts. Agriculture Service Boards are well positioned to coordinate extension at a local level, which is necessary for effective extension service (Gosselin 2009; Labarthe et al. 2012; Yang & Ou 2022) and results in improved accountability as local extension agents are keen on getting feedback so that farmers determine extension priorities (Anderson & Feder 2007). At the provincial scale, bodies like Results Driven Agriculture Research (RDAR) could support partnerships between researchers, private industry, producers, and consumers, across the province. Adoption of new practices and products from recent research can create long-term benefits (RDAR 2022b), and improve sustainability of extension (Anderson & Feder 2007).

Post-secondary institutions currently play a minor role in agricultural extension in Alberta compared to other regions, especially in the USA (AIC 2017; Brewin et al. 2022). While post-secondary institutions produce new research findings and information, they do not have the capacity or mandate to provide extension services (RDAR 2022a). Survey respondents found disconnect between universities and agricultural working groups at the expense of loss of new research findings. Canadian colleges and universities played vital roles in early extension efforts, but any current extension efforts from the post-secondary sector is the jurisdiction of individual departments and faculties (AIC 2017; Brewin et al. 2022; Kantar et al. 2023). The early access to university research paired with access to a local extension network is a strength of public extension systems that has been lost in Alberta (Krell et al. 2016). Additional steps to make research findings accessible to producers will be necessary to extend the reach of post-secondary institutions beyond research audiences (Kantar et al. 2023).

The survey conducted in this study helps to provide a benchmark understanding of the current entomological extension ecosystem in Alberta (RDAR 2022a). Extension effectiveness can be further evaluated by monitoring extension inputs, indicators and patterns of extension use, extension outputs and gains to participating (Zall et al. 2004; Franz 2015; RDAR 2022b; Yang & Ou 2022). This approach allows extension professionals to assess long term social, economic, and environmental impacts of extension activities and ensure system accountability (Knook et al. 2018; Davis 2020; Kantar et al. 2023). Monitoring and evaluation of extension activities ensures quality services and identification of gaps in the system. Quantitative evidence of extension impact would improve funding opportunities for extension activities (RDAR 2022b; Yang & Ou 2022). Measurement of the adoption of new practices and the impact of extension activities, however, is a challenge in the current extension ecosystem in Alberta (Anderson & Feder 2007; AIC 2017; RDAR 2022b). Extension efforts in Alberta could be improved by creating standardized reporting criteria. Currently, RDAR works with research partners and other funders to identify "Extension Key Performance Indicators" to evaluate extension activities in a standardized and intentional way across organizations (RDAR 2022b). Long-term funding beyond support of research projects is needed to develop broad extension goals (Yang & Ou 2022; ASB 2023) and build relationships and connections within the system (Milburn et al. 2010). Funding broad-based extension programs is difficult due to large upfront costs and delayed benefits (Brewin et al. 2022; Giulivi et al. 2023; Milburn et al. 2010). An additional challenge is the development of extension infrastructure in rural areas with unreliable access to internet and other modes of digital communication (Chowdhury & Odame 2013; Spencer & McConnell 2021).

Conclusion

There is substantial entomological knowledge and technology exchange that occurs within Alberta, and this project is the first to evaluate the use of entomological extension resources by producers. The survey evaluation suggests that the results obtained are valid and reliable. Reduced public-sector supported extension in the province has led to a growth in extension activities in the private sector that need to be evaluated (Brewin et al. 2022; Knapp 2021). Multiple lines of evidence suggest that extension professionals should use a wide range of communication channels to effectively reach the target population (Anderson & Feder 2007; Cooke et al. 2017; Kantar et al. 2023; Marantidou 2011; Nettle et al. 2022). This study found that producers use a wide variety of extension resources and communication channels, but use and trust of sources was variable. Survey results indicate that the potential of digital extension tools has not been reached but, the stigma associated with digital tools needs to be reduced before they can be successfully used (Gosselin 2009). Albertan producers will likely adapt to using new extension tools and information as they are well-educated, come from multigenerational farms, and are not overly concerned about the cost of extension (Milburn et al. 2010). The results of this survey, combined with information obtained from the extension worker survey in Chapter 3, were used to create a list of the top five recommendations to improve agricultural extension in Alberta moving forward (Table 1.6).

A follow-up survey in 5 years could assess the extension system after the transition away from provincial government involvement in the system. The survey could also be adapted for use in other sectors of agricultural extension by using similar measures to allow comparison across fields of study. To expand the scope of information collected on extension in the province, click data could evaluate the use of digital tools by producers.

Supporting extension systems makes the agricultural sector more sustainable, more responsive to the needs of producers, and more resilient in the face of environmental, economic, and political changes (Anderson & Feder 2007; Warsame 2015; AIC 2017; Yang & Ou 2022). Ensuring extension practices run efficiently maximizes return on investments supporting research and extension activities (RDAR; 2022a). Evaluation of factors related to entomology extension can result in improvements to other areas of the agricultural extension system and contribute to long term social, economic, and environmental benefits.

Table 1.1: Major factors addressed in the producer survey with data elements that relate to the factors, aspects used to measure the data elements, and questions in which they were measured.

Factor to address	Data elements related to factors	Aspects used to measure data elements	Measured in question
Extension use by producers	Usage of types of extension resources	Types of information sources used	10, 16
		Frequency of usage of resources over the year	20
		Ease of use of material	21
		Perceived helpfulness of material	21
	Involvement in extension	Participation in crop commission activities	1
Producer preferences for extension	Trust of types of extension resources	Likelihood of implementing recommendations	19
		Reliability of information	19
	Extension issues	Cost of extension	21
		Access to extension	21
	Producer needs	Type of information needed	14, 17, 18
		Type of communication preferred	19, 23
		Information about chemical controls	17
Entomological issues facing producers	Farm/ farmer information	Crops grown	2, 3
		Succession plan	6
		Farm information	7, 9
		Farmer demographics	24, 25, 26, 27
	Agricultural practices used by producers	Pest control measures used	11
		Prioritized values in pest control	18
		Area of farm managed with chemical inputs	5, 13
		Usage of beneficial insects	4, 17
		Alternative pest control practices	14, 15, 16
		Usage of technology	21
	Damage from insect pests	Pests managed and monitored	9
		Cost of pest control	12, 17
		Issues with chemical controls	17
	Pest monitoring	Monitoring methods used	10
		Issues with monitoring	17, 21
		Challenges with identification	17
		Invasive species	17

Table 1.2: Summary of question types and topics in the producer survey questionnaire. The total number of questions was 76. Each Likert-scale question response option is considered as a separate question in this table, and for data analyses.

Response type	**Number of questions**
Open ended	3
Closed ended	73
Type of question	**Number of questions**
Multiple choice	7
Multiple response	11
Short or long answer	5
Likert-scale	53
Question topic	**Number of questions**
Farm information	5
Farming practices	6
Pest management	24
Extension use	36
Demographics	5

Table 1.3: Survey promotion and administration over the survey period (1 January, 2023 to 31 May, 2023). Online promotion included publication on websites, and dissemination via email and social media. Presentations were formal PowerPoint presentations on the project to promote the survey at conferences and events. In-person events included promotional materials at an administered booth or table to distribute paper copies of the survey at conferences and events.

Type of promotion	Details	Target audience
Online promotion	Shared on social media. Primarily shared through twitter accounts by crop commodity groups and agricultural organizations (123 tweets/ retweets).	Agricultural producers and extension workers
	Forwarded survey to producers in contact with the research team and other fellow entomologists.	Agricultural producers
	Emails sent with link to survey by various crop commissions: Alberta Pulse Growers, Potato Growers of Alberta, Alberta Canola, and Alberta Grains.	Agricultural producers
	Survey shared at virtual Agronomy Update 2023 (March 17, 2023).	Agricultural producers and extension workers
	Survey promoted in "The Rural Woman" podcast during the Farming Smarter Conference (February 14-15, 2023).	Agricultural producers and extension workers
Online publication	Alberta Pulse Growers quarterly Pulse Crop News Magazine (October 1, 2022).	Agricultural producers
	Published twice on the Weekly Updates of the Prairie Pest Monitoring Network website (July 29, 2022; August 26, 2022).	Agricultural producers
	Farms.com website (Feb 13, 2023).	Agricultural producers
	Alberta Wheat and Barley's Growing Point online magazine (August, 2022).	Agricultural producers
	Published three times on Canola Watch Community Connections by the Canola Council of Canada (November 1, 2022; December 14, 2022; January 11, 2023).	Agricultural producers and extension workers

Type of promotion	Details	Target audience
	Published twice in Farming Smarter's Marketing Newsletters (December 12, 2022; January 12, 2023).	Agricultural producers and extension workers
	Published in Alberta Sugar Beet Growers newsletter (August 2022).	Agricultural producers
Presentation (online)	Canola Council of Canada's Canola Watch conference call (November 1, 2022).	Agricultural producers
Presentation (in-person)	2021 Entomological Society of Alberta conference.	Scientific audience
	2022 Western Forum of Pest Management.	Agricultural extension workers
	2022 Entomological Society of Canada and Entomological Society of America Joint Annual Meeting.	Scientific audience
	2023 Entomological Society of Alberta conference.	Scientific audience
	2023 Entomological Society of Canada and Entomological Society of Saskatchewan Joint Annual Meeting.	Scientific audience
In-person promotion	Distributed by contacts at Alberta Canola at grower engagement meeting in Grande Prairie, AB (December 15, 2022).	Agricultural producers
	Distributed by contact at Alberta Canola at grower engagement meeting in Lethbridge (January 17-18, 2023).	Agricultural producers
In person booth/table	AgriTrade trade show (November 9-11, 2022).	Agricultural producers and extension workers
	AgSmart expo (August 9-10, 2022).	Agricultural producers and extension workers
	Alberta Pulse Growers AGM in Red Deer, AB (November 10, 2022).	Agricultural producers and extension workers
	Alfalfa Seed Commission AGM in Brooks, AB (November 22, 2022).	Agricultural producers and extension workers
	Alberta Canola grower engagement meeting in Olds, AB (November 29, 2022).	Agricultural producers and extension workers

Type of promotion	Details	Target audience
	Alberta Canola grower engagement meeting in Fort Saskatchewan, AB (December 1, 2022).	Agricultural producers and extension workers
	Research Driven Agriculture Research 2023 Research Showcase (January 10, 2023).	Agricultural producers and extension workers
	The Crossroads Crop Conference (January 25-26, 2023).	Agricultural producers and extension workers
	The Farming Smarter Conference (February 14-15, 2023).	Agricultural producers and extension workers

Table 1.4: Insect pests monitored and managed by survey respondents (question #9). Percentage and number of respondents who monitored or managed various insect pests with foliar insecticides and seed treatments. (n=300)

Insect	Managed or monitored		Foliar insecticide targets		Insecticide seed coat targets	
	Percentage	Number of Respondents	Percentage	Number of Respondents	Percentage	Number of Respondents
Flea beetles	69.03%	185	64.8%	83	82.0%	137
Cutworms	52.99%	142	23.4%	30	41.9%	70
Lygus bugs	50.75%	136	41.4%	53	6.6%	11
Grasshoppers	46.64%	125	33.6%	43	1.8%	3
Bertha armyworm	36.19%	97	18.8%	24	5.4%	9
Wheat midge	32.46%	87	7.0%	9	5.4%	9
Wireworms	32.09%	86	4.7%	6	32.9%	55
Diamondback moth	31.34%	84	17.2%	22	1.8%	3
Aphids	25.37%	68	14.8%	19	3.6%	6
Wheat stem sawfly	22.39%	60	3.1%	4	4.2%	7
Stored grain pests	21.64%	58	4.7%	6	1.8%	3
Cabbage seedpod weevil	20.52%	55	21.1%	27	3.0%	5
Pea leaf weevil	20.15%	54	10.2%	13	12.0%	20
Alfalfa plant bug	10.82%	29	11.7%	15	1.2%	2
Alfalfa weevil	10.07%	27	13.3%	17	0.6%	1
Cereal leaf beetle	9.70%	26	3.1%	4	2.4%	4
Thrips	8.21%	22	0.8%	1	1.8%	3
Leafhoppers	7.84%	21	2.3%	3	1.2%	2

Insect	Managed or monitored		Foliar insecticide targets		Insecticide seed coat targets	
Spider mites	7.46%	20	4.7%	6	0.6%	1
Red turnip beetle	6.34%	17	0.8%	1	1.8%	3
Greenhouse pests	4.10%	11	0.8%	1	0.6%	1
Other (please specify)	3.36%	9	1.6%	2	0.0%	0
European skipper butterfly	2.99%	8	0.8%	1	2.4%	4
Mealy bugs	2.99%	8	2.3%	3	0.6%	1
Leafminers	2.24%	6	0.8%	1	0.6%	1
Did not target a specific pest			0.0%	0	1.2%	2

Table 1.5: Statistical tests used in analyses of survey questionnaires. Responses from all questions used for a test were analyzed against responses from all other questions used for that test.

Test	Questions examined
Cronbach's α	Likert scale questions (17,18,19,20,21)
Item-rest correlations	Likert scale questions (17,18,19,20,21)
Kruskal Wallis test	Count data from multiple response questions (1, 2, 9, 10, 11, 14, 15, 16)
	Ordinal and nominal response questions (5, 8, 12, 13)
	Likert scale questions (17,18,19,20,21)
	Demographic variables of respondent's and information about their farms (6, 7, 23, 24, 25, 26, 27)
Pearson correlation heatmaps	Count data from multiple response questions (2, 9, 10, 11, 14, 15, 16)
	Ordinal and nominal response questions (5, 8, 12, 13)
	Likert scale questions (17,18,19,20,21)
	Ordinal demographic variables (24, 26, 27)
χ^2 Goodness of fit test	Demographic information (24, 25) and chemical coverage (5, 11, 13) vs census data
One sample t-test	Farm size (8) vs census data

Table 1.6: Top five recommendations to improve agricultural extension in Alberta (no specific order).

Number	Recommendations
1.	Extension providers should use a wide variety of communication channels to reach all types of producers.
2.	Cost of pest management and insecticide options are major concerns with which producers require support.
3.	Increase coordination with public organizations without the incentive of profit for extension to provide unbiased information.
4.	Increase coordination among agricultural players to consolidate entomology extension resources and facilitate easy access for producers.
5.	Set aside funds in planning for extension or provide long-term R&D funding envelopes to allow evaluation of extension activities.

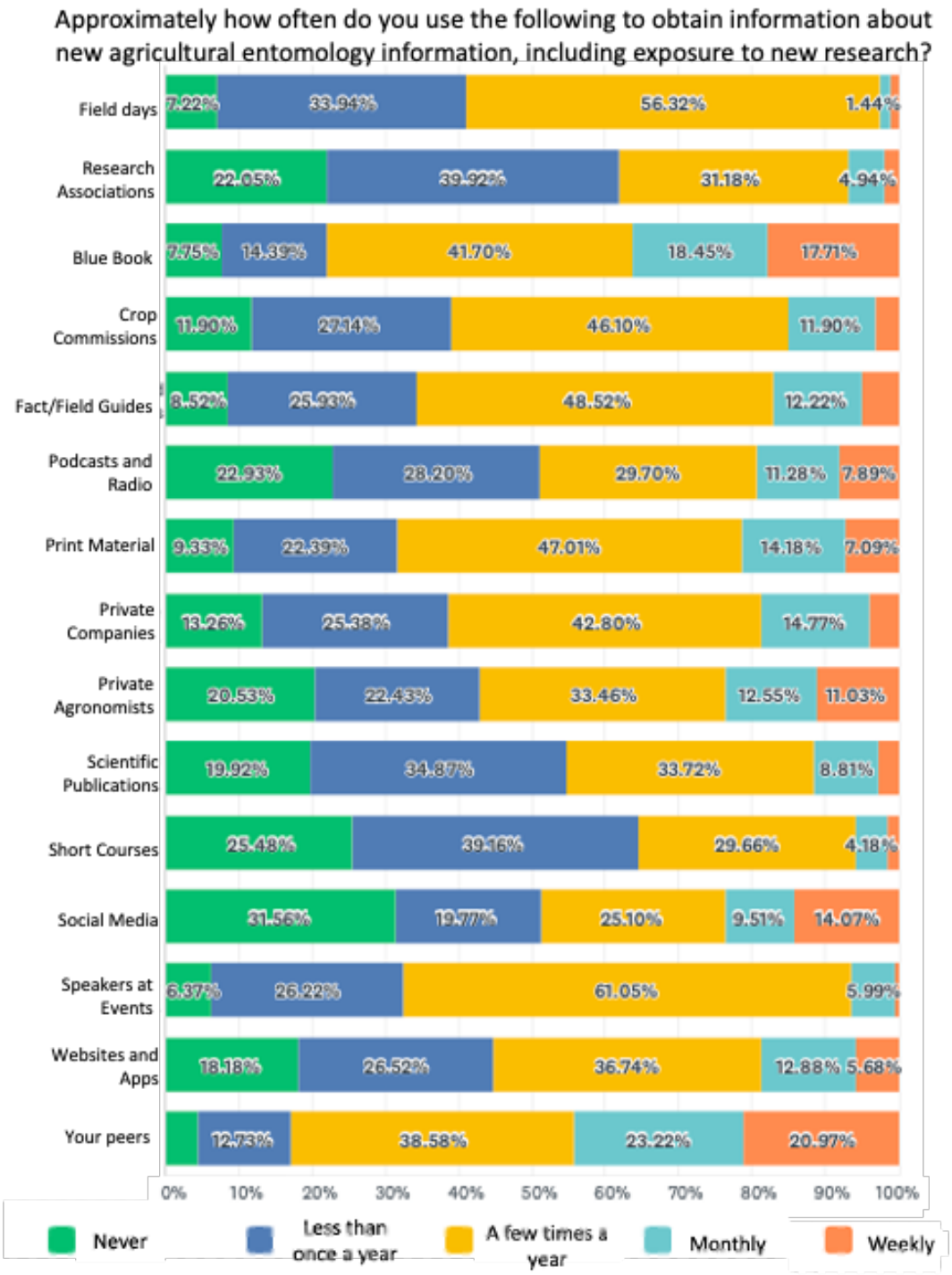

Figure 1.1: Results from Likert-scale question #20 that examined the frequency of use of different types of agricultural entomology information sources. (Cronbach's α = 0.86) (n=300)

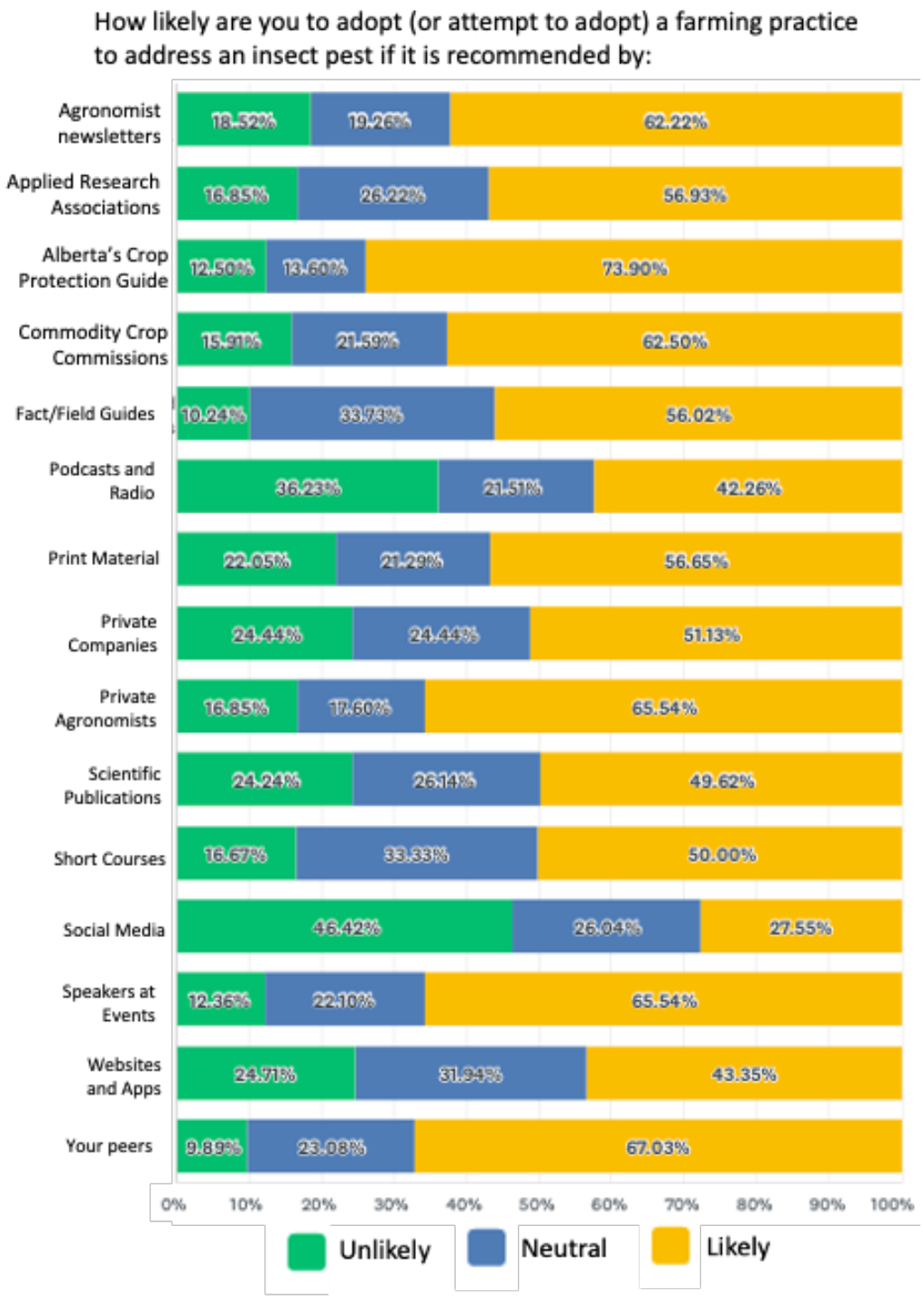

Figure 1.2: Results from Likert-scale question #19 that examined the relative trustworthiness of different entomological extension sources. (Cronbach's $\alpha = 0.86$) (n=300)

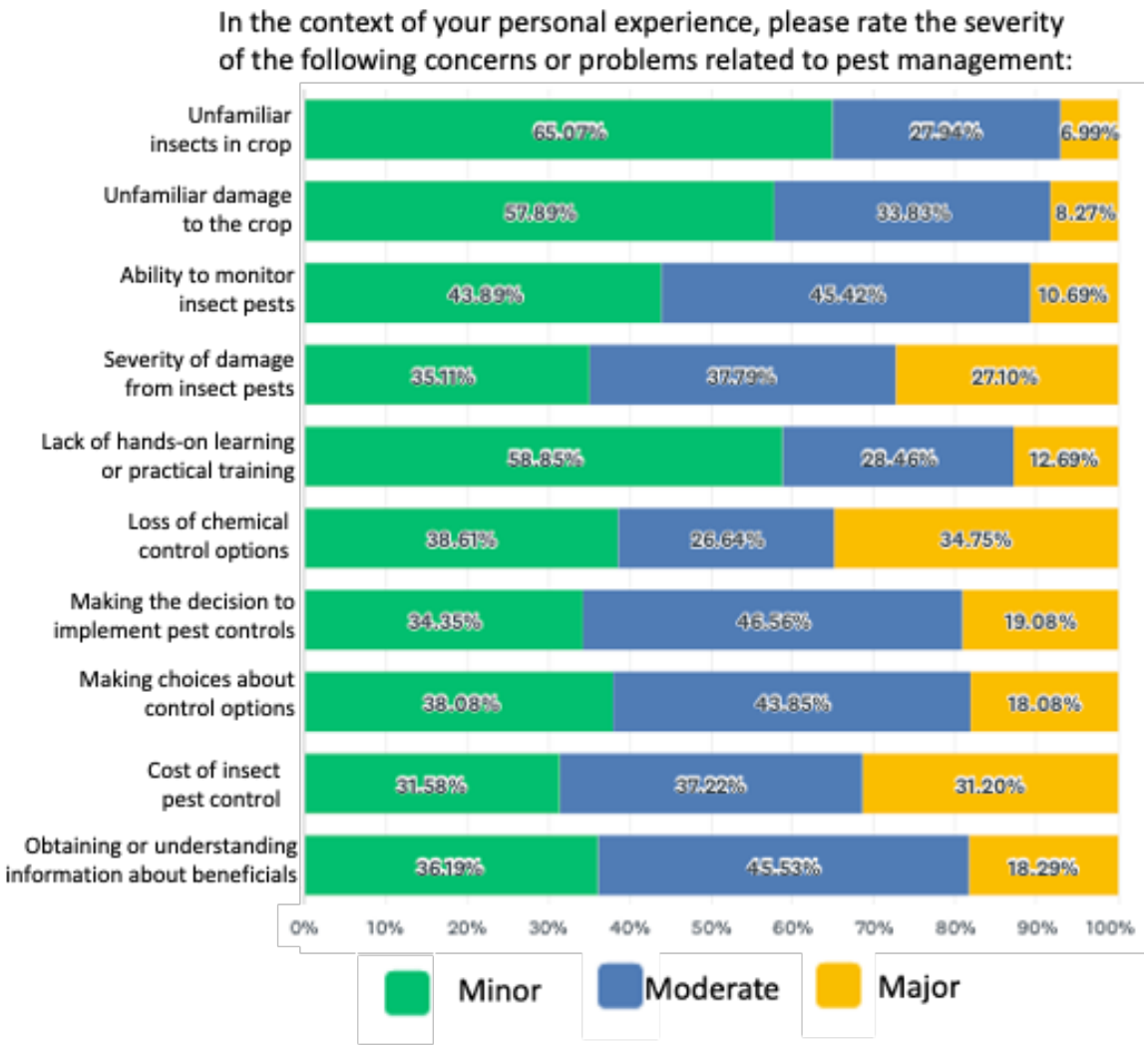

Figure 1.3: Results from Likert-scale question #17 that examined the severity of problems related to insect pest management. (Cronbach's $\alpha = 0.80$) (n=300)

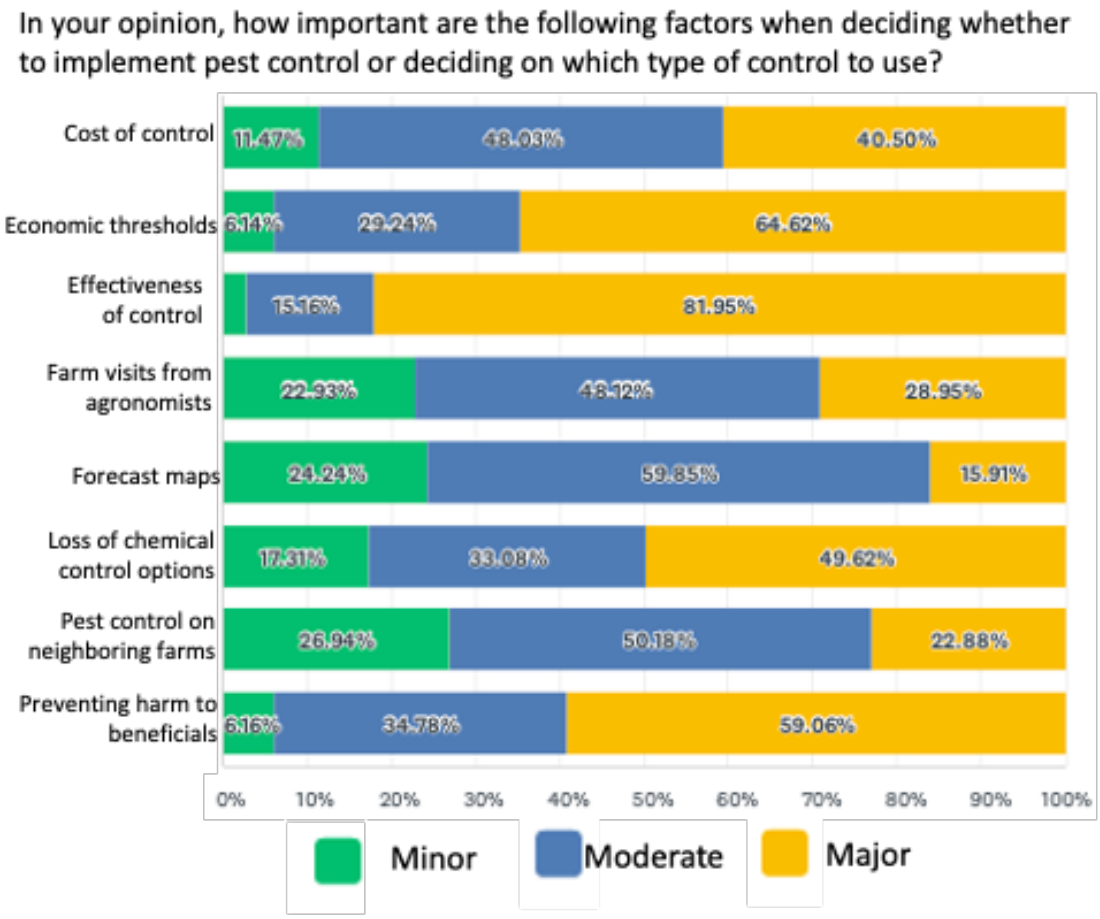

Figure 1.4: Results from Likert-scale question #18 that examined the priorities of producers in the implementation of insect pest management. (Cronbach's $\alpha = 0.67$) (n=300)

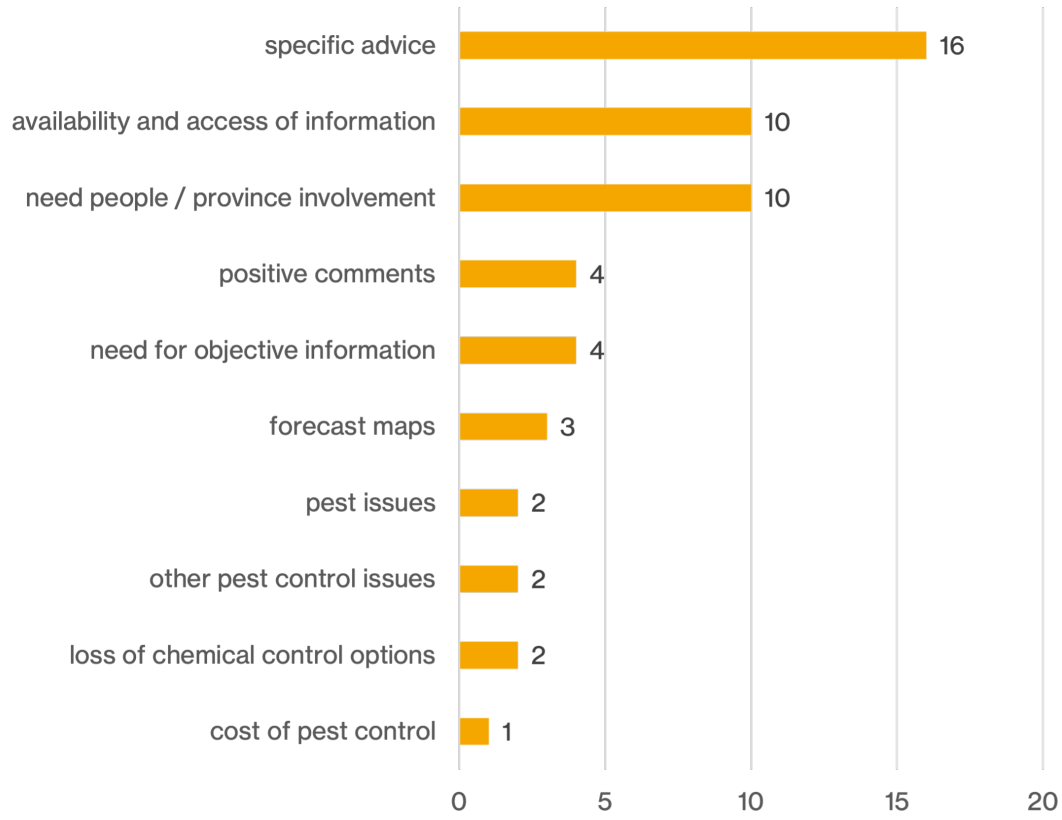

Figure 1.5: Number of producer comments on issues regarding pest management and entomology extension from question #22. A total of n=38 responses were collected and tagged with the categories noted above. The most common responses included advice for a specific issue in pest management or extension.

Figure 1.6: “What’s Bugging You?” survey questionnaire logo created by Ilan Domnich to assist in brand recognition and convey professionalism.

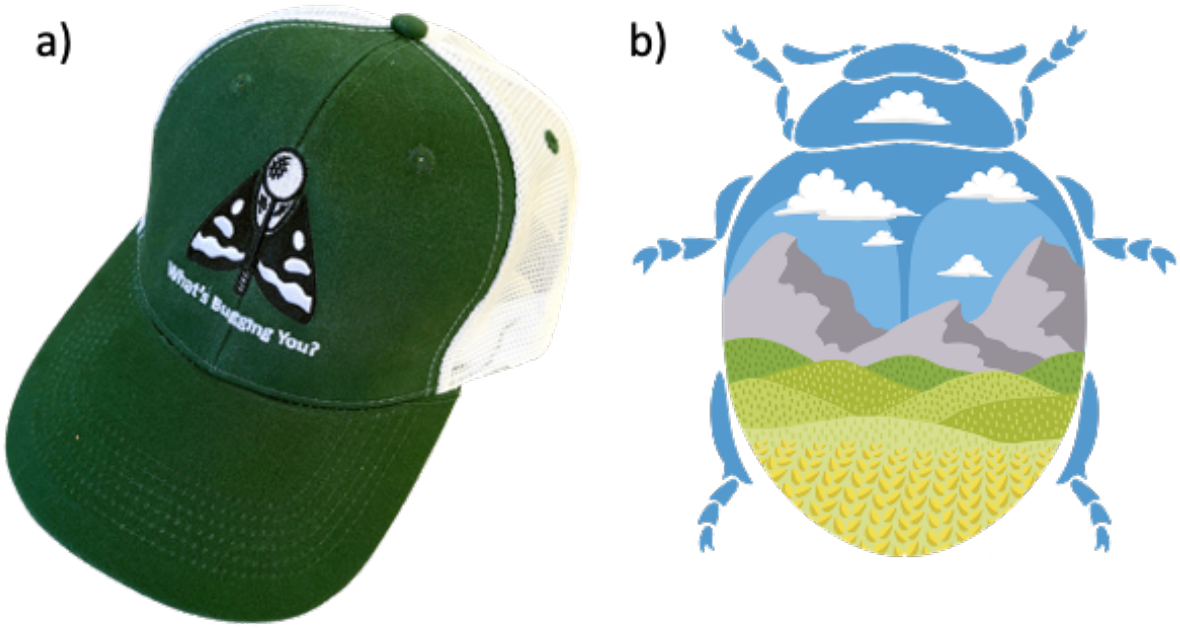

Figure 1.7: “What’s Bugging You?” survey questionnaire gift items with designs created by Ilan Domnich to assist in recruitment of respondents. Gifts included a) trucker hats incorporating the survey title and logo and b) vinyl stickers and acrylic pins with the design of the Alberta crest on the back of a coccinellid beetle.

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Chapter 3: What's bugging you? A survey of perspectives of extension professionals on the status of entomology extension in agriculture in Alberta, Canada

Introduction

Agricultural extension includes services and activities that share agronomic knowledge and research developments to drive agricultural improvement (AIC 2017; Baffoe et al 2021). Modern extension programs value bidirectional communication between researchers and producers to ensure research efforts respond to the needs of producers (Izukanne 2014; AIC 2017; Zall et al. 2004). Recent changes to the agricultural extension system in Alberta, Canada draw attention to the need to understand extension gaps and opportunities for improvement (Knapp 2021; RDAR 2022b). Increased privatization and loss of provincial extension services has resulted in crop commodity associations and industry groups taking a leading role in the support of knowledge transfer activities (AIC 2017; ASB 2023; Brewin et al. 2022; Laforge et al. 2021). The provincial government currently has a lead role in policy and public good projects, whereas industry leaders promote agricultural extension efforts (AIC 2017; Kantar et al. 2023). Unlike in other jurisdictions in North America (AIC 2017; Brewin et al. 2022) involvement of post-secondary institutions in agricultural extension in Alberta is at the discretion of researchers and in most cases is not part of the mandate of the research position.

Provincial support of agricultural research, development, and extension in Alberta is the highest in Canada (AIC 2017), but the majority of these funds likely support research and development (R&D) projects since Alberta has reduced provincial extension more than other Prairie Provinces (Gosselin 2009). Other Prairie Provinces employ public agrologists to provide advice and extension services to producers without a fee for services. Saskatchewan has extension professionals (n=53) based out of regional offices (n=10) (Government of Saskatchewan n.d.). Much like Alberta, Saskatchewan closed the rural extension offices that

existed across the province, but the regional offices that replaced them continue to provide extension services at a local level (Gosselin 2009). Producers in Saskatchewan can access advice from a range of extension specialists through a toll-free phone line, at in-person events and through government-produced publications (Saskatchewan Ministry of Agriculture 2023). Public agrologists work on-site with farmers to address issues on crop management, environmental considerations, technology transfer, business support, and new challenges such as insect outbreaks (Gosselin 2009). Extension is part of the mandate of the Province of Saskatchewan Ministry of Agriculture and is facilitated by collaboration with industry partners and post-secondary institutions with agriculture programming (Saskatchewan Ministry of Agriculture 2023). The Ministry of Agriculture in Saskatchewan uses a wide breadth of communication modes and engages the public in a variety of ways. The success and impact of agricultural extension efforts are tracked in Saskatchewan to find opportunities for improvement (Hurlbert & Pittman 2014). Manitoba has undergone consolidation in provincial extension services after the closure of many regional offices and a shift to more online extension and phone services (Wichers 2021). Private industry provides the majority of agronomic advice in Manitoba, however provincial extension agents are valued and considered important sources of unbiased information (Government of Manitoba 2016; MAFRI 2011). In Manitoba, the website for the Department of Agriculture provides a variety of extension services. Collaboration between the provincial entomologist and post-secondary institutions is common, including research projects, guest lectures, and extension events (Gavloski 2023), as the University of Manitoba is the only university with a Department of Entomology in Canada. The government-directed agricultural extension strategies used in Saskatchewan and Manitoba distribute resources to all parts of the

industry and innovation hierarchy (AIC 2017). In contrast, the more heavily privatized extension model in Alberta is driven by profitable investments and commodities.

The US Cooperative Extension System (CES) in the United States of America (USA) involves state-owned extension providers partnered with land-grant universities and the United States Department of Agriculture (USDA) to deliver publicly supported agricultural extension (USDA 2022; Brewin et al. 2022; Milburn et al. 2010; Williams n.d.). The development and administration of agricultural extension programs is based at universities, which translate research into materials aimed for the agricultural industry. At a smaller scale, extension educators also operate out of local offices and live and work in the agricultural communities, allowing them to build trust, respond to local needs, and get input from producers (Extension Foundation 2023). In other countries, most universities with agricultural programming have limited engagement with producers, but the unique CES system has successfully supported an ever-evolving agricultural sector for over a century (Brewin et al. 2022; Milburn et al. 2010; Williams n.d.). Land-grant university budgets for extension, however, have decreased in recent years (Krell et al. 2016; Norton & Alwang 2020), and the system has become more privatized (Swanson et al. 2022; Brewin et al. 2022). Most states now charge fees for a portion of their extension services (Norton & Alwang 2020). Extension in the USA often receives industry funding, and most extension workers report regularly partnering with industry on extension efforts (Krell et al. 2016). While the extension system in the USA has a legal base for coordination, the British North America Act in Canada defines education as provincial responsibility but is not explicit about extension and research (Gill 1996), and each province has a distinct extension system.

Government-supported extension efforts in North America have switched much of their focus to public good efforts, such as climate change mitigation and resource management (Anderson & Feder 2007; Krell et al. 2016; Milburn et al. 2010; Norton & Alwang 2020; Rollins et al. 2018). In many instances, private agricultural industry groups provide the majority of information and advice related to farm profitability and productivity as they may have more direct contact and can better tailor extension to the needs of individual farmers (AAFC 2022a; Brewin et al. 2022; Davis 2020; Krell et al. 2016; Mangheni 2016; Warsame 2015). Advertising by private companies also serves to provide information about products and practices without expense for producers (Krell et al. 2016). The competitive nature of the private system promotes accountability to producers, and the small-scale operations can improve coordination of management, but results in a loss of economies of scale in training and reduction in links with research (Anderson & Feder 2007; Gosselin 2009). As the structure of extension programs changes, evaluation and refinement of programs will be necessary so that extension providers remain relevant and keep up with modern agricultural practices and innovations. The perspective of individuals conducting agricultural extension comes with an understanding of the limitations and challenges facing the system and the industry. This study examines agricultural extension in Alberta, Canada from the perspective of extension professionals with a focus on agricultural extension information targeting insects. Insects have a substantial impact on virtually every food crop around the globe, whether as pests or beneficial species. Public knowledge about the importance of insects is generally low, so entomological information is commonly needed (Baker et al. 2014; Zevo 2019; Sankovitz 2021).

In this project, we administer a survey to extension professionals who work in Alberta to gain information on entomological issues facing producers, the agricultural extension ecosystem,

and potential opportunities for improvement of extension programs. Survey questionnaires are a common tool used by agricultural organizations to evaluate the reach of extension programs, the needs of producers, and evaluation of extension (Roberts and Rao 2012; Warsame 2015; Halbritter et al. 2021; Hollmann et al. 2022). Here we use a scientific survey administered to extension professionals to: 1) determine entomological issues facing producers; 2) identify methods to streamline and create collaborative extension efforts; and 3) compile and compare current entomological extension efforts in Alberta.

Survey design and methodology

Survey design and data collection

A literature search identified tools and methods used in agricultural extension in Alberta, as well as common issues in extension and pest management to guide the creation of the questionnaire. Question design began with factors that could be explored to help answer the research objectives (above) such as commonly reported pest management issues, assessment and tracking of extension efforts, communication channels used in agricultural extension targeting insects, and priorities of extension efforts. Survey design guidelines outlined previously in Chapter 2 were used to increase the likelihood of survey completion. Supplemental figures are in Appendix C, and a copy of the survey is in Appendix D.

Survey questions were primarily closed-ended with topics focused on pest management, development of extension activities, and methods to streamline extension in Alberta (Table 2.1) (Appendix D). Both online surveys administered on SurveyMonkey® , and paper surveys distributed at in-person events were used to reduce the chance of a bias appearing in the sample resulting from the mode of survey administration. A “brand” was developed for the larger project to create project recognition to promote participation of extension professionals (Illingworth

2017). The survey was reviewed by the project team and in interviews with extension entomologists (n=4) using a "think-aloud" format (Ericsson 2003; Wolcott & Lobczowski 2021). Pre-written questions facilitated the review of the survey by extension professionals and helped identify any potentially missing response options.

We calculated the minimum sample size for the survey to be representative of extension professionals using the following equation (Gideon 2012):

$X = 0.25 / (\text{margin of error} / \text{z-score})^2$

minimum sample size = (X * target population size) / (X + target population size – 1)

The total number of agricultural extension workers was obtained from the "Agrologist" position on the province of Alberta website *Alis* (https://alis.alberta.ca). This term includes agricultural representatives, consultants, and specialists in both the public and private sectors, which would make up the majority of the target audience for the survey. In 2022, there were ~1500 people in the province employed in this category (Alis - Alberta, 2022). Given a confidence level of 95% (α=.05) and a margin of error of 5%, a minimum of 306 participants is required.

University of Alberta Research Ethics Board (REB) approval was obtained to conduct this work, since it involves the study of people (study ID: Pro00114256). Once approved, the survey was administered between 1 January and 31 May 2023. The survey (Appendix D) was distributed to extension professionals directly through email (n= 283 emails sent to individuals and organizations in entomology extension in Alberta) and more widely over social media. Direct contact was made with extension professionals in Alberta associated with Applied Research Associations (ARAs), post-secondary schools with agriculture programs, agricultural commodity commissions, private agronomists, and private corporations. In addition, the survey was promoted at two in-person events: 1. Crossroads (January 25-26, 2023, Red Deer, AB); and

2. Farming Smarter (February 14-15, 2023, Lethbridge, AB) that were well attended by extension professionals. The survey targeting extension professionals was also administered at the same events as the producer survey (Table 1.2).

Statistical analyses

Prior to analyses, respondents that did not meet the criteria of the target population were removed from the dataset. Respondents were removed if they worked outside of Alberta, or if they declared that extension was not officially or unofficially part of the mandate of their employment. Predominantly incomplete submissions were removed, numerical responses were coded for consistency, ordinal variables were converted into numerical responses, and binary response variables (yes/no) were coded into numerical responses (0 and 1). In the demographic data, only male and female genders were considered because other genders formed less than 1% of respondents. Responses such as 'I don't know' or 'Prefer not to answer' were considered as missing variables for analyses unless measuring non-response rates. The number of responses selected in questions that permitted multiple responses was used as count data in addition to the response variables. Data were cleaned in Microsoft Excel and subsequent analyses were performed in the free open software program *Jamovi* (The Jamovi Project 2023).

A Kruskal Wallis test was used with an $\alpha=0.05$ to identify factors, such as demographics, that impacted responses. Pearson correlation heatmaps revealed the strength and direction of relationships recovered in the data, which allowed identification of additional patterns in the data between individual questions (Cohen 1977).

Survey evaluation

The survey was evaluated to ensure the questions accurately measured the desired factors and represented the target audience (Gideon 2012; Gallhofer & Saris 2007; Tsang et al. 2017). Non-response, the proportion of empty responses to a given question, was evaluated through

identification of mandatory questions that were skipped by >5% of respondents (Cohen 1977). Reliability was evaluated through Cronbach's α (Gallhofer & Saris 2007; Gideon 2012) which evaluates the shared variance among responses to a group of questions, such as a set of individual prompts within a Likert-scale question. The Cronbach's α metric should be high (above α=0.6) if all of the questions in the scale measure the same factor (Cohen 1977). Item-rest correlations highlighted prompts within Likert-scale questions that behaved differently in terms of responses, with values below R^2=0.2 flagged for investigation. These analyses reveal potential issues in the survey, such as sampling errors or a selection bias (Gideon 2012) and can be used to determine credibility of the results.

Extension map development

A visual map of resources providing online agricultural entomology extension information in Alberta was created to help users find the information they need in a centralized location (https://www.mindmeister.com/app/map/2753997962?t=UTlaUiaGYK). Visualization of the map can additionally identify potential gaps in agricultural entomology extension. The map identifies connections among working groups in agriculture to provide a visual representation of agricultural extension efforts within the province. The online mind-mapping software MindMeister® was selected to design the map due to ease of navigation and use for the end user. Extension efforts displayed on the map were collected based on extensive online searches, information provided by extension professionals, and scouting for extension providers at conferences and trade shows (Table 1.2).

Results

Survey administration and demographics

A total of 445 surveys were received from extension professionals over the five-month survey period. A small number of survey participants (n=27) who worked outside of Alberta were removed, as well as 10 individuals that reported that extension was not part of their work mandate. After cleanup, 354 surveys were usable for data analyses, which exceeded the calculated minimum sample size (306). No mandatory survey questions had a non-response rate higher than 5%. A total of 94 paper surveys were entered manually into the SurveyMonkey® platform from in-person events, and an additional 42 respondents signed up for the survey at events prior 1 January 2023.

The survey captured a wide range of respondents from different groups in the agricultural industry (Fig. 2.1). Each type of agricultural extension professional was represented by at least 13% of respondents, except for provincial extension employees who represented only 2.6% of respondents (Fig. 2.1). Many respondents (30%) were employed by private service and product providers. Most respondents considered extension as an official part of their job, but 18.2% of respondents considered entomology extension an unofficial part of their employment mandate.

Producer issues and extension needs

Pest management issues were evaluated with a Likert-scale question (question #7, Appendix D) (Fig. 2.2). Extension professionals identified the most important issues as ‘cost of pest control’ (59.3%) and ‘the loss of insecticide options’ for producers (55.6%). ‘The lack of insects to control weeds within crops’ was the only response option considered generally unimportant. A Kruskal Wallis test showed that respondent location impacted responses to potential issues of ‘resistance to insecticides’ ($p<0.001$) and ‘the loss of chemical control options’ ($p=0.016$). Cronbach’s α was 0.62 for question #7, and all item-rest correlations were above

R^2=0.2 except ‘the cost of pest management’ (R^2=0.15). Respondents who frequently received questions from producers about best management practices (BMP’s) viewed the issue of ‘actively monitoring and using thresholds’ as more important (R^2=0.33), and respondents frequently asked about invasive species viewed ‘invasive species’ (R^2=0.31) and ‘the lack of insects to control weeds’ as with greater importance (R^2=0.3).

Responses to another Likert-scale question (question #3, Appendix D) showed that producers often asked extension professionals about chemical control options (41.1%) and insect identification (40.2%), and less frequently asked about overall best management practices (24.9%), conservation practices (30.2%), and invasive species (32.6%) (Fig. 2.3). This question had a Cronbach’s $\alpha = 0.73$, and all item-rest correlations were above R^2=0.2. Strong correlations occurred between inquiries related to pest management tactics. For instance, questions about economic thresholds were asked to the same respondents who were questioned about chemical control options (R^2=0.43), best management practices (R^2=0.46), and current pest issues (R^2=0.32). Significant correlations also occurred in inquiries about insects. Queries about invasive species and insect identification (R^2=0.31), and beneficial insects (R^2=0.37) were significantly correlated. Similarly, inquiries about new pest damage and current pest issues were correlated (R^2=0.31).

Issues that affect agricultural extension were evaluated in question #8 of the survey (Appendix D) (Fig. 2.4). Respondents categorized ‘funding and support of extension activities’ as the biggest issue (36.5%) facing the sector. ‘Clear access to extension’ was also a highly ranked concern of extension professionals (29.8%). Cronbach’s α was 0.66 for question #8, and all item-rest correlations were above R^2=0.2 The Kruskal Wallis test showed that location of extension professionals impacted the ‘opportunities for one-on-one communication’ during

extension activities (p=0.047). Many extension professionals located in the Peace Region of northwestern Alberta reported that 'opportunities for one-on-one communication' was a major issue. The test also showed that the count of the modes of communication used by respondents negatively impacted respondent's views on the severity of extension issues provided as response options (all p-values <0.05).

High priority opportunities to enhance agricultural extension in Alberta were explored in question #9 of the survey (Appendix D) (Fig. C2.1). Most of the proposed ideas for enhancement received support from extension professionals. The least supported suggestion was the development of Program Development Models that was supported by only 33% of respondents. The most supported idea was provincial support of a permanent Insect Specialist (66%). The open-ended question #10 (Appendix D) allowed extension professionals to provide additional comments on agricultural entomology extension in Alberta. Many respondents (n=121) took the opportunity to comment and these comments were divided into 13 different categories (Fig. 2.5). Most comments were focused on the challenge in access and availability of entomological information, the need for more support for extension, and the desire for more objective information providers, such as government extension agents.

Methods of agricultural entomology extension in Alberta

The means by which extension is conducted in the province were explored in question #4 of the survey (Appendix D) (Fig. C2.2). Most respondents preferred one-on-one extension interactions (67%). Respondents also frequently used print material (59%), electronic newsletters (58%), and presentations at agricultural events (53%) to communicate extension information to producers. Scientific publications (27%) and web-based apps (33%) were the least commonly used methods of extension. The number of modes of communication used by respondents related

to the number of methods used to evaluate extension activities (R^2=0.31) and the number of priority factors for agricultural extension enhancement (R^2=0.3).

Some respondents (26.6%) revealed that their organizations do not evaluate extension activities (question 5, Appendix D). Some organizations track the effectiveness of extension through direct feedback (49%) and click data (48%). Other organizations track impacts of extension efforts through trends of use (38%), shifts in attitudes/behaviours (29%), and user impact stories (29%). Respondents commented that extension was also tracked through both paper records and social media monitoring tools. The Likert-scale question #6 (Appendix D) on extension priorities revealed that all the listed options were considered important (Fig. C2.3). Timeliness (67%) and the accessibility (63%) of information were high priorities for most respondents. Whereas, understandability of extension information (60%) and forming lasting relationships with producers (58%) were also highly supported. Cronbach's α was 0.54 for question #6, and only the focus on beneficial insects (R^2=0.06) and the formation of long-lasting professional relationships (R^2=0.19) had poor item-rest correlations. Respondents who considered extension as an official part of their work mandate were less likely to consider accuracy (p=0.002) and understandability (p=0.005) of extension information, and access to information (p=0.001), as important. These findings should be interpreted with caution since only 64 respondents (18.2%) considered extension an unofficial part of their work.

Map of online entomology extension in Alberta

The map of online entomology extension in Alberta is publicly available (https://www.mindmeister.com/app/map/2753997962?t=UTlaUiaGYK) and the information used for the map can be found in Appendix E. A total of 85 extension providers and efforts were included (Fig. 2.6) and categorized into seven types of agencies, and some extension efforts are nested under their provider. The nested structure of the map and the green arrows that connect

closely associated organizations allows visualization of extension efforts and the relationships among extension providers and activities. Each provider or activity includes an external link to the source and is tagged with up to 15 categories of information, based on three general groupings: pest control options and use, insect biology and ecology, and general entomology communication. Users can search within the map for the information they need and a clickable link to each source is included for easy access.

Discussion

Survey administration, evaluation, and demographics

The results of our survey are robust because the number of respondents in the dataset (n=354) exceeded the target sample size. This might be attributed to direct communication with hundreds of extension providers, the short survey length (~five minutes), or a vested interest by extension professionals in agricultural extension. A high response rate can indicate that questions were delivered in a convenient and understandable way (Gideon 2012). A large number of survey responses were received from outside Alberta and had to be removed from analyses. Clearer messaging about the locality of the target audience by including provincial imagery (i.e. flag, crest) in the recruitment information could reinforce the Alberta-specific nature of the project.

Most extension professionals surveyed consider entomology extension as an official part of their work mandate, although 17% of respondents only conduct extension in an unofficial capacity. The survey captured all types of players in the agriculture industry (Fig. 2.1), but there was a lack of provincial extension professionals. This result was expected due to the withdrawal of the province of Alberta from agricultural extension over the last few decades (Dika 2021; Knapp 2021; Spencer & McConnell 2021). The number of government extension workers may be higher in the other Prairie Provinces that are more actively involved in extension (AIC 2017;

MAFRI 2011; Saskatchewan Ministry of Agriculture 2023), and in the USA, where land-grant universities work closely with state government entities (Brewin et al. 2022). The largest portion of respondents came from the private sector. This could be due to a large number of extension professionals in private industry, or that industry employees whose contact information is accessible online were easy to contact. Demographics of agrologists (Fig. C2.4) are not reported on the provincial *Alis* site (https://alis.alberta.ca) and so cannot be compared directly to the demographic variation in our study. Almost half of respondents were younger than 35. Positions that require a high level of skills and training often attract younger professionals (Anderson & Feder 2007; AIC 2017), and older individuals may have moved into management roles.

Producer issues and extension needs

Extension professionals may have a more holistic view of producer issues than the farmers themselves, as they deal with numerous producers on a regular basis. Some of the most important pest-related issues reported by extension professionals, however, are similar to those of producers (Chapter 2) and include control costs and the loss of insecticide options (Fig. 2.2). Input costs facing Canadian producers have increased over the past two decades and directly impact farm revenue (Laforge et al. 2021; CCFI 2022). Bans of various insecticides have made pest management decisions more difficult for producers and may result in ineffective control due to a lack of available options or knowledge of the system (Pest Management Regulatory Agency 2020). Extension professionals were not concerned about the lack of insect biocontrol agents of weeds, as this may only be important for organic farmers with limited access to chemical herbicides. Survey respondents rated pest issues as severe if they received many inquiries on the topic. They may have used the frequency of inquiries to gauge the level of importance of an issue to producers. Similar to the response of producers (Chapter 2), extension professionals rated insect identification as a major entomological extension issue. The importance of pest issues to

extension professionals across Alberta was affected by location, as different issues occur in different cropping regions (AAFC 2022b).

The biggest issue revealed in the survey about the delivery of entomology extension was the need for increased support (Fig. 2.4). Funding for extension is not conventionally covered in research project budgets (Brewin et al. 2022; RDAR 2022b) and has weak political support due to unclear impacts that have resulted in many reports of extension draining fiscal resources (Anderson & Feder 2007). Since the impacts of extension may be difficult to quantify, especially since farmers' decisions are influenced by many factors, funders may prioritize activities that have more direct effects (Anderson & Feder 2007; Giulivi et al. 2023). Effects that are difficult to measure can be evaluated through "soft" measurement techniques, such as interviews and focus groups, that explore impacts on non-quantifiable indicators of extension performance, such as decision-making skills and knowledge (Knook et al. 2018). Evaluation methods often may require data before program implementation, so evaluation must be incorporated into program design (Knook et al. 2018). A lack of clear guidelines to find extension information was also identified by extension professionals as problematic. This supports the need for improved coordination within the agricultural extension system in Alberta (Knapp 2021; Laforge et al. 2021). There is currently no centralized hub for producers and extension professionals to access entomological information across commodities (Gosselin 2009). The Cronbach's α metric was particularly low for questions related to extension issues in our survey, which indicates that respondents expressed their own values and views on the severity of these issues facing the delivery of extension. Respondents working in the Alberta Peace Region expressed issues with effective one-on-one communication, potentially due to the distance between farms in the north (Henning-Smith et al. 2019). Fewer extension delivery issues were reported by respondents that

used many modes of communication. Multiple communication modes are generally desired by producers (Anderson & Feder 2007; Anastasios et al. 2010; Marantidou et al. 2011) and can help increase producers' adoption of new practices and technologies (Giulivi et al. 2023), but inconsistent results in previous studies indicate more research is needed in this field (Van Campenhout et al. 2021).

Extension professionals who responded to our survey did not support Program Development Models as a way to enhance extension activities (Fig. 2.5). Although these are implemented by many organizations in Alberta as a framework that can be used to evaluate and replicate a successful program, extension professionals trained in science or agriculture may lack understanding of these models. Respondents most favoured the idea of a long-term Provincial Insect Specialist position to support agricultural entomology extension in Alberta. The loss of this position in 2020 was felt widely by extension agents as a loss of expertise in the public extension system (Knapp 2021; RDAR 2022b). Fragmentation of the extension system in Alberta agriculture was revealed from responses with a desire for greater coordination among organizations working in this area. A survey of Agricultural Fieldmen conducted by Alberta's Department of Agriculture and Rural Development revealed similar wants for more linkages in the extension system (Gosselin 2009). Collaboration allows more effective dissemination of information than the pluralistic model currently in place in Alberta (Burner et al. 2009; ASB 2023).

Three major extension issues were expressed in the open-ended comments provided by 34.2% of survey respondents (Fig. 2.5). Comments highlighted the importance of access and availability of extension information. Easily accessible information is important for both producers and extension professionals (Chapter 1; Anderson & Feder 2007; Gosselin 2009).

Producers can become frustrated if too much effort is required to simply locate relevant and reliable information (Edwards-Jones 2006). Extension professionals also expressed concern about the level of entomology knowledge of some producers. A lack of understanding of pest biology can make it difficult to learn about new pest management tactics and approaches. Producers may have cultural and physical barriers that limit access to extension material (AIC 2017; Chowdhury & Odame 2013; Spencer & McConnell 2021). Comments from extension professionals reflected the difficulty of reaching producers in rural communities who have barriers due to infrastructure or culture. Many survey respondents commented on the need for funding to support additional personnel who are dedicated to providing extension. Local extension in the province often relies on volunteers (Gosselin 2009) as they are less costly than other approaches, but these may not be reliable in the long run (Rollins et al. 2018). Support for extension and improved coordination among players could result in a common analytics platform to standardize extension evaluation and allow providers to develop the most effective extension efforts (AIC 2017; Burroughs 2000; RDAR 2022b; Yang & Ou 2022).

Methods of agricultural entomology extension in Alberta

All communication modes were used by at least a quarter of survey respondents (Fig. C2.2). Most respondents report one-on-one interactions as a highly used method of information exchange that can occur anywhere including at conferences and trade shows attended by extension professionals and producers. Participation in these events impacts the perspectives and behaviours of agricultural producers (Chapter 2). Print material and electronic newsletters are the top sources of information for some commodities (Pulse Canada 2023) and are used frequently by extension professionals. These are good sources of information on policy changes, pest issues, or news from within the region. Extension professionals do not rely on scientific publications to communicate research findings to producers, even though many respondents work for Applied

Research Associations and academia. Digital resources and online tools such as social media are often supported by organizations providing extension information (AIC 2017; Chowdhury & Odame 2013; Giulivi et al. 2023; Madonna et al. 2023). In this survey, mobile web applications were not frequently used by extension professionals, although they've proven to be favoured tools by many extension workers in other studies and can be cost effective at large scales (Giulivi et al. 2023). This may be the result of high startup costs for effective apps, and high maintenance costs to keep information updated and relevant to each user's locality (Qiang et al. 2012; Schulz et al. 2022). Traditional modes of knowledge exchange remain important in spreading the results of new research. A range of communication channels is needed to get information to all stakeholders (Anderson & Feder 2007; AIC 2017; Kantar et al. 2023; Marantidou 2011). Associations among the number of communication modes used by extension professionals, the tracking methods, and priorities of extension in our survey may indicate that professionals who conduct a lot of extension activities are knowledgeable about the guiding principles behind extension.

Extension programs need to be evaluated to determine program effectiveness and success and to highlight areas for potential improvements (Burroughs 2000; Zall et al. 2004; AIC 2017; Davis 2020; RDAR 2022b). Evaluation also provides feedback from producers on issues that can impact the direction of applied research and extension efforts and help tailor it to producers' needs (Anderson & Feder 2007; RDAR 2022a). A quarter of survey respondents do not track or evaluate extension activities, which is a common pattern seen in extension programs around the world (Knook et al. 2018). In addition to typical challenges in extension evaluation, it is difficult in Alberta due to a lack of a convenient and comparable evaluation system across the sector (Warsame 2016, Yang & Ou 2022).

Extension professionals who responded to our survey considered all aspects of extension delivery as important to its success (Fig. C2.3). Timeliness and the accessibility of information were of high priority to both extension professionals and Albertan producers (Chapter 2). High value was placed on long lasting relationships with producers and this sentiment was echoed in the comments by extension professionals. Face-to-face relationships between extension professionals and producers make the biggest impacts on the perspectives and behaviours of producers (Gosselin 2009; AIC 2017). Respondent age impacted response to factors affecting extension delivery, whereby younger respondents placed higher weight on priorities to improve extension. Respondents who had extension as part of their official job description expressed less concern about aspects affecting extension delivery. It could be that these professionals are more concerned about the reach or impact of extension activities, or measurable changes in behaviours of producers.

Map of online entomology extension in Alberta

A list of entomology extension efforts in the province was desired by more than half of survey respondents (Fig. C2.1), and other extension experts in the province (Gosselin 2009). The map of online entomology extension in Alberta created as part of this study, partially addresses this need. A large portion of entomology extension in the province is provided by commodity commissions (18 providers + 5 projects), and private industry (11 providers + 1 project), who also provide the widest variety of information. Resources that provide a narrow scope of information include academia, with a focus on research, and news organizations, with a focus on general regional updates. The low number of linkages between organizations in the map unveils the disconnect among extension providers in Alberta, as the majority are independent. The visualization of extension information and its providers may help agencies make extension more

efficient through the identification of opportunities for collaboration, prevention of duplicate resources, and guidance in finding new information.

The extension map will be hosted online and is accessible to view with a link (https://www.mindmeister.com/app/map/2753997962?t=UTlaUiaGYK). To keep the map as a useful tool, it will need to be supported into the future. As extension changes within the province, the map will require updates to stay relevant and ensure links are operational. The map may become a useful tool for users to find relevant entomology information to suit their needs.

Conclusion

This was the first Alberta-wide evaluation of agricultural entomology extension from the perspective of extension workers. The survey captured individuals from different career backgrounds, with a notable lack of provincial government employees as the province shifts agricultural efforts to policy and research funding (Dika 2021; Knapp 2021; Spencer & McConnell 2021). The survey revealed that extension professionals use many modes of communication, but favour in-person interactions and print material for knowledge translation and transfer.

Extension workers were well aware of entomological of issues facing producers and had similar concerns about loss of control options and control costs that were expressed by producers (Chapter 2). The biggest extension issues were sustainable funding, accessibility, and coordination of extension in the province. Funding options need to be refined through funds set aside for extension activities or long-term R&D funding envelopes that allow adequate evaluation opportunities (Brewin et al. 2022; Knapp 2021; Laforge et al. 2021; RDAR 2022b). The lack of provincial prioritization of extension may require private funding, such as the “fee-for-service” model some providers currently use, which can make producers less willing to share

information (Van den ban 2000; Anderson & Feder 2007). Subsidies for extension services are justified when the general public benefits from extension, such as environmental protection and consumer health (Norton & Alwang 2020; Van den ban 2000), as these are likely to be scarcely supplied by private industry (Krell et al. 2016), and when the goal is to better reach low-income farmers (Anderson & Feder 2007; Mangheni 2016; Norton & Alwang 2020). The need for accessibility and visibility of extension information was also reported in open-ended comments from extension workers and producers alike (Chapter 2). Coordination of extension services could improve accessibility and address the need for standardized evaluation procedures. The extension map created in this project highlights opportunities to build connections and improve coordination across the system. Survey analytics showed that extension priorities are impacted by the role of extension professionals and their location, so these factors should be considered when targeting the development of extension efforts. A favoured approach was a centralized position to oversee entomology extension across the province, but responsibility of funding that role is unclear (Knapp 2021).

It may provide valuable insight to conduct a similar survey in the future to see how extension practices change and to observe the longer-term impacts of the pluralistic extension system in Alberta. Assessment of specific occupational backgrounds of survey respondents may provide more refined information on the organizations involved in agricultural entomology extension in the province. With a large number of extension activities happening in the province, there is no question that Alberta has the entomology expertise to provide accurate information to producers in the province. The delivery of this extension, however, is quite variable, and may benefit from consistency in application and evaluation to allow continued improvements in the future.

Table 2.1: Summary of question types and topics in extension professional survey questionnaire. The total number of questions was 41. Likert-scale question response options are considered as separate questions in this table, and for data analysis.

Response type	**Number of questions**
Open ended	2
Closed ended	39
Type of question	**Number of questions**
Multiple choice	3
Multiple response	4
Short or long answer	2
Likert-scale	32
Question topic	**Number of questions**
Employment information	2
Planning and development of extension	9
Pest management issues	19
Improving extension	8
Demographics	3

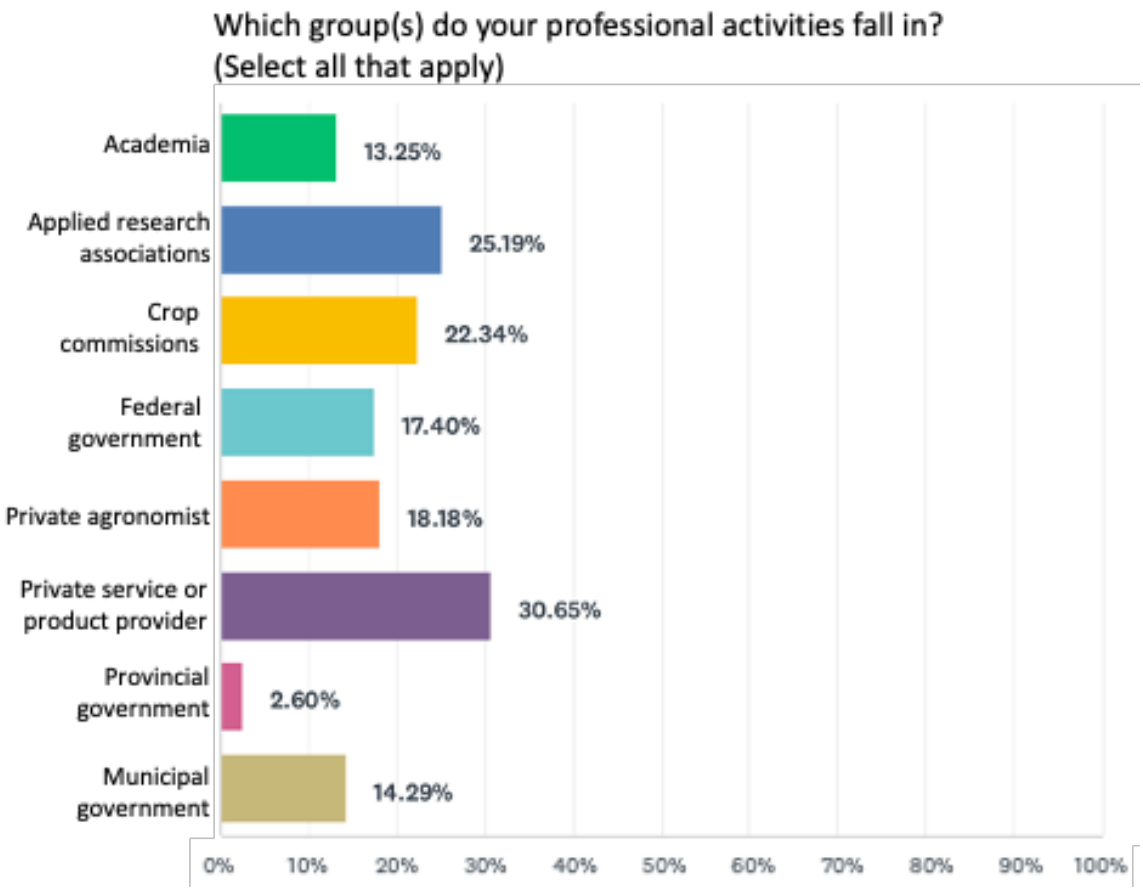

Figure 2.1: Agricultural organizations or positions that employ extension professional survey respondents (n=354).

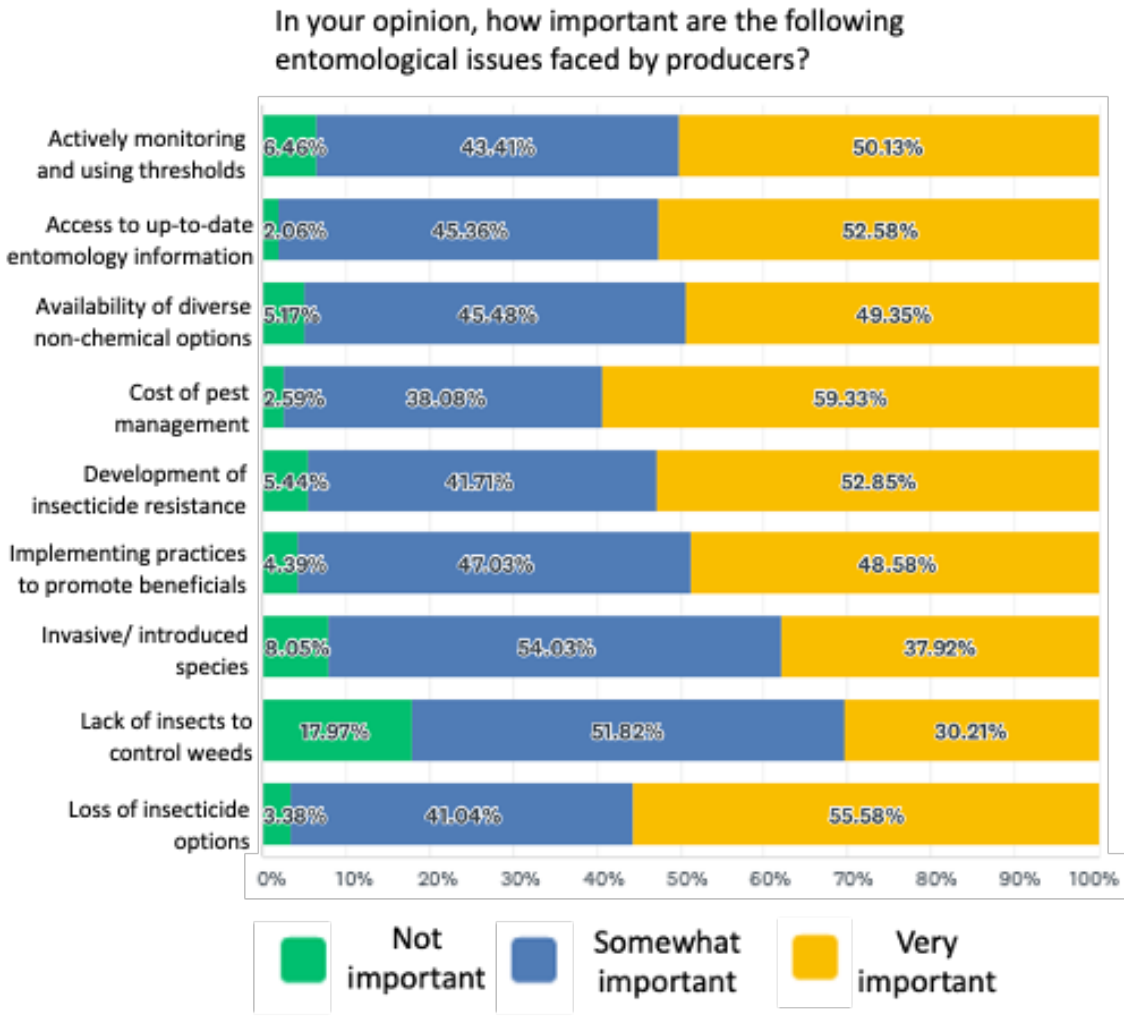

Figure 2.2: Results of Likert-scale question # 7 (Appendix D) from survey measuring respondents' perspectives on the severity of entomological issues currently faced by producers in Alberta. (Cronbach's $\alpha = 0.62$, n=354)

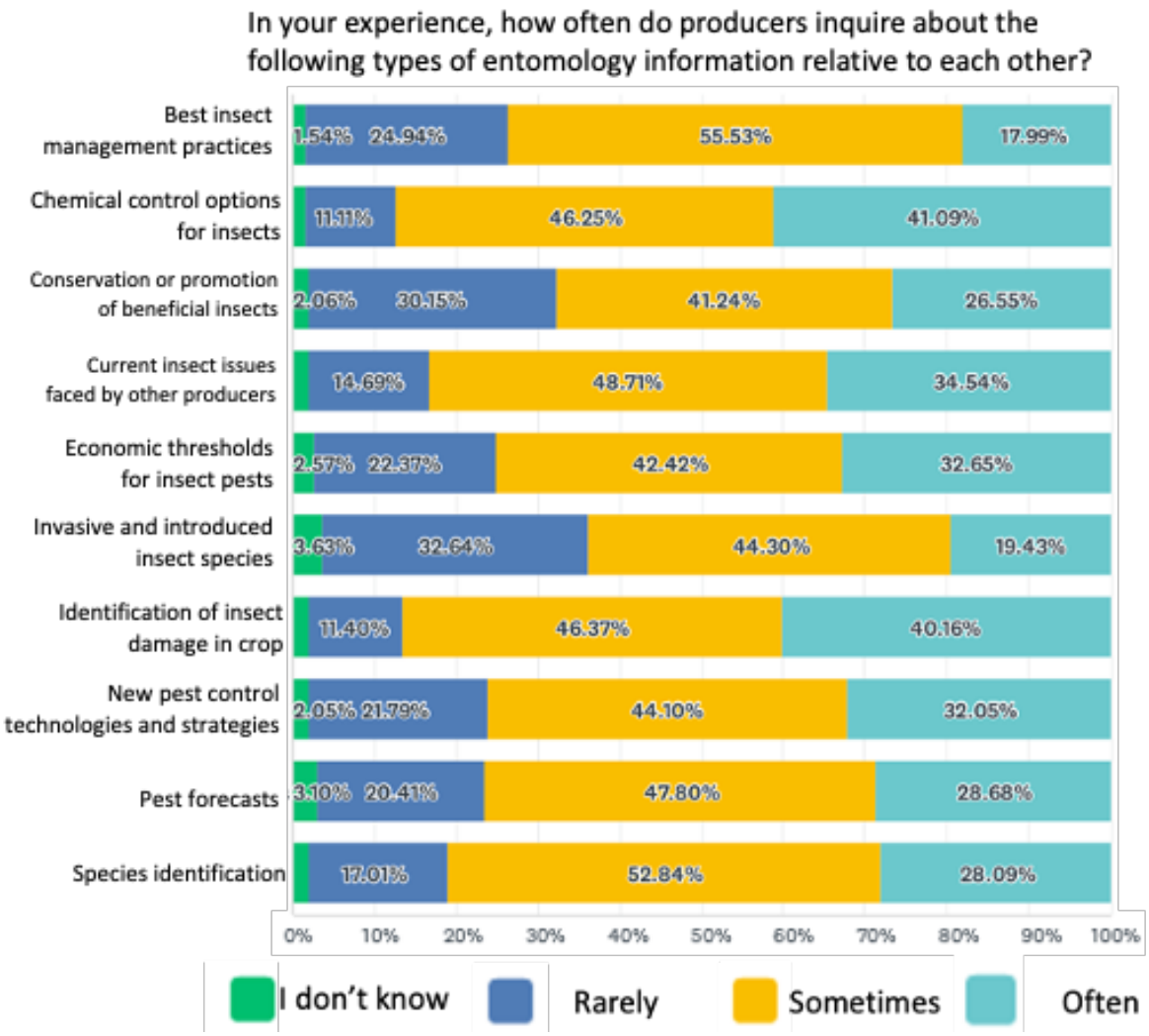

Figure 2.3: Results of Likert-scale question #3 (Appendix D) asking respondents about how often producers inquired about different topics related to insect pest management. (Cronbach's α = 0.73, n=354)

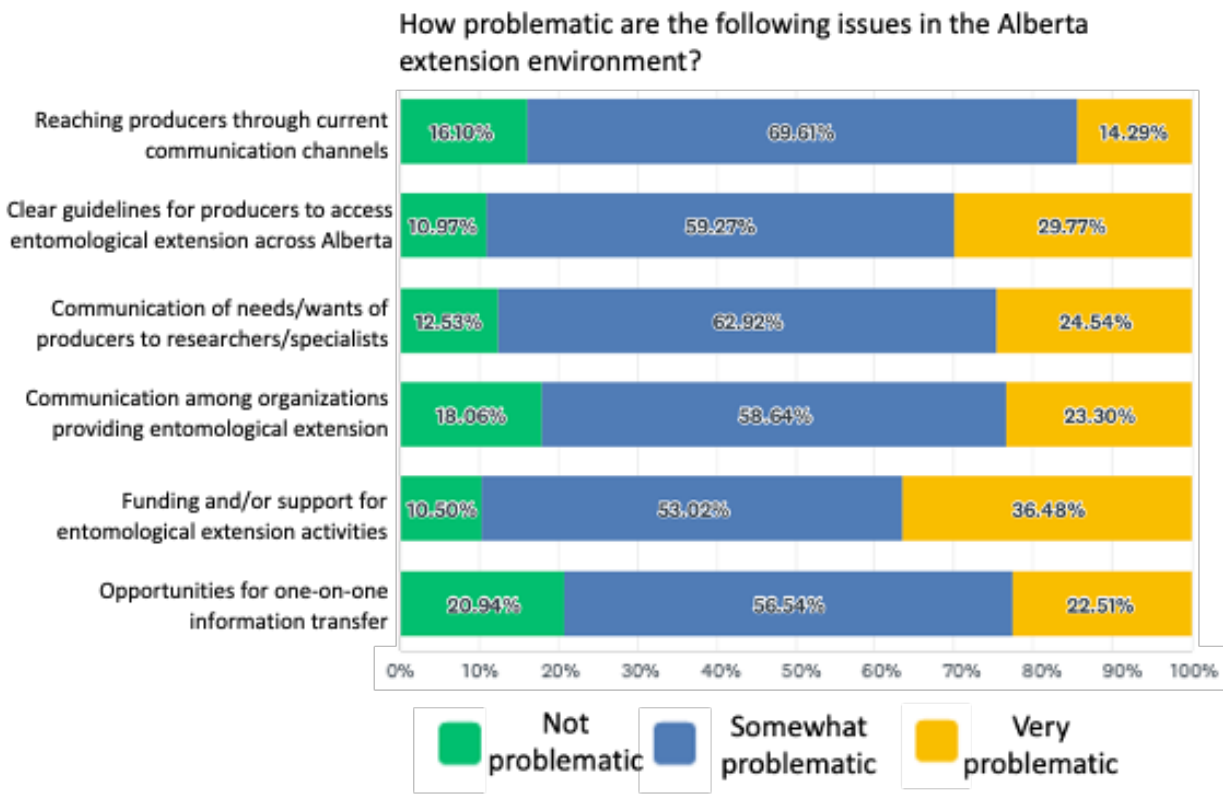

Figure 2.4: Results of Likert-scale question #8 (Appendix D) asking respondents about perspectives on potential issues around agricultural extension in Alberta. (Cronbach's $\alpha = 0.66$, n=354)

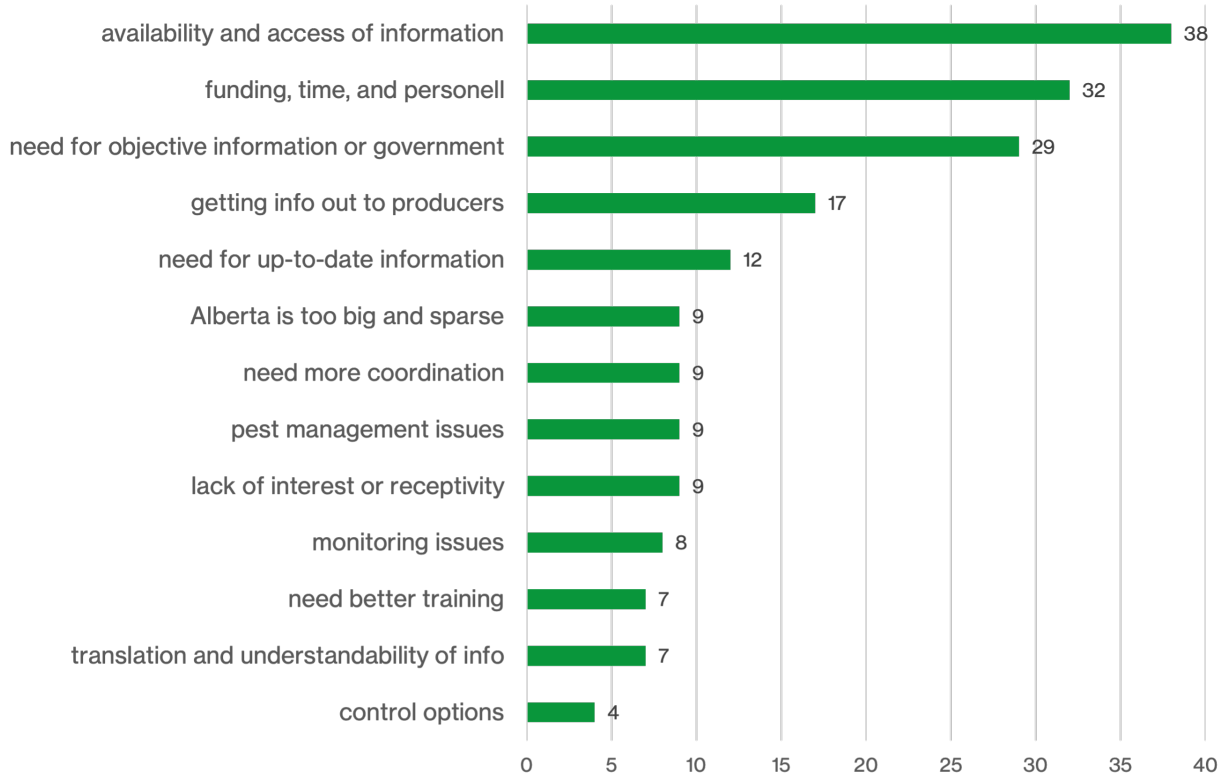

Figure 2.5: Number of comments provided by extension professionals on issues affecting high quality entomological extension in Alberta (question #10). A total of n=121 responses were collected and assigned to one of 13 categories that reflect the major needs and perspectives of extension professionals.

Figure 2.6: Screenshots of map of online entomology extension in Alberta involving 85 identified resource providers and extension activities. The map includes: a) 15 searchable categories of information classified by colour into pest control options and use, insects and the environment, or entomology communication (left), instructions for general use (centre), and 7 types of extension agencies (right), b) expandable nodes to explore types of extension providers with clickable links to associated websites, and c) relationships between extension providers indicated through green arrows (association) or a nested hierarchy, and expandable categories of information to indicate the type of information provided. The extension map was made with MindMeister® online platform and can be accessed here.

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Chapter 4: Conclusion

This project was the first of its kind to evaluate the entomological extension system in Alberta from the perspectives of both producers and extension professionals. Information collected from the survey questionnaires can be used to develop and evaluate extension efforts in the province. The results of these surveys shed light on the preferences of producers, gaps in the extension system, and potential paths to improvement for agricultural entomology extension.

Both surveys had good response rates over the course of the project, and in-person promotion was essential to administration of the producer survey. Extension professionals responded to the survey and were eager to provide feedback on Alberta's extension system. The number of extension professionals that conducted the survey exceeded the minimum sample size required and many extension professionals provided insightful comments. The surveys captured a diversity of members from each target audience. Extension professionals represented a wide range of organizations and occupations. The mode of survey administration and the specific entomology-related focus of the survey might explain the difference in producer respondents as compared to agricultural census data.

Respondent views on pest and extension issues in the province differed between surveys. Extension professionals expressed more concern about pest management issues than did producers (Fig. 1.3 and Fig. 2.2). Extension workers were more concerned about issues facing the system than producers (Fig. A1.7 and Fig 2.4). This could be because extension professionals are more aware of the agricultural extension system across the province, or due to the fact that they are employed by the system. Both surveys revealed that producers are concerned about promoting habitat for beneficial insects (Fig. 1.4), although best management practices and conservation of beneficial insects are some of the least asked about topics by producers (Fig.

2.4). Cronbach's α was consistently lower for Likert-scale questions in the extension worker survey. This indicates that extension professionals respond differently to these types of questions compared to producers, as producer responses were more consistent. Perhaps this is because producers have similar goals and interests, while extension workers work in a variety of positions for organizations with varying mandates.

Most issues facing the agricultural extension system in Alberta were perceived differently between the two survey populations. Extension professionals and producers, however, did consistently view the loss of chemical control options and the cost of insect pest management as the most important entomological issues facing producers. Similarly, the priorities of extension professionals align with producer needs for easily accessible information delivered in a timely manner. Both producers and extension professionals use a variety of communication channels. Traditional methods such as in-person and print communication are still important to producers, but there may be opportunities to enhance the use of digital resources.

The results of the surveys, as well as the creation of the online entomology extension map, reinforce what has been discussed among players in the agriculture industry to date. There is a desire in the industry for a centralized source of entomology extension efforts to improve coordination among providers and facilitate access to knowledge and resources for end-users. The dependency on commodity organizations and private industry to provide extension in Alberta results in widespread and varied sources of information and a lack of standardized evaluation tools. Alberta's extension system faces challenges of underfunding, physical and cultural barriers to technology adoption, and climate change, among others. These issues can be tackled by strengthening Alberta's agricultural extension through recommendations identified through this study (Table 1.6). Improvements to the effectiveness of the extension activities is an

important way to strengthen Alberta's agricultural system and provide it with resilience in the face of difficulty.

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Appendix A

Table A1.1: Statistical tests used in analysis of survey questionnaires. All questions used for a test were analyzed against all other questions used for that test.

Test	**Questions examined**
Cronbach's α	Likert scale questions (17,18,19,20,21)
Item-rest correlations	Likert scale questions (17,18,19,20,21)
Kruskal Wallis test	Count data from multiple response questions (1, 2, 9, 10, 11, 14, 15, 16)
	Ordinal and nominal response questions (5, 8, 12, 13)
	Likert scale questions (17,18,19,20,21)
	Demographic variables of respondent's and their farms (6, 7, 23, 24, 25, 26, 27)
Pearson correlation heatmaps	Count data from multiple response questions (2, 9, 10, 11, 14, 15, 16)
	Ordinal and nominal response questions (5, 8, 12, 13)
	Likert scale questions (17,18,19,20,21)
	Ordinal demographic variables (24, 26, 27)

Table A1.2: Summary of crops grown by respondents (question #2, Appendix B) in producer survey directly compared to crops grown by respondents in Alberta according to the 2021 census (Statistics Canada 2022b). Livestock farmers made up a large proportion of producers in the census, but are not included in this table since this information was not obtained from the producer survey. (n=300)

Crop type in survey	Number of farms	Percentage	Census crop type	Number of farms	Percentage
Canola or flaxseed	244	81.3%	Oilseed (except soybean) farming	6078	14.6%
Wheat or barley or rye or buckwheat or oats	272	90.7%	Wheat and other grain farming	7474	18.0%
Corn	43	14.3%	Corn farming	43	0.1%
Dry beans or dry field peas or faba beans or lentils or soybeans	237	79.0%	Dry pea and bean farming	347	0.8%
Alfalfa and other forage	113	37.7%	Hay farming	5078	12.2%
Greenhouse crops	6	2.0%	Greenhouse, nursery and floriculture production	421	1.0%
Potatoes	18	6.0%	Potato farming	123	0.3%
Total farms	**300**		Total farms	**41505**	

Table A1.3: Total number of members in Alberta crop and livestock commissions in descending order, and number and percentage of commission members that replied to the producer survey (question #1, Appendix B). (n=300)

	Total number of members	**Number of participants**	**Percentage replied**
Alberta Grains[1]	18000	197	1.09%
Alberta Beef Producers[2]	18000	75	0.42%
Alberta Canola Producers Commission[3]	14000	165	1.18%
Alberta Pulse Growers[4]	5400	111	2.06%
Prairie Oat Growers Association[5]	3000	13	0.43%
Alberta Organic Producers Association[6]	700	5	0.71%
Alberta Pork Producers[7]	500	11	2.20%
Alberta Chicken Producers[8]	253	15	5.93%
Alberta Sugar Beet Growers[9]	200	7	3.50%
Potato Growers of Alberta[10]	150	11	7.33%
Alfalfa Seed Commission[11]	110	25	22.73%
Alberta Greenhouse Growers Association[12]	23	6	26.09%
Alberta Farm Fresh Producers Association	Unknown	7	Unknown
Alberta Horticultural Association	Unknown	4	Unknown
Total Participants		**300**	

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Table A1.4: High correlations ($R^2 \geq 0.4$) in question #20 (Appendix B) between relative frequency of use by producers of different entomology extension resources. (n=300)

Type of resources	Resource 1	Resource 2	R^2 value
Print/ in-person	Print material	Service and product providers	0.45
	Print material	Peers	0.41
	Crop commissions	Blue book	0.40
	Crop commissions	Service and product providers	0.41
	Service and product providers	Private agronomists	0.64
Digital media	Social media	Websites	0.61
	Social media	Online courses	0.47
	Social media	Podcasts and radio	0.49
	Websites	Online courses	0.42
	Websites	Podcasts and radio	0.53
	Podcasts and radio	Online courses	0.50
Other correlations	Podcasts and radio	Print material	0.46
	Websites	Speakers at in-person events	0.49
	Websites	Print material	0.47
	Websites	Peers	0.42

Table A1.5: High correlations ($R^2 \geq 0.4$) in question #19 (Appendix B) between relative trust levels by producers for different entomology extension resources. (n=300)

Type of resources	Resource 1	Resource 2	R^2 value
Print/ in-person	Print material	Crop commissions	0.44
	Print material	Newsletters	0.41
	Print material	Scientific publications	0.54
	Print material	Service and product providers	0.54
	Crop commissions	Fact sheets	0.64
	Crop commissions	Agronomist newsletters	0.44
	Crop commissions	Speakers at in-person events	0.57
	Crop commissions	Scientific publications	0.56
	Speakers at in-person events	Fact sheets	0.49
	Speakers at in-person events	Blue book	0.45
	Speakers at in-person events	Applied research associations	0.50
	Speakers at in-person events	Agronomist newsletters	0.55
	Speakers at in-person events	Scientific publications	0.50
	Applied research associations	Fact sheets	0.49
	Applied research associations	Scientific publications	0.48
	Agronomist newsletters	Blue book	0.42
	Agronomist newsletters	Service and product providers	0.43
	Peers	Speakers at in-person events	0.68
	Peers	Fact sheets	0.54

Type of resources	Resource 1	Resource 2	R^2 value
Digital media	Social media	Websites	0.62
	Social media	Podcasts and radio	0.48
	Websites	Podcasts and radio	0.52
Other correlations	Social media	Service and product providers	0.51
	Social media	Scientific publications	0.50
	Social media	Fact sheets	0.51
	Social media	Crop commissions	0.61
	Social media	Agronomist newsletters	0.48
	Podcasts and radio	Service and product providers	0.42
	Podcasts and radio	Print material	0.46
	Podcasts and radio	Fact sheets	0.60
	Podcasts and radio	Crop commissions	0.49
	Podcasts and radio	Agronomist newsletters	0.44
	Podcasts and radio	Speakers at in-person events	0.48
	Podcasts and radio	Scientific publications	0.50
	Websites	Speakers at in-person events	0.69
	Websites	Fact sheets	0.46
	Websites	Scientific publications	0.50
	Websites	Agronomist newsletters	0.54

Table A1.6: Producer survey (Appendix B) item nonresponse levels for questions that exceed 5% (n=300).

Question	Missing values	Percentage
Percentage of field with synthetic fertilizer and pesticide applied	28	9.3%
Size of farm	18	6.0%
Cost per acre of treating fields for insect pests	101	33.7%
Issues in pest management (Likert-scale question)	39-49	13%-16.3%
Factors affecting pest management decision (Likert-scale question)	27-46	9%-15.3%
Relative trust of information sources (Likert-scale question)	57-159	19%-53%
Frequency of usage of information sources (Likert-scale question)	27-43	9%-14.3%
Issues in entomology extension (Likert-scale question)	35-42	11.7%-14%

Correlation Heatmap

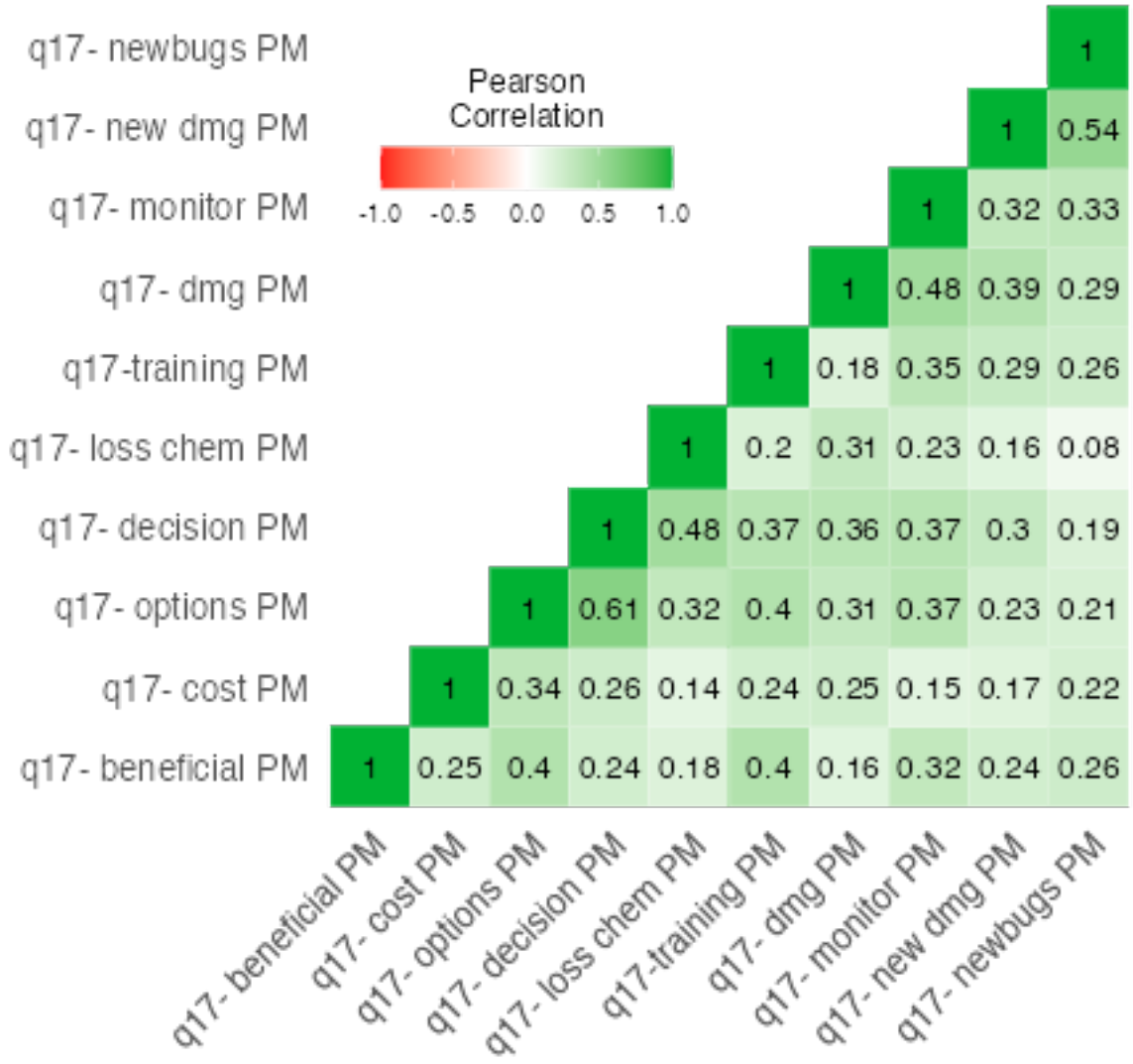

Figure A1.1: Example of a Pearson correlation heatmap generated using *Jamovi* software. This map shows Likert-scale question #17 about problems related to pest management, indicating correlations between response options.

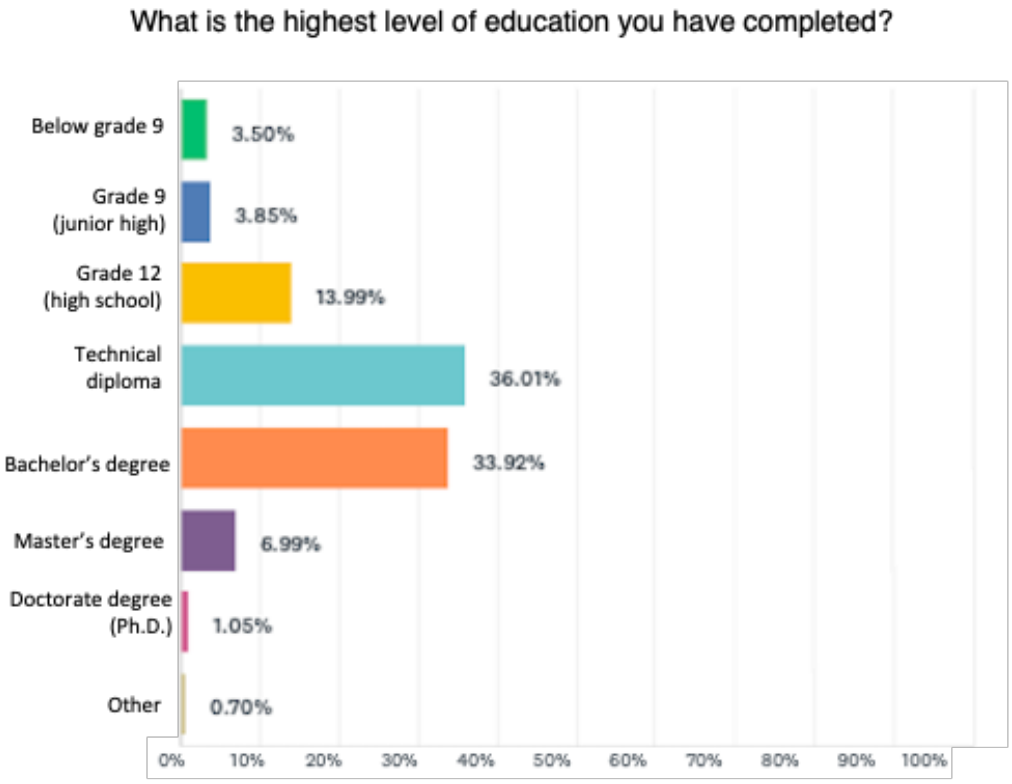

Figure A1.2: Proportions of producer survey respondents with varying levels of education. (Question #27, Appendix B) (n=282)

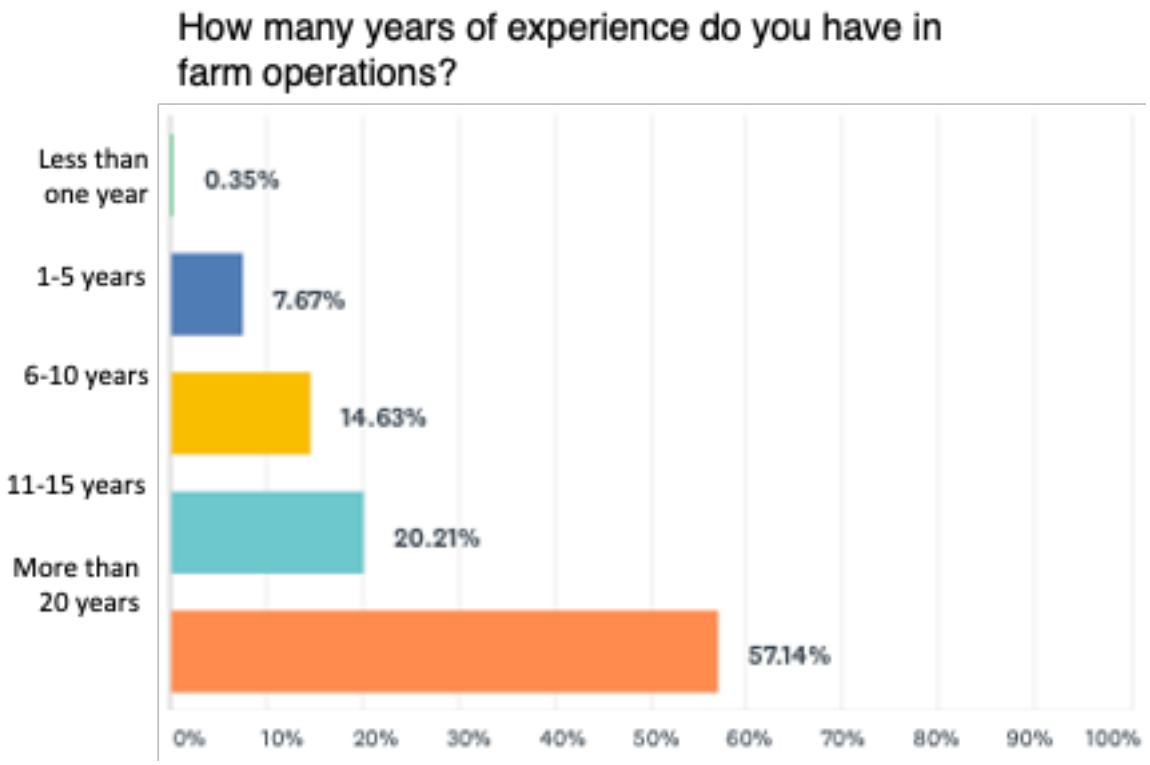

Figure A1.3: Proportions of producer survey respondents with varying levels of experience in farm operations. (Question #26, Appendix B) (n=282)

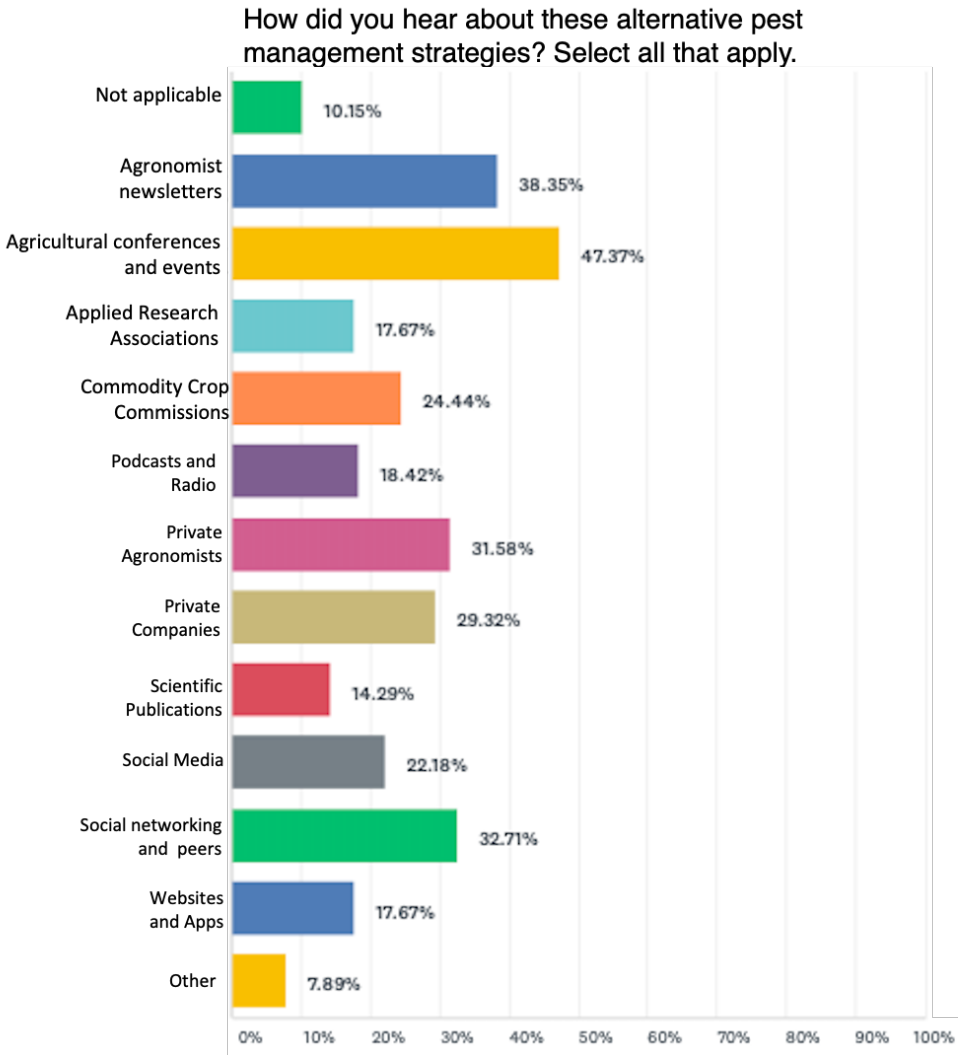

Figure A1.4: Sources of alternative pest management information reported by respondents in the producer survey. (Question #16, Appendix B) (n=300)

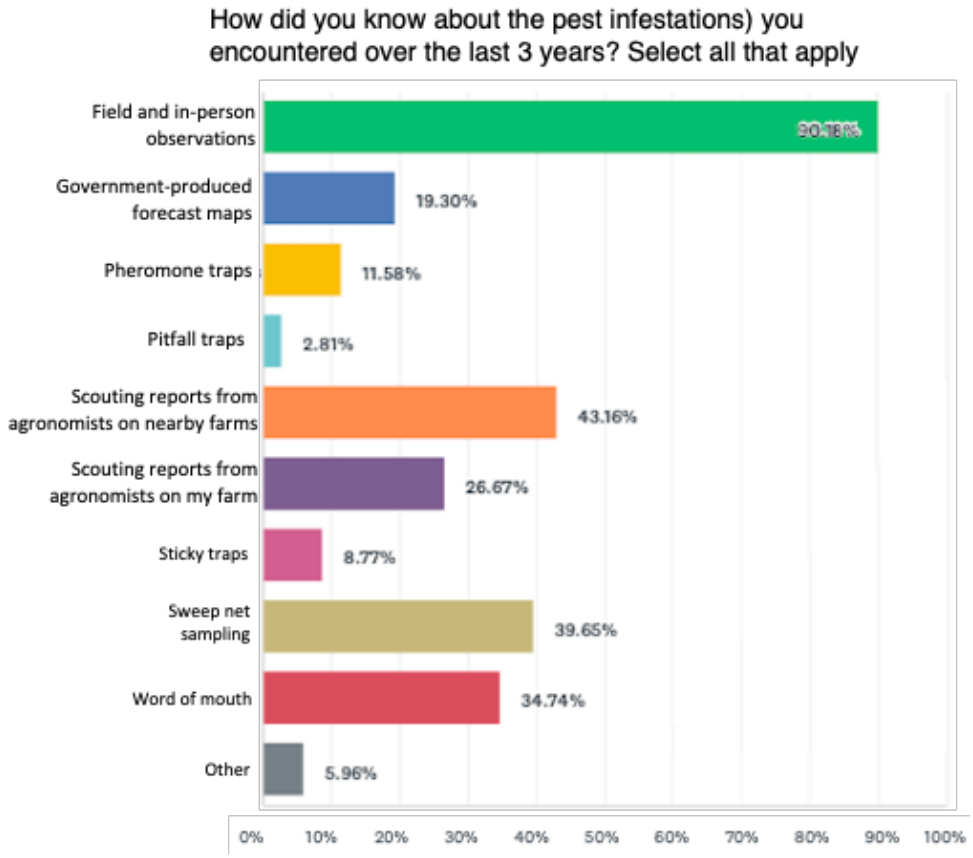

Figure A1.5: Methods of pest monitoring that alerted producers to pest populations in their fields over the past 3 years. (Question #10, Appendix B) (n=300)

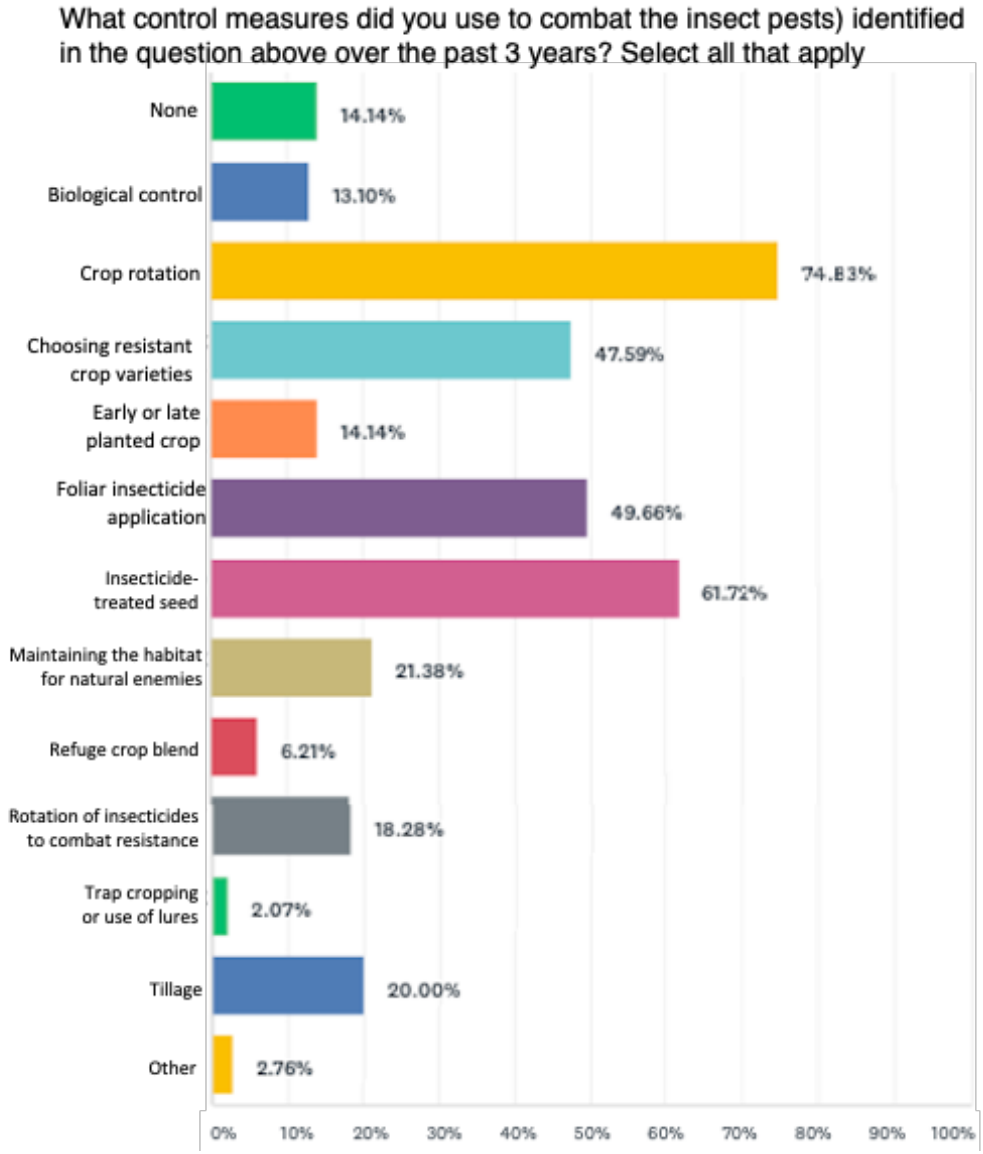

Figure A1.6: Pest control tactics employed by producers over the past 3 years. (Question #11, Appendix B) (n=300)

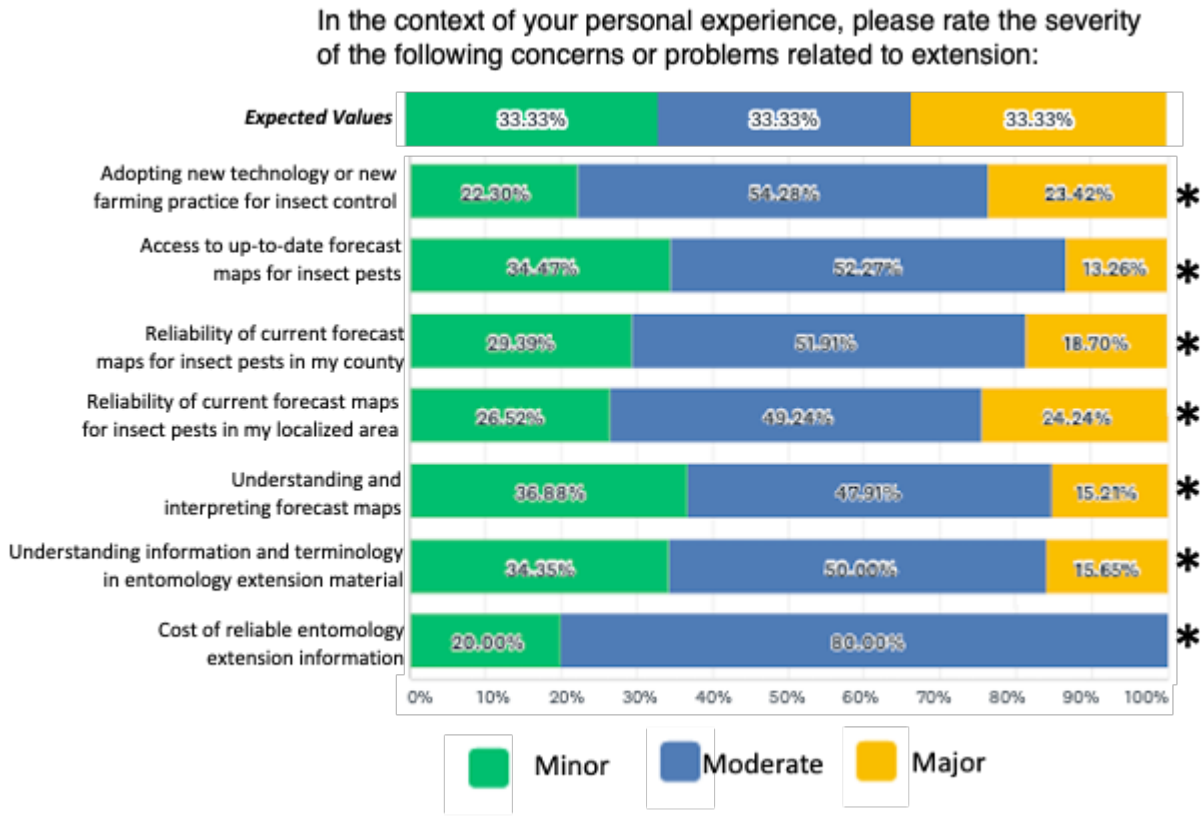

Figure A1.7: Problems related to entomology extension reported by producers. (Question #21, Appendix B) (n=300)

Appendix B

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What's Bugging You?

An assessment of entomology extension in agriculture in Alberta

Be involved in shaping the direction of entomological extension in Alberta by filling out the following survey. "**Extension**" refers to the communication of information between researchers and producers. Prompted by recent discussions at **RDAR** (Results Driven Agriculture Research) meetings, this survey is part of an MSc research project in the Faculty of Science at the University of Alberta that will scientifically assess the effectiveness and producer preferences for entomological extension in agriculture in Alberta.

This survey will take approximately 20 minutes to complete. You can leave out any questions with which you are not comfortable. We appreciate your responses.

If you have any questions, comments, or if you'd like to be contacted about the results of this study, please contact MSc candidate Ilan Domnich at *domnich@ualberta.ca*, or Dr. Maya Evenden (Principal Investigator) at *mevenden@ualberta.ca*, Department of Biological Sciences, University of Alberta. You can contact the University of Alberta Research Ethics office at reoffice@ualberta.ca if you have questions about the research ethics approval for this project. (University of Alberta Research Ethics ID: Pro00114256)

Please note that you can withdraw your responses from the survey by contacting the researchers within 1 month of completing the survey.

You may take this page with you when submitting the survey if you'd like to save this information.

This project is funded by: RDAR Results Driven Agriculture Research; ALBERTA PULSE GROWERS

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Please enter your email: _____* *Required*

Your email is used as an identifier for your survey responses and will not be shared or published in any way. In the unlikely event that any answers need clarification, your email may also be used to contact you. You will NOT receive any spam after submitting this survey. All contact information will be deleted once data analyses are complete.

Part 1

The following questions are about your farm and the commodities grown:

*Note that we are collecting information to see if livestock is part of your operation but the majority of questions are about crops.

Q 1) **Select the top provincial commissions and other associations (up to 4) that you are actively involved in by placing a 1, 2, 3 and 4 in the boxes provided.**

- ☐ Alberta Barley
- ☐ Alberta Beef Producers
- ☐ Alberta Canola Producers Commission
- ☐ Alberta Chicken Producers
- ☐ Alberta Farm Fresh Producers Association
- ☐ Alberta Greenhouse Growers Association
- ☐ Alberta Horticultural Association
- ☐ Alberta Organic Producers Association
- ☐ Alberta Pork Producers
- ☐ Alberta Pulse Growers
- ☐ Alfalfa Seed Commission
- ☐ Alberta Sugar Beet Growers
- ☐ Alberta Wheat Commission
- ☐ Potato Growers of Alberta
- ☐ Prairie Oat Growers Association
- ☐ Other_____

Q 2) **Which of the following are crops that you have grown in the past 3 years?** *Check all that apply*

- ☐ Alfalfa seed
- ☐ Alfalfa forage
- ☐ Barley
- ☐ Buckwheat
- ☐ Canary seed
- ☐ Canola
- ☐ Chickpeas
- ☐ Corn
- ☐ Dry beans
- ☐ Dry field peas
- ☐ Faba beans
- ☐ Forage (other than alfalfa) and silage crops
- ☐ Flaxseed
- ☐ Greenhouse crops
- ☐ Hemp
- ☐ Horticultural crops
- ☐ Lentils
- ☐ Market garden crops
- ☐ Mustard seed
- ☐ Oats
- ☐ Potatoes
- ☐ Rye
- ☐ Safflower
- ☐ Soybeans
- ☐ Sugar beets
- ☐ Sunflower seed
- ☐ Wheat
- ☐ Other: _____

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Q 3) **Over the past three years, which crops have been included in your crop rotation?** *(If applicable, write them in the space below)*

Q 4) **Do you actively use pollinators for your crop (ex. honey bees, leafcutter bees, bumble bees)?**

- ☐ Yes
- ☐ No

Q 5) **Approximately what percentage of your farm area is treated with synthetic fertilizer and pesticide?**

_____%

Q 6) **Is this a multigenerational family farm?**

- ☐ Yes
- ☐ No

Q 7) **What is the location of your farm? Please provide either the county name or the first three digits of your postal code.**

County name: _____

First 3 digits of postal code: _____

Q 8) **How many acres do you farm?** *(Put 0 if you are a greenhouse grower)*

_____Acres

Part 2

The following questions will ask about challenges within your cropping system:

Q 9) **Which insects did you manage (i.e. monitor for and/or implement controls) in your crops over the last 3 years? Of those, which insects were targeted with foliar insecticides, or insecticide-treated seed?** *(Check all that apply)*

	Monitored or implemented controls	*Targeted with foliar insecticides*	*Targeted with insecticide-treated seed*
Aphids	☐	☐	☐
Alfalfa weevil	☐	☐	☐
Alfalfa plant bug	☐	☐	☐
Bertha armyworm	☐	☐	☐
Cabbage seedpod weevil	☐	☐	☐
Cereal leaf beetle	☐	☐	☐
Cutworms	☐	☐	☐
Diamondback moth	☐	☐	☐
European skipper butterfly	☐	☐	☐
Flea beetles	☐	☐	☐
Grasshoppers	☐	☐	☐
Greenhouse pests	☐	☐	☐

	Monitored or implemented controls	*Targeted with foliar insecticides*	*Targeted with insecticide-treated seed*
Leafhoppers	☐	☐	☐
Leafminers	☐	☐	☐
Lygus bugs	☐	☐	☐
Mealybugs	☐	☐	☐
Pea leaf weevil	☐	☐	☐
Red turnip beetle	☐	☐	☐
Spider mites	☐	☐	☐
Stored grain pests	☐	☐	☐
Thrips	☐	☐	☐
Wheat midge	☐	☐	☐
Wheat stem sawfly	☐	☐	☐
Wireworms	☐	☐	☐
	☐	☐	☐

Other: _____

Q 10) **How did you know about the pest infestation(s) you encountered over the last 3 years?** *(Check all that apply)*

- ☐ Field/in-person observations
- ☐ Government-produced forecast maps
- ☐ Pheromone traps
- ☐ Pitfall traps
- ☐ Scouting reports from professional agronomists/consultants or government officials on **my** farm
- ☐ Scouting reports from professional agronomists/consultants or government officials on **nearby** farms
- ☐ Sticky traps
- ☐ Sweep net sampling
- ☐ Word of mouth
- ☐ Other: _____

Q 11) **What control measures did you use to combat the insect pest(s) identified in the question above over the past 3 years?** *(Check all that apply)*

- ☐ None
- ☐ Biological control (direct application of fungi, bacteria, nematodes, mites, or insects as biological control agents)
- ☐ Crop rotation
- ☐ Choosing resistant crop varieties
- ☐ Early or late planted crop (e.g., winter wheat)
- ☐ Foliar insecticide application
- ☐ Insecticide-treated seed
- ☐ Maintaining the habitat for natural enemies (predators and parasitoids) that provide biological control
- ☐ Refuge crop blend (ex. Refuge in a Bag/ RIB)
- ☐ Rotation of insecticides to combat resistance
- ☐ Trap cropping or use of lures
- ☐ Tillage
- ☐ Other: _____

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Q 12) **Of the fields treated for insect pests, what was the average cost per acre?**

- ○ Less than $5 per acre
- ○ $5-$10 per acre
- ○ $11-$15 per acre
- ○ $16-$20 per acre
- ○ $21-$25 per acre
- ○ $26-$30 per acre
- ○ $31-$35 per acre
- ○ $36-$40 per acre
- ○ $41-$45 per acre
- ○ $46-$50 per acre
- ○ More than $50 per acre
- ○ I don't know
- ○ Other: _____

Q 13) **On average, what percentage of your farm was treated with foliar insecticides in the last 3 years?**

_____%

Q 14) **Are you familiar with any of these alternative pest management strategies?**
(Check all that apply)

- ☐ Baits
- ☐ Biological control (using insects and mites)
- ☐ Biological control (using fungi, bacteria, nematodes)
- ☐ Crop variety selection
- ☐ Drone/satellite surveys (e.g.,. NDVI, field mapping)
- ☐ Intercropping
- ☐ Machine learning algorithms
- ☐ Maintaining habitat for natural enemies/beneficial insects (predators, parasitoids, pollinators)
- ☐ Mating disruption
- ☐ New-to-market insecticides
- ☐ New-to-market crops genetically engineered for insect resistance
- ☐ Residue removal
- ☐ Trap cropping
- ☐ Other: _____

Q 15) **Of the alternative pest management strategies in the previous question, which were used on your farm in the last 3 years?**

- ☐ Baits
- ☐ Biological control (using insects and mites)
- ☐ Biological control (using fungi, bacteria, nematodes)
- ☐ Crop variety selection
- ☐ Drone surveys (e.g.,. NDVI, field mapping)
- ☐ Intercropping
- ☐ Machine learning algorithms
- ☐ Maintaining habitat for natural enemies/beneficial insects (predators, parasitoids, pollinators)
- ☐ Mating disruption
- ☐ New-to-market insecticides
- ☐ Residue removal
- ☐ Trap cropping
- ☐ None
- ☐ Other: _____

Q 16) **How did you hear about these alternative pest management strategies?**
(Check all that apply)

- ☐ Not applicable
- ☐ Agronomist newsletters and bulletins
- ☐ Agricultural conferences/events
- ☐ Applied Research Association
- ☐ Crop commission
- ☐ Podcasts, radio, webinars
- ☐ Private agronomists
- ☐ Retail service and product suppliers
- ☐ Scientific publications and journals
- ☐ Social media
- ☐ Social networking (peers and other producers)
- ☐ Websites and apps
- ☐ Other: ____

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Q 17) **In the context of your personal experience, please rate the severity of the following concerns or problems related to pest management:**

	Minor	*Moderate*	*Major*
Unfamiliar insects in crop	☐	☐	☐
Unfamiliar damage to the crop	☐	☐	☐
Ability to monitor insect pests in crop	☐	☐	☐
Severity of damage from insect pests	☐	☐	☐
Lack of hands-on learning with a coach or practical training at a farm	☐	☐	☐
Loss of chemical control options	☐	☐	☐
Making the decision of whether to implement insect pest controls	☐	☐	☐
Making choices about control options for insect pests (choice of pesticides, cultural control options, etc.)	☐	☐	☐
Cost of insect pest control	☐	☐	☐
Obtaining or understanding information about beneficial insects	☐	☐	☐

Q 18) **In your opinion, how important are the following factors when deciding whether to implement pest control or deciding on which type of control to use?**

	Not important	*Somewhat important*	*Very important*
Cost of control	☐	☐	☐
Economic thresholds	☐	☐	☐
Effectiveness of control	☐	☐	☐
Farm visits from agronomists	☐	☐	☐
Forecast maps	☐	☐	☐
Loss of chemical control options	☐	☐	☐
Pest controls implemented by neighbouring farms	☐	☐	☐
Preventing harm to beneficial insects (predators, parasitoids, pollinators)	☐	☐	☐

Part 3

The following questions will ask about your use of and preferences for extension material.
**Extension refers to the communication of information between researchers and producers.*

Q 19) **How likely are you to adopt (or attempt to adopt) a farming practice to address an insect pest if it is recommended by:**

	Unlikely	*Likely*	*I don't know*
Agronomist newsletters and bulletins	☐	☐	☐
Applied Research Associations (ARA's)	☐	☐	☐
Alberta's Crop Protection Guide (aka Blue Book)	☐	☐	☐
Commodity crop commissions and associations	☐	☐	☐
Podcasts, radio, webinars	☐	☐	☐
Print material (ex. agronomist newsletters and bulletins)	☐	☐	☐
Private agricultural product and service providers	☐	☐	☐
Private agronomists	☐	☐	☐
Scientific publications and journals	☐	☐	☐
Social media	☐	☐	☐
Speakers at agricultural conferences/events	☐	☐	☐
Websites and apps	☐	☐	☐
Your peers (fellow producers)	☐	☐	☐

Q 20) **Approximately how often do you use the following to obtain information about new agricultural entomology information, including exposure to new research?**

	Never	*Less than once a year*	*A few times a year*	*Monthly*	*Weekly*
Agricultural field days	☐	☐	☐	☐	☐
Applied research associations (ARA's)	☐	☐	☐	☐	☐
Alberta's Crop Protection Guide (aka Blue Book)	☐	☐	☐	☐	☐
Commodity crop commissions and associations	☐	☐	☐	☐	☐
Factsheets and field guides	☐	☐	☐	☐	☐

	Never	*Less than once a year*	*A few times a year*	*Monthly*	*Weekly*
Podcasts, radio, webinars	☐	☐	☐	☐	☐
Print material (ex. agronomist newsletters and bulletins)	☐	☐	☐	☐	☐
Private agricultural product and service providers	☐	☐	☐	☐	☐
Private agronomists	☐	☐	☐	☐	☐
Scientific publications and journals	☐	☐	☐	☐	☐
Short courses (online or in-person)	☐	☐	☐	☐	☐
Social media	☐	☐	☐	☐	☐
Speakers at agricultural conferences/events	☐	☐	☐	☐	☐
Websites and apps	☐	☐	☐	☐	☐
Your peers (fellow producers)	☐	☐	☐	☐	☐

Q 21) **In the context of your personal experience, please rate the severity of the following concerns or problems related to extension:**

***** *Extension refers to the communication of information between researchers and producers.*

	Minor	*Moderate*	*Major*
Adopting new technology or new farming practice for insect control	☐	☐	☐
Access to up-to-date forecast maps for insect pests	☐	☐	☐
Reliability of current forecast maps for insect pests in my county	☐	☐	☐
Reliability of current forecast maps for insect pests in my localized area	☐	☐	☐
Understanding and interpreting forecast maps	☐	☐	☐
Understanding information and terminology in entomology extension material	☐	☐	☐

Q 22) **In the space below, please add any additional comments or critiques you have about the entomological extension system in Alberta, and how it can be improved (ex. is extension lacking for a certain crop? A certain region? A certain pest?):**

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Part 4

The following questions will ask for demographic information about you and your operation:

Q 23) **Which of the following best describes the way you like to learn?** (Check all that apply)

- ☐ Auditory or verbal learner (learn by hearing/repeating)
- ☐ Logical or mathematical learner (learn using numbers/math)
- ☐ Reading or writing learner
- ☐ Tactile, physical, or kinesthetic learner (learn by doing)
- ☐ Visual learner (learn by seeing)
- ☐ I don't know

Q 24) **What is your age?**

- ○ 15-19
- ○ 20-24
- ○ 25-29
- ○ 30-34
- ○ 35-39
- ○ 40-44
- ○ 45-49
- ○ 50-54
- ○ 55-59
- ○ 60+

Q 25) **What is your gender?**

- ○ Male
- ○ Female
- ○ Non-binary
- ○ Other
- ○ Prefer not to answer

Q 26) **How many years of experience do you have in farm operations?**

- ○ Less than 1 year
- ○ 1-5 years
- ○ 6-10 years
- ○ 11-20 years
- ○ More than 20 years

Q27) **What is the highest level of education you have completed?**

- ○ Below grade 9
- ○ Grade 9 (junior high)
- ○ Grade 12 (high school)
- ○ Technical diploma (post-secondary)
- ○ Bachelor's degree (post-secondary)
- ○ Master's degree (graduate studies)
- ○ Doctorate degree (Ph.D.)
- ○ Other: _____

Thank you

for taking the time to complete this survey! By doing so you have provided insight into the agricultural entomology extension system in Alberta.

Please place the survey into to the drop box provided. You may keep the front page for your reference.

Appendix C

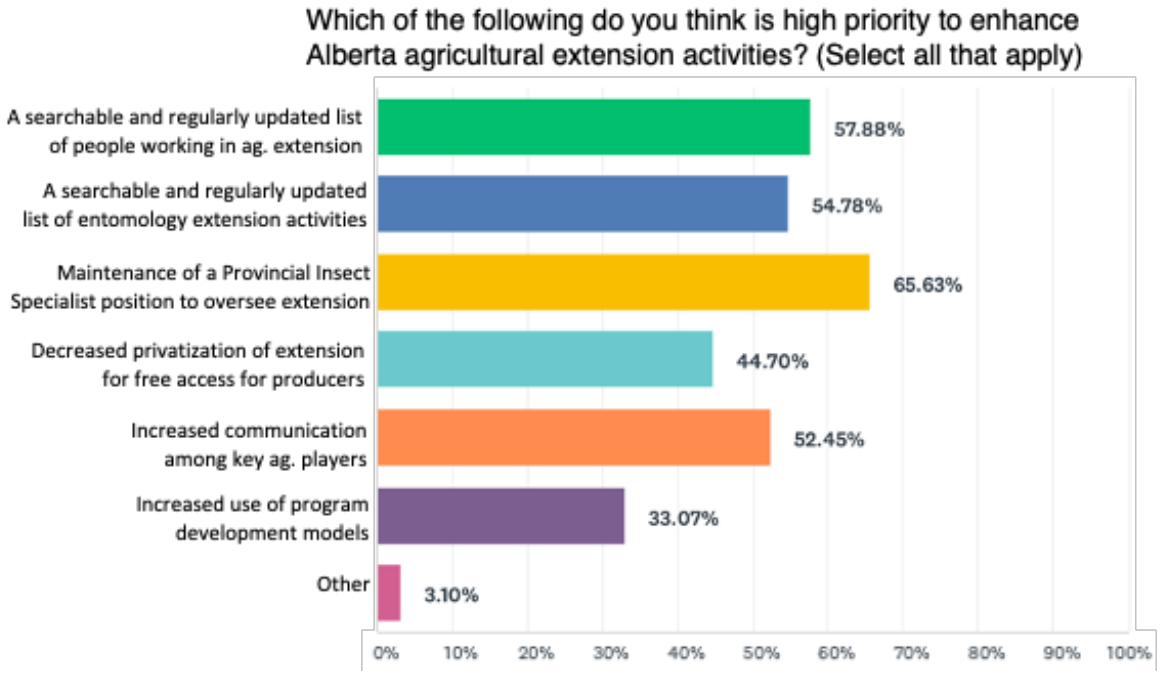

Figure C2.1: Proportions of respondents that consider the listed factors to be important considerations to enhance agricultural extension in Alberta. (Question #9, Appendix D) (n=354)

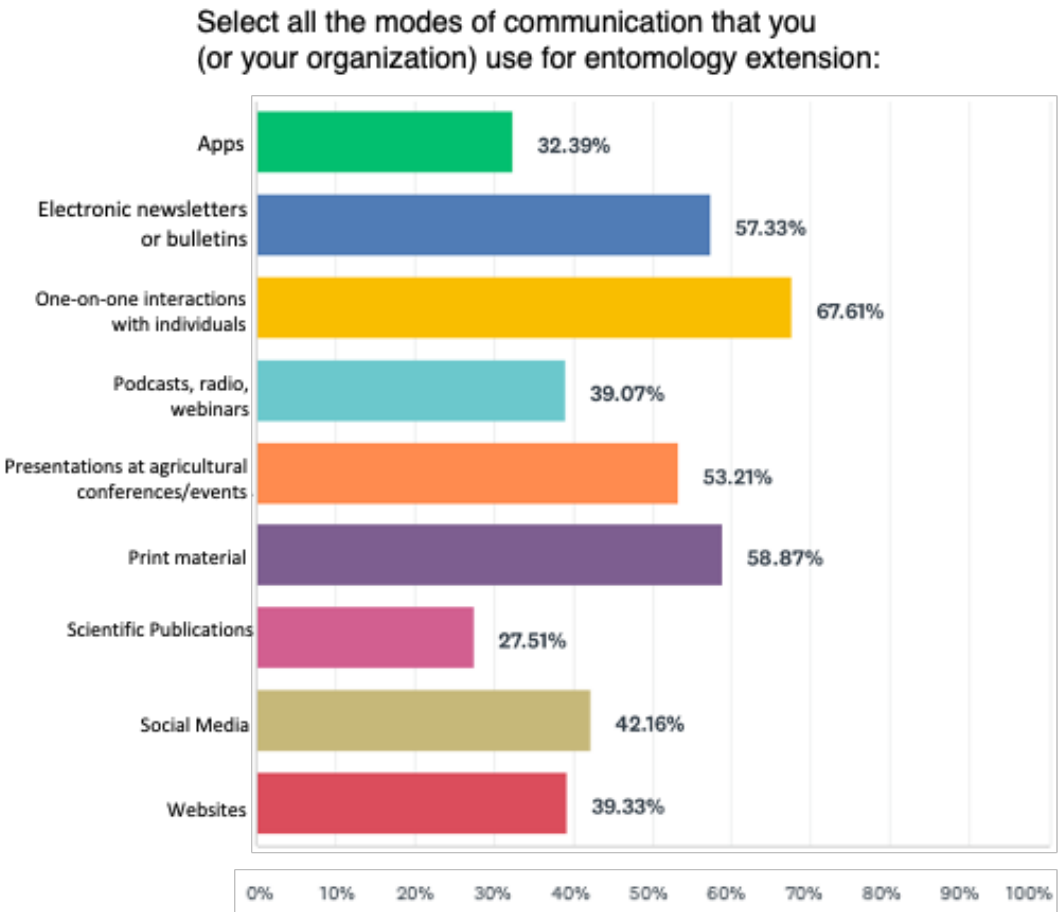

Figure C2.2: Proportions of respondents that use listed communication channels to conduct agricultural extension in Alberta. (Question #4, Appendix D) (n=354)

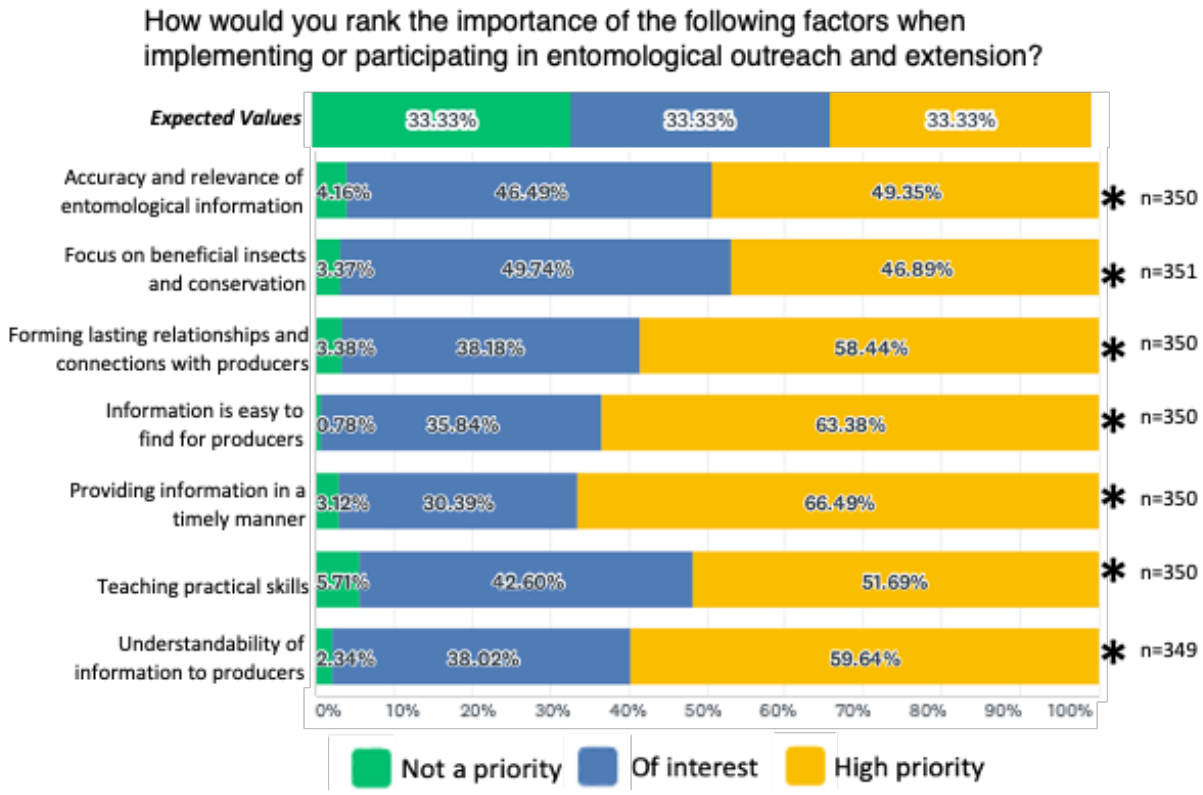

Figure C2.3: Results of Likert-scale question #6 (Appendix D) measuring different values of respondents' when implementing entomology extension activities. (Cronbach's $\alpha = 0.54$)

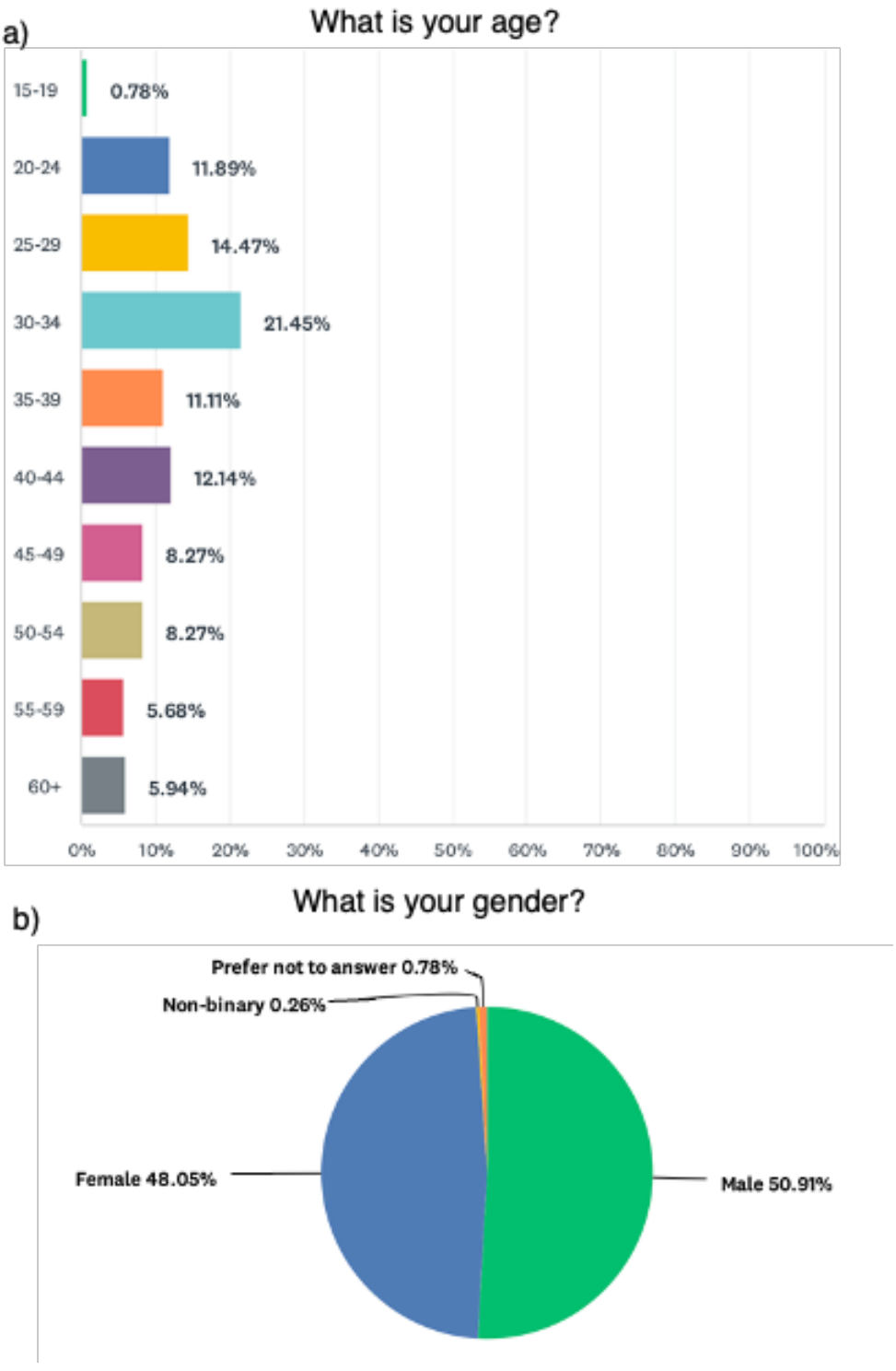

Figure C2.4: Demographic information for extension worker survey respondents (Appendix D) identifying a) respondent's age brackets (question #11, n=352) and b) self-identified gender (question #12, n=350).

Appendix D

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What's Bugging You?

An assessment of entomology extension in agriculture in Alberta

Part 2: The Extension Survey

As someone working with producers to discover problems and helping to provide answers, which falls under the umbrella of "extension", you've been invited to fill out the following survey. Prompted by recent discussions at RDAR (Results Driven Agriculture Research) meetings, this survey is part of a MSc research project in the Faculty of Science at the University of Alberta that will scientifically assess the effectiveness and producer preferences for entomological extension in agriculture in Alberta.

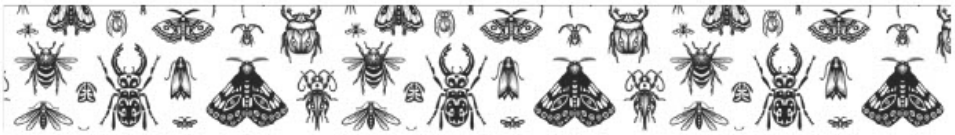
This survey will take approximately 7 minutes to complete. You can leave out any questions with which you are not comfortable. Please complete the survey by following the attached link. We appreciate your responses.

For any questions or comments, please contact MSc candidate Ilan Domnich at domnich@ualberta.ca, or Dr. Maya Evenden (Principal Investigator) at mevenden@ualberta.ca, Department of Biological Sciences, University of Alberta.

You can contact the University of Alberta Research Ethics office at reoffice@ualberta.ca if you have questions about the research ethics approval for this project.

You may take this page with you when submitting the survey if you'd like to save this information.

Funded by: RDAR Results Driven Agriculture Research; ALBERTA PULSE GROWERS



Please enter your email or phone number: _____* *Required*

*Your email or phone number is used as an identifier for your survey responses and will not be shared or published in any way. All contact information will be deleted once data analyses are complete.

1. Which group(s) do your professional activities fall in? *(Select all that apply)*
   - ☐ Academia
   - ☐ Applied Research Associations (ARA's)
   - ☐ Crop commissions
   - ☐ Federal government
   - ☐ Private agronomist (self-employed)
   - ☐ Private service or product provider
   - ☐ Provincial Government
   - ☐ Municipal Government

2. Do you consider communication of insect information to and from agricultural producers, as part of your work mandate?
   a. Yes
   b. Not officially
   c. No

3. In your experience, how often do producers inquire about the following types of entomology information relative to each other?

	Rarely	*Sometimes*	*Often*	*I don't know*
Best insect management practices	☐	☐	☐	☐
Chemical control options for insects	☐	☐	☐	☐
Conservation or promotion of beneficial insects	☐	☐	☐	☐
Current insect issues faced by other producers	☐	☐	☐	☐
Economic thresholds for insect pests	☐	☐	☐	☐
Invasive and introduced insect species	☐	☐	☐	☐
Identification of insect damage in crop	☐	☐	☐	☐
New pest control technologies and strategies	☐	☐	☐	☐
Pest forecasts	☐	☐	☐	☐
Species identification	☐	☐	☐	☐

4. Select all the modes of communication that you (or your organization) use for entomology extension: *(Select all that apply)*
   - ☐ Apps
   - ☐ Electronic newsletters and bulletins
   - ☐ One-on-one interactions with individuals
   - ☐ Podcasts, radio, webinars
   - ☐ Presentations at agricultural conferences/events
   - ☐ Print material (ex. agronomist newsletters, bulletins, fact-sheets)
   - ☐ Scientific publications and journals
   - ☐ Social media
   - ☐ Websites

5. How do you or your organization keep track of the impact of your extension activities? (Ex. number of people reached, trends, impact stories, etc.) *(Select all that apply)*
   - ☐ Asking for feedback from users
   - ☐ Impact stories from users
   - ☐ Tracking the number of people reached or involved
   - ☐ Tracking trends in usage of material
   - ☐ Tracking shifting attitudes and behaviours resulting from extension
   - ☐ Do not keep track of the impact of extension activities
   - ☐ I don't know

6. How would you rank the importance of the following factors when implementing or participating in entomological outreach and extension?

		Not a priority	*Of Interest*	*High priority*
a	Accuracy and relevance of entomological information	☐	☐	☐
b	Focus on beneficial insects and conservation	☐	☐	☐
c	Forming lasting relationships and connections with producers	☐	☐	☐
d	Information is easy to find for producers	☐	☐	☐
e	Providing information in a timely manner	☐	☐	☐
f	Teaching practical skills	☐	☐	☐
g	Understandability of information to producers	☐	☐	☐

7. In your opinion, how important are the following entomological issues faced by producers?

		Not important	*Somewhat important*	*Very important*
a	Actively monitoring and using economic thresholds	☐	☐	☐
b	Access to up-to-date and relevant entomology information (such as local pest forecasts)	☐	☐	☐
c	Availability of diverse non chemical pest management options (such as agronomic options and host plant resistance)	☐	☐	☐
d	Cost of insect pest management	☐	☐	☐
e	Development of insecticide resistance in pests	☐	☐	☐
f	Implementing practices to promote beneficial insects (predators, parasitoids, pollinators)	☐	☐	☐
g	Invasive and introduced insect species	☐	☐	☐
h	Lack of insects to control weeds within crops	☐	☐	☐
i	Loss of insecticide options	☐	☐	☐

8. How problematic are the following issues in the Alberta extension environment?

		Not problematic	*Somewhat problematic*	*Severely problematic*
a	Reaching producers through current communication channels	☐	☐	☐
b	Clear guidelines for producers to access entomological extension across Alberta	☐	☐	☐
c	Communication of needs/wants of producers to researchers/specialists	☐	☐	☐
d	Communication among organizations providing entomological extension (ex. crop commissions, ARAs)	☐	☐	☐
e	Funding and/or support for entomological extension activities	☐	☐	☐
f	Opportunities for one-on-one information transfer	☐	☐	☐

9. Which of the following do you think is high priority to enhance Alberta agricultural extension activities? (*Select all that apply)*
    - ☐ A comprehensive and searchable list of individuals and organizations working in agricultural extension in Alberta that is regularly updated
    - ☐ A comprehensive and searchable list of entomology extension activities in Alberta that is regularly updated
    - ☐ Maintain a long-term Provincial Insect Specialist position to oversee entomology extension efforts in the whole province
    - ☐ Decreased privatization of extension resources to increase access to experts for all producers
    - ☐ Increased communication among key entomological extension players through a central organization
    - ☐ Increased use of program development models to develop and evaluate entomology extension activities in Alberta
    - ☐ Other (please describe):

10. In your opinion, what other issues do you see affecting high quality entomological extension for Alberta producers? Answer in the space below:

11. What is your age?
    a. 15-19
    b. 20-24
    c. 25-29
    d. 30-34
    e. 35-39
    f. 40-44
    g. 45-49
    h. 50-54
    i. 55-59
    j. 60+

12. What is your gender?
    a. Male
    b. Female
    c. Non-binary
    d. Other
    e. Prefer not to answer

13. In which county do you work?

    _____

Please note that you can withdraw your responses from the survey by contacting the researchers within 1 month of completing the survey.

Thank you for taking the time to complete this survey! By doing so you have provided insight into the agricultural entomology extension system in Alberta. If you're interested in the results of this study, please email Ilan Domnich at domnich@ualberta.ca and you will be contacted about our findings once the project is complete.

Appendix E

Extension effort or provider	Category	Chemical control options	Insecticide information	Instructions for insecticide use	Physical and cultural control	Biological control information	Insect ID and biology	Environmental enhancement	Economic thresholds	Monitoring information	Pollinator health and protection	One-on-one help	Events	Current research	General insect news	Public educational	Website URL
Old's College	Academia													✓			https://www.oldscollege.ca
Lethbridge College - Research Centre	Academia													✓			http://www.lethbridgecollege.ca/carie
University of Lethbridge	Academia													✓			https://www.ulethbridge.ca
Lakeland College	Academia													✓			https://www.lakelandcollege.ca/index.aspx
University of Alberta - Faculty of ALES	Academia													✓			https://www.ualberta.ca/agriculture-life-environment-sciences/index.html
Smoky Applied Research and Demonstration Association (SARDA)	ARA												✓	✓	✓		https://sarda.ca/
North Peace Applied Research Association (NPARA)	ARA						✓						✓	✓	✓		https://npara.ca
The Chinook Agricultural Research Alliance (CARA)	ARA													✓			https://chinookappliedresearch.ca/about
Mackenzie Applied Research Association (MARA)	ARA												✓	✓	✓		https://mackenzieresearch.ca
Agricultural Research Extension Council of Alberta (ARECA)	ARA							✓					✓	✓			https://areca.ca
Battle River Research Group (CRRG)	ARA												✓	✓			https://www.battleriverresearch.com/
Gateway Research Organization (GRO)	ARA												✓	✓	✓		https://gatewayresearchorganization.com
Peace Country Beef & Forage Association (PCBFA)	ARA							✓			✓		✓	✓			https://www.peacecountrybeef.ca
Lakeland Agricultural Research Association (LARA)	ARA												✓	✓		✓	https://laraonline.ca
Alberta Environmental Farm Plan	ARA (ARECA)							✓					✓				https://www.albertaefp.com
Farming Smarter	Commission			✓									✓	✓	✓	✓	https://www.farmingsmarter.com

Western Grains Research Foundation	Commission													✓			https://wgrf.ca/
Alberta Pulse Growers	Commission				✓		✓		✓				✓	✓	✓		https://albertapulse.com
Alberta Grains	Commission												✓	✓	✓		www.albertawheatbarley.com/
Alfalfa Seed Commmission	Commission	✓			✓		✓		✓				✓	✓	✓		https://alfalfaseedab.com
Potato Growers of Alberta	Commission												✓	✓	✓		https://www.albertapotatoes.ca
Alberta Oat Growers Commission	Commission												✓	✓	✓		https://poga.ca
Alberta Farm Fresh Producers Association	Commission												✓				https://albertafarmfresh.com
Alberta Horticultural Association	Commission												✓				https://abhorta.ca/wp/
Alberta Organic Producers Association	Commission											✓	✓				https://www.albertaorganicproducers.org/
Alberta Sugar Beet Growers	Commission												✓				http://www.albertasugarbeets.ca/
Alberta Beef Producers	Commission													✓		✓	www.albertabeef.org/
Alberta Chicken Producers	Commission												✓	✓		✓	https://chicken.ab.ca
Alberta Pork	Commission												✓				https://www.albertapork.com
Alberta Farm Fresh Producers Association	Commission												✓	✓			https://albertafarmfresh.com
Alberta Beekeepers Commission	Commission	✓	✓	✓	✓				✓	✓	✓			✓			https://www.albertabeekeepers.ca
Canola Council of Canada	Commission				✓		✓		✓		✓		✓	✓	✓		https://www.canolacouncil.org
Alberta Agrisystems Living Lab	Commission (Alberta Beef Producers)												✓	✓			https://www.agrisystemsll.ca/
Learn Canola	Commission (Alberta Canola)															✓	http://learncanola.com/
Shop talk with Sheri	Commission (Alberta Grains)														✓		www.albertawheatbarley.com/
GrainsWest	Commission (Alberta Grains)													✓	✓		https://grainswest.com/
The Growing Point Podcast	Commission (Alberta Grains)													✓	✓		https://thegrowingpointpodcast.podbean.com
Canola Research Hub	Commission (Canola Council of Canada)													✓	✓		https://www.canolacouncil.org/research-hub/

Canola Encyclopedia	Commission (Canola Council of Canada)				✓		✓	✓	✓	✓				✓			https://www.canolacouncil.org/canola-encyclopedia/
Alberta Canola	Commission (Canola Council of Canada)				✓		✓		✓	✓		✓	✓	✓	✓	✓	https://albertacanola.com
Alberta's Crop Protection Guide (Blue Book)	Commission (Various)	✓	✓	✓				✓	✓								https://www.albertabluebook.com
Alberta Insect Pest Monitoring Network	Gov of Alberta (Alberta Agriculture)						✓			✓							https://www.alberta.ca/alberta-insect-pest-monitoring-network
Agriculture Service Boards	Gov. of Alberta							✓				✓					asb/
Alberta Agiculture	Gov. of Alberta						✓	✓								✓	https://www.alberta.ca/agriculture
Association of Alberta Agricultural Fieldmen	Gov. of Alberta (ASBs)											✓					https://aaaf.ab.ca/about/about-aaaf.html
Pest Management Regulatory Agency	Gov. of Canada	✓	✓	✓		✓		✓			✓						https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html
Canadian Food Inspection Agency (CFIA)	Gov. of Canada						✓	✓		✓							https://inspection.canada.ca/eng/1297964599443/1297965645317
Agriculture and Agri-Food Canada - Tools	Gov. of Canada	✓	✓	✓	✓	✓	✓	✓		✓				✓			https://agriculture.canada.ca/en/agricultural-production
Canadian Grain Commission	Gov. of Canada	✓		✓	✓		✓							✓	✓		https://grainscanada.gc.ca/en/
TopCropManager	Gov. of Canada												✓	✓			https://www.topcropmanager.com/
Prairie Pest Monitoring Network (PPMN)	Gov. of Canada (AAFC)				✓		✓		✓	✓			✓	✓			https://prairiepest.ca
Regenerative Alberta Living Lab	Gov. of Canada (AAFC)							✓									https://www.regenlivinglab.org
Field Heroes	Gov. of Canada (PPMN)				✓	✓	✓	✓	✓	✓	✓			✓		✓	https://fieldheroes.ca
Real Agriculture	Gov. of Canada (PPMN)													✓	✓		https://www.realagriculture.com
Online Local Newspapers in Alberta	News												✓		✓		https://onlinenewspapers.com/alberta-canada.shtml
Cochrane Eagle	News														✓		https://www.cochraneeagle.ca/alberta-agriculture
Global News	News														✓		https://globalnews.ca/tag/alberta-agriculture/
Farms.com	News														✓		https://www.farms.com/
Glacier Farm Media	News														✓		https://home.farmmedia.com
Frontline Farming Canada	News														✓		https://rfdtvcanada.ca/program/FRONTLINE

The Rural Woman Podcast	News														✓		https://wildrosefarmer.com/the-rural-woman-podcast/
Ducks Unlimited Alberta	News				✓			✓									https://www.ducks.ca/places/alberta/
Agriville	News (Farms.com)											✓		✓	✓		https://www.agriville.com
Better Farming	News (Farms.com)													✓	✓		https://www.betterfarming.com
Grainews	News (Glacier Farm Media)												✓		✓		https://www.grainews.ca
The Western Producer	News (Glacier Farm Media)														✓		https://www.producer.com
GrowPro	News (Glacier Farm Media)														✓		https://www.producer.com
Alberta Farmer Express	News (Glacier Farm Media)												✓		✓		https://www.albertafarmexpress.ca/
Results Driven Agriculture Research	Non-Profit													✓	✓		https://rdar.ca
Alberta Association of Agricultural Societies	Non-Profit												✓				https://www.albertaagsocieties.ca
Safety FX	Non-Profit			✓													https://www.safetyfx.ca/
Rural Roots Canada	Non-Profit													✓	✓		https://www.ruralrootscanada.com
AgSafe Alberta	Non-Profit			✓												✓	https://agsafeab.ca/
AgTechSteam	Non-Profit						✓									✓	https://agtechsteam.ca
Ag for Life	Non-Profit												✓			✓	https://www.agricultureforlife.ca
Corteva Agriscience	Private Industry	✓	✓	✓		✓				✓	✓	✓					https://www.corteva.ca/en/resources/tools-and-apps.html
Bayer Crop Science	Private Industry	✓	✓	✓	✓									✓			https://www.cropscience.bayer.ca
BASF Canada Agricultural Solutions	Private Industry	✓	✓	✓										✓			https://agriculture.basf.ca/
AgraCity	Private Industry	✓	✓	✓						✓		✓					https://www.agracity.com/
AgroPlus	Private Industry	✓										✓					https://www.agroplus.ca
Western Winter Wheat Initiative	Private Industry									✓							https://www.growwinterwheat.ca
AgVisorPro	Private Industry						✓					✓			✓		https://getagvisorpro.com
Plants Dig Soil Consulting Ltd.	Private Industry											✓		✓	✓		https://www.plantsdigsoil.com
20/20 Seed Labs	Private Industry									✓		✓	✓	✓			https://2020seedlabs.ca
Western Ag.	Private Industry											✓				✓	https://www.westernag.ca