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Review Paper

INTEGRATED CROP PEST MANAGEMENT PRACTICES: A CLASSIFICATION BASED ON A RAPID REVIEW OF INTERNATIONAL AND CANADIAN LITERATURE

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ABSTRACT

Crops are vulnerable to weeds, fungi, insects, nematodes, rodents and diseases. To address these threats rapidly, farmers tend to adopt a curative approach based on the use of synthetic pesticides (fungicides, herbicides, insecticides) rather than a preventive approach without pesticides. This reliance on pesticides poses risks to human health, the environment, and wildlife, including pollinators such as bees and bats. Reducing pesticide use has thus become an important societal and political objective worldwide. In Canada, the Government of Quebec's Sustainable Agriculture Plan (PAD) 2020 –2030 promotes, as its first objective, the adoption of alternative practices aimed at reducing pesticide sales by 500,000 kilograms by 2030 and decreasing health and environmental risks by 40%. This article takes stock of alternative practices of synthetic pesticides use in the literature in Canada and internationally from the perspective of Integrated Crop Pest Management (ICPM) stages and the Ministry of Agriculture Fisheries and Food of Quebec (MAFFQ) typology[1], to see which ones could possibly be used in Quebec. To do this, we used the "Rapid Review" method of the literature based on the exploitation of 71 scientific references. The findings indicate that countries with agroeconomic conditions comparable to those of Canada are adopting alternative and good agricultural practices, as well as physical, mechanical, biological, and biotechnical control methods; however, pesticide use often persists alongside these approaches. While practices belonging to the prevention and intervention stages through physical, mechanical, biological, and chemical control appear to be highly adopted by producers, practices belonging to the pest knowledge, monitoring, evaluation, and feedback stages appear to be poorly adopted by producers. The authors recommend improving access to information on crop pests and ICPM practices, along with enhancing farmers' awareness of the economic, health, and environmental risks associated with pesticide use. Future research should focus on classifying and analyzing ICPM practices by stage to support the development of public policy recommendations tailored to each stage, particularly regarding incentives and barriers to adoption, as well as their impacts on producers.

Key words: *pesticides, herbicides, insecticides, fungicides, integrated crop pest management practices.*
JEL code: Q01 Q50 Q55 Q57

Abbreviations:
ICPM – Integrated Crop Pest Management;
MAFFQ – Ministry of Agriculture Fisheries and Food of Quebec

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[1] The different components of ICPM are knowledge, prevention, field or greenhouse monitoring, intervention, evaluation, and feedback, as well as pesticide management if and only if necessary. It encourages the use of prevention and intervention practices that are alternatives to synthetic pesticides.

INTRODUCTION

The use of pesticides has consequences on the health of farmers, consumers (cancer, eczema, Parkinson's etc.) (Gauthier, 2012; Ghisi et al., 2016; Rezende et al., 2021; Kalpna et al., 2022), on birth mortality (Dias et al., 2019, 2023) on the environment (soil degradation, water contamination) (Bonansea et al., 2018; Deguine et al., 2021; Giard et al., 2022; Rietra et al., 2022), and health of wildlife such as bees (Blot et al., 2019; Battisti et al., 2021; Vázquez et al., 2023) and bats (Eyal, 2024). These impacts underscore the importance of reducing pesticide use in agriculture.

In Canada, particularly in Quebec, the Sustainable Agriculture Plan 2020-2030 aims to reduce pesticide sales by half a million kilograms and health and environmental risks by 40% (MAPAQ, 2021a). To achieve this, the adoption of alternative practices of pesticides is recommended (MAPAQ, 2021a).

However, several key questions remain: What alternative practices are currently implemented worldwide, particularly in countries with agroeconomic conditions similar to those of Quebec and Canada? How can these practices be classified? Which ones would be most suitable for Quebec? And what incentives or barriers influence their adoption? This study reviews alternative approaches to synthetic pesticide use in Canada and internationally through the lens of Integrated Crop Pest Management (ICPM) and the typology developed by the Ministry of Agriculture, Fisheries and Food of Quebec (MAFFQ), with the aim of identifying those that could potentially be applied in Quebec and Canada.

Integrated Crop Pest Management is a sustainable, science-based decision-making process that combines biological, cultural, physical, and chemical tools to identify, manage, and reduce pest risks, along with tools and strategies pest for control in a manner that minimizes overall economic, health and environmental risks (Dara, 2019; Goulet et al., 2023; Vasconcellos et al., 2023). According to Vasconcelos et al. (2022), the main objective of the ICPM is to reconcile ecological preservation and economic profitability through the balanced use of biological, cultural, and chemical practices.

According to Deguine et al. (2021), two main approaches to integrated management can be distinguished. The first approach prioritizes biodiversity, and the services associated with it, in particular what they call biocontrol, i.e. conservation control, by which natural enemies' resident in an ecosystem are stimulated by human interventions targeted before any form of chemical control is used. In this logic, priority is given to so-called proactive practices, in this case crop rotation, resistant varieties, tillage, and the introduction of natural enemies, while reactive type practices (chemical pesticides) should not be used only when other measures fail to maintain pest densities below the intervention thresholds. This phase is qualified as an indirect and preventive phase by several other authors in the literature (James et al., 2010; Costa et al., 2019; Dara, 2019; Magarey et al., 2019; Kalpna et al., 2022). The intervention threshold is a decision indicator of the best time at which a pesticide should be used, to give maximum possible effectiveness. It establishes the limit from which a means of control is profitable depending on the damage caused by the pest, the quantity of pest's present, the cost of the intervention and the value of the crop (Le Duc et al., 2004) cited by Louvel et al. (2012). The second existing approach is less recommended by researchers to the extent that it advocates intervention by chemical control when predefined intervention thresholds are exceeded on agricultural operations as various studies demonstrate (Goulet, 2017; Magarey et al., 2019; Möhring et al., 2020; Deguine et al., 2021; Möhring and Finger, 2022; Vasconcelos et al., 2022; Espig and Henwood, 2023; Goulet et al., 2023).

The literature on alternative practices to pesticide use covers various practices and factors influencing their adoption or effectiveness on crop yields. While some studies have focused on the adoption of a single practice such as crop rotation or the choice of cultivars for example (Cook, 1981; Liebman and Dyck, 1993; Krupinsky et al., 2004; Cook, 2006; Angus et al., 2015; Preissel et al., 2015; Andert et al., 2016; Cook, 2021); herbicides (Beckie, 2006; Duke and Powles, 2008; Beckie, 2011; Harker and O'Donovan, 2013; Heap and Duke, 2018; Peterson et al., 2018; Zhang et al., 2018, 2019; Beckie et al., 2021; Zhang et al., 2023) or still mechanical weeding (Angus et al., 2015; Pannacci et al., 2017, 2018; Pratap et al., 2023), others were interested in a set of integrated management practices (Beckie, 2011; April et al., 2012; Gauthier, 2012; West and Cissé, 2014; Beckie and Harker, 2017; Belzile et al., 2018; Belzile, 2019; Costa et al., 2019; Dara, 2019; Lee et al., 2019; Magarey et al., 2019; Kalpna et al., 2022; Rietra et al., 2022; Vasconcelos et al., 2022; Vasconcellos et al., 2023) (crop rotation, choice of cultivars, mechanical weeding, physical, biological, chemical control, etc.). Among the practices found in the literature, those relating to prevention seem to be the most recurrent, such as crop rotation and the choice of seeds due to their positive impact on reducing the use of pesticides by farmers to the extent that it enriches the soil with nitrogen as various studies demonstrate (Andert et al., 2016; Costa et al., 2019; Rietra et al., 2022; Vasconcelos et al., 2022). Cultivar selection is cited as a practice that has proven to reduce the abundance of weed species as various studies demonstrate (Duke and Powles, 2008; April et al., 2012; Bérubé, 2017; Kabir et al,, 2017; Lesur-Dumoulin et al., 2017; Vryzas et al., 2020; Rietra et al., 2022; Bérubé, 2024).

Apart from the techniques relating to prevention in the stages of Integrated Crop Pest Management, the use of pesticides, especially herbicides and insecticides, is the intervention practice most used by farmers in the studies. These practices are present among farmers who tend to choose the less labor-intensive control option, which is potentially more effective in the short term and perceived to guarantee less crop losses as various studies demonstrate (Nicol and Kennedy, 2008a; Gauthier, 2012; Barbosa et al., 2015; LeBude et al., 2017; Belzile et al., 2018; David et al., 2021; Deguine et al., 2021; Goulet et al., 2023).

The objective of this article is twofold: first, to identify and define alternative practices to the use of synthetic pesticides at both international and Canadian levels; and second, to classify them according to the typology developed by MAPAQ. The findings will contribute to the development of a research protocol for a forthcoming scoping review within a larger research project in Quebec, which aims to identify the most suitable alternative practices for achieving the objectives of the Quebec Government's Sustainable Agriculture Plan (PAD) 2020–2030, as well as the factors influencing their adoption in Canada and globally.

This study contributes to the literature in several ways. First, to our knowledge, it represents the first rapid review and classification of alternative pesticide practices using MAFFQ's ICPM typology. Second, the typology used to classify pesticide reduction practices could facilitate their identification as well as the incentives or barriers to their adoption, and this in stages. Finally, the metadata base can be used for future research. Our article does not claim to exhaustively list all integrated pest management practices adopted in countries with agroeconomic characteristics comparable to those of Quebec and Canada. This is explained by the fact that it is a rapid review conducted over two months. However, it does offer us a first glimpse of alternative pesticide practices predominantly used in other countries, and therefore those that could potentially be promoted in Quebec.

The results indicate that countries with agroeconomic conditions similar to those of Canada adopt alternative practices such as good agricultural practices, screening, and physical, mechanical, biological, and biotechnical control techniques, yet continue to rely heavily on synthetic pesticides. Overall, preventive and intervention-stage practices (physical, mechanical, biological, biotechnical, and chemical control) are more commonly adopted than those related to knowledge, monitoring, evaluation, and feedback. This underscores the importance of classifying alternative pesticide practices by stage and demonstrates the relevance of MAFFQ's typology.

The paper is structured as follows. Following this introduction, Section 2 presents the methodology for literature selection and analysis. Section 3 reviews integrated pest control practices identified in Canadian and international literature, highlighting those most relevant for the forthcoming scoping review within the research project *"Practices for Reducing the Use of Synthetic Pesticides in Agriculture in Quebec: Sociopolitical and Macroeconomic Study of Effects, Barriers, and Incentives."* Two summary tables of practices applied to multiple crops in Canada and abroad, classified according to ICPM stages, are presented. Section 4 concludes the paper.

MATERIAL AND METHODS

To address the research questions, a rapid review methodology was employed (Haby et al., 2016; Garritty et al., 2021; Hamel et al., 2021; Bellanti et al., 2022). This approach was deemed most appropriate given the two-month time frame available for the study. One of the main objectives of this rapid review was to generate preliminary results that would guide the development of a subsequent scoping review, to be conducted during the first phase of the research project entitled *"Practices to Reduce the Use of Synthetic Pesticides in Quebec: A Socio-political and Macroeconomic Study of Effects, Barriers, and Incentives."*

Databases used

Relevant literature was retrieved from several databases, most of which were accessed through the Laval University Library. The primary databases consulted were CAB Abstracts, ABI/INFORM Global, Web of Science, and EconLit. Additional searches were conducted using Google Scholar and ResearchGate. Complementary information was also gathered from the official websites of the Government of Canada and international agricultural organizations such as the Food and Agriculture Organization of the United Nations (FAO) and the World Trade Organization (WTO).

Research strategies

The search was done using keywords and combinations of keywords. As an example, we can cite: adoption, agriculture, agroecosystem, arthropod, pest, "biological control", biopesticides, Canada, "crops disease", "crops infestation", "crops parasitism", "crops pathogen", "crops predation", "crop rotation", cultivate, "damaging organism", glyphosate, "European Union countries", horticulture, herbicide, integrated "pest management", "insect pest", "pest parasite", "pest control", "pest management", pesticide, fungicide, insecticide, "mechanical control", “natural enemy”, “natural pest control”, “Organisation for Economic Cooperation and Development”, “physical control” , Quebec, reduction , reduce, “synthetic pesticides”, tillage and weed. Most of the keywords were truncated when introduced into the databases, and combinations with the “AND” and “OR” search operators were made. The most targeted countries were Canada, the United States, the countries of the European Union to which were added Norway, Switzerland, Australia, and New Zealand and some other in and OECD countries. The search gave us 162 documents of which we read the summaries. Subsequently, we retained 71 of the 162 references because they corresponded more to our research topic and selection criteria. The full texts of these 71 references were fully used to carry out this rapid review. The search for references lasted a week and their sorting took 30 days and was validated by two researchers.

Selection criteria

We selected the documents according to the following criteria:

- The document must deal with the adoption of pesticide or alternative practice(s) to the use of pesticides in agriculture.
- The pesticides or alternative practice(s) addressed in the document must be clearly identified and explained in the document.
- The document must indicate the reason(s) why growers use this pest management practices.
- The document must relate to one or more of the countries listed above.
- The document is written in French or English.

Documents were excluded if they did not meet any of the criteria listed above. The publication period was not used as a selection criterion because the objective at this stage of the research project was to explore the range of alternative practices to synthetic pesticides, regardless of the publication date. The application of these criteria resulted in a final corpus of 71 scientific documents**.**

Content analysis method and extraction strategies

The information needed to answer our research question was extracted once the final 71 documents had been selected. We extracted the information from the documents in a raw form. The thematic synthesis analysis method (Thomas and Harden, 2008) allowed us to group the results according to the types of integrated pest management practices. Regarding the content analysis and extraction strategy, and more specifically the basis on which the practices were classified, we grouped the practices according to the definition of Integrated Pest Management formulated by the Government of Quebec (MAPAQ, 2021a, 2021b). Integrated Crop Pest Management is a five-step decision-making method which consists of using all the necessary techniques to reduce populations of harmful organisms efficiently and economically, while respecting health and the environment (MAPAQ, 2021a, 2021b). The different components of ICPM are knowledge, prevention, field or greenhouse monitoring, intervention, evaluation, and feedback as well as pesticide management if and only if necessary. It encourages the use of prevention and intervention practices that are alternatives to synthetic pesticides.

RESULTS AND DISCUSSION

The analysis of the results revealed that most studies were conducted between 1981 and 2024. However, we found three rare studies on crop rotation practices before 1920, notably those from Belford (1899), McAlpine (1904) and Bolley (1913). This demonstrates the relatively ancient and traditional nature significance of this practice among agricultural producers (Preissel et al., 2015).

The analysis of the results also reveals that most studies were conducted in Europe (27), followed by the United States (18), and Canada (11). These results suggest the importance of agriculture in these countries, as well as the issue of reducing synthetic pesticides in agriculture. Some studies covered several countries (8). Only three studies focused on Australia. The research covered several agricultural sectors, with field crops, market gardening, and fruit crops being the most represented in the metadata.

Integrated crop pest management practices found in literature

Several control methods can be used against pests and diseases, such as genetics (plant improvement or selection of varieties resistant to specific pests and diseases), cultural practices (cultivation practices that modify the environment, the condition of the host or the behavior of the pest or disease), physical controls (use of devices, machines or other physical methods to control pests), biological controls (use of natural enemies of pests beneficial insects that are pathogenic and promote their development) and biotechnical (use of physiological mechanisms or environmental behaviors of insects, which will negatively affect their survival) as various studies demonstrate

(Goldberger and Lehrer, 2016; Costa et al., 2019; Magarey et al., 2019; Vryzas et al., 2020; Deguine et al., 2021; Boudwin et al., 2022; Kalpna et al., 2022; Swart et al., 2023). When none of the previous methods are available for a specific pest or disease, the use of pesticides (herbicides, fungicides, insecticides) seems to be the option to choose.

- **Good cultural practices**

Crop rotation is a good cultural practice consisting of planting different crops sequentially on the same field, mainly to combat pest and weed pressures and improve soil quality, and thus sustainably increase crop yield (Bigler and Albajes, 2011; April et al., 2012; Belzile and Li, 2014; Angus et al., 2015; Andert et al., 2016; Vryzas et al., 2020; Rietra et al., 2022). The practice of crop rotation is very old and was used primarily for growing wheat in the 1900s. Literature has shown that wheat is a crop that has a particular history with pests. It suffered from chronic and severe symptoms of patches of "white spots" (areas of stunted plants with sterile spikes dying prematurely) in Canada and Australia in the 1900s. According to Preissel et al. (2015), crop rotation techniques were recommended by authors such as McAlpine (1904) in Victoria in Australia, Belford (1899) in Manitoba, Bolley (1913) in North Dakota, in the United States, Nilsson- Ehle (1920) in Sweden and Cook (1981) in northern Europe. As one of the first integrated pest management practices, it has been the subject of several studies in the literature and has been highlighted as a very advantageous practice for the producer insofar as it enriches the soil, reduces the use pesticides through weed control and reduces crop enemies as various studies demonstrate (Angus et al., 2015; Lesur-Dumoulin et al., 2017; Costa et al., 2019; Rietra et al., 2022).

Improved varieties that are well adapted to local environmental conditions (temperature, nutrient supply, pests and disease pressure) grow healthier and are more resistant to pests and diseases (April et al., 2012; West and Cissé, 2014; Costa et al., 2019; Dara, 2019). They are recommended in agriculture even if they are not appreciated by consumers and are expensive according to various studies (Krupinsky et al., 2004; Gauthier, 2012; Angus et al., 2015; Jones et al., 2017; Janssen et al., 2019; Lee et al., 2019; Rietra et al., 2022).

Other physical and cultural control methods that can eliminate or reduce the number of pests or pathogens present on farms are intercropping, cover crops, mulches and soil solarization to reduce pests and incidence of disease. Deep plowing, fire and flaming, can also be used and has also been cited (Costa et al., 2019; Dara, 2019; Kalpna et al., 2022; Rietra et al., 2022). Soil solarization is an effective method for controlling a variety of soil pests and diseases and is non-polluting (Costa et al., 2019). It consists of using solar energy through a thin transparent film which is placed on the previously watered surface of the soil, during the hot periods of the year and for a period of at least 30 days. Intercropping contributes to crop protection by breaking pest and disease cycles, creating barriers to the spread of pests and diseases, improving the biodiversity of arthropods, natural enemies, providing food, alternative shelters and breeding sites, and generating conditions for better plant health which are known to increase plant resistance (Liebman and Dyck, 1993; April et al., 2012; Costa et al., 2019; Rietra et al., 2022). Cover crops on the other hand are planted to manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, biodiversity, and wildlife in an agroecosystem. Destroying crop residues and carrying out deep cultivation leads to the elimination of reproduction sites and control of the development stages of the pest in the soil (April et al., 2012). Cleaning used infected or infested equipment, regular cleaning of field equipment, preventing accidents of contamination of fields not infested by human activity are also important practices to prevent the spread of the pest (April et al., 2012; West and Cissé, 2014; Belzile et al., 2015; Dara, 2019).

- **Physical control methods**

Insect pests can first be controlled using traps, bait, nets, or even mating disruption techniques according to various studies (April et al., 2012; Goldberger and Lehrer, 2016; Abdollahzadeh et al., 2017; Bérubé, 2017; Costa et al., 2019; Dara, 2019; Magarey et al., 2019; Babendreier et al., 2020; Boudwin et al., 2022). Traps often contain hazardous materials that attract and eliminate pests when they approach or enter them. Other materials proven to be used in physical control are luminous or pheromone-scented devices (Kirsch, 1988; Thomson et al., 1999; Waldner, 2005; Witzgall et al., 2010; Costa et al., 2019).

To resolve the presence of weeds instead of using herbicides, manual or mechanical weeding practices are recommended first. These practices are, however, not appreciated by farmers in the sense that they require several turns in the fields, more labor, significant diesel costs (for mechanical weeding) which is considered non-ecological by most producers as various studies demonstrate (April et al., 2012; Aubert et al., 2012; D'Antoni et al., 2012; Gauthier, 2012; Costa et al., 2019; Allmendinger et al., 2022; Dara, 2019; Lee et al., 2019; Deguine et al., 2021).

- **Biological and biotechnological control**

In integrated pest management, the practice of biological control has been the subject of several definitions, yet that of Eilenberg et al. (2001) is the most retained in the literature (Costa et al., 2019). According to these authors, biological control involves the use of living organisms to suppress the population density or impact of a specific pest, making it less abundant or less damaging than it otherwise would be. So biological control consists of the use by humans of living organisms specifically chosen to counter a particular pest in agriculture (Grogan and Goodhue, 2012; Abdollahzadeh et al., 2017; Babendreier et al., 2020; Goldberger and Lehrer, 2016). These organisms can be of several kinds, namely predators, parasitoids, parasites and pathogenic insects among others as indicated by several searches (Bailey et al., 2010; Grogan and Goodhue, 2012; Goldberger and Lehrer, 2016; Muneret et al., 2018; Costa et al., 2019; Johnson et al., 2021; Rietra et al., 2022).

Biotechnical control refers to the use of a physiological mechanism or environmental behavior of the insect, which will negatively affect the survival of the organisms (Goldberger and Lehrer, 2016; Lamichhane et al., 2017; Damalas and Koutroubas, 2018; Jones, 2020; Li et al., 2020; Ayilara et al, 2023; Johnson et al., 2021). In this regard, pheromones are widely used to disrupt pest ecology and reduce crop losses due to pests. They can be used to disrupt insect mating through high concentrations of ambient pheromones to confuse males or to hide female tracks. These practices require good knowledge but also sufficient information on the biology and ecology of pests and even assistance to be adopted by farmers (Bailey et al., 2010; April et al., 2012; Abdollahzadeh et al., 2017; LeBude et al., 2017; Deguine et al., 2021; Vasconcelos et al., 2022; Vasconcellos et al., 2023). These techniques are good for the environment, but their adoption requires demonstration of the effectiveness of natural enemies in controlling pests as indicated several studies (Grogan and Goodhue, 2012; Belzile et al., 2018; Costa et al., 2019; Dara, 2019; Babendreier et al., 2020; Deguine et al., 2021; Boudwin et al., 2022). Biological control has several advantages according to Bailey et al. (2010), Costa et al. (2019) and Kalpna et al. (2022), namely long-term management of the target pest and limited side effects directed against a single or a few related pests.

- **Chemical control and biopesticides**

Depending on the types of active ingredients, biopesticides can be microbial or biochemical pesticides according to several authors (Bailey et al., 2010; Glare et al., 2012; Damalas and Koutroubas, 2018; Costa et al., 2019; Chander, 2022; Kalpna et al., 2022; Ayilara et al., 2023). Those of microbial types are used in the control of plant diseases and are based on microorganisms (bacteria, fungi, viruses, or protozoa) as active ingredients or the metabolites they produce. Those of biochemical types are natural substances that control pests and are non-toxic unlike conventional pesticides which are generally synthetic materials that directly kill or inactivate the pest. Biochemical pesticides include substances, such as insect sex pheromones, which interfere with mating, as well as various fragrant plant extracts that attract insect pests to traps. The use of chemical pesticides can have a side effect on natural enemies. When a pesticide is used to control a pest, natural enemies also disappear, either by dying or migrating to another ecosystem (Gauthier, 2012; Louvel et al., 2012; Costa et al., 2019; Hurley and Mitchell, 2020; Deguine et al., 2021). Their adoption is recommended only as a last resort because of their consequences on the health of farmers and consumers and the environment. Producers tend to use them even if their costs are expensive, because they require less labor and time and have immediate effects on pests as various studies demonstrate (Louvel et al., 2012; Belzile et al., 2017; Belzile and Li, 2014; Costa et al., 2019; Lamichhane, 2017; Lamichhane et al., 2018; Belzile, 2019; Pedersen et al., 2019; Deguine et al., 2021; Zhang, Olsson and Hopkins, 2023). In nurseries, for example, fungicides and herbicides are used as preventive measures because they reduce the cost of manual weeding and prevent the infestation of new weeds transported with nursery stock (LeBude et al., 2017)

Summary tables of integrated pest management practices found in studies and classified by stages

In Tables 1 and 2 below, we list the different practices adopted by producers in the literature according to the five stages of the ICPM of MAPAQ. We first have a table relating to research carried out outside Canada and secondly one presenting research carried out in Canada.

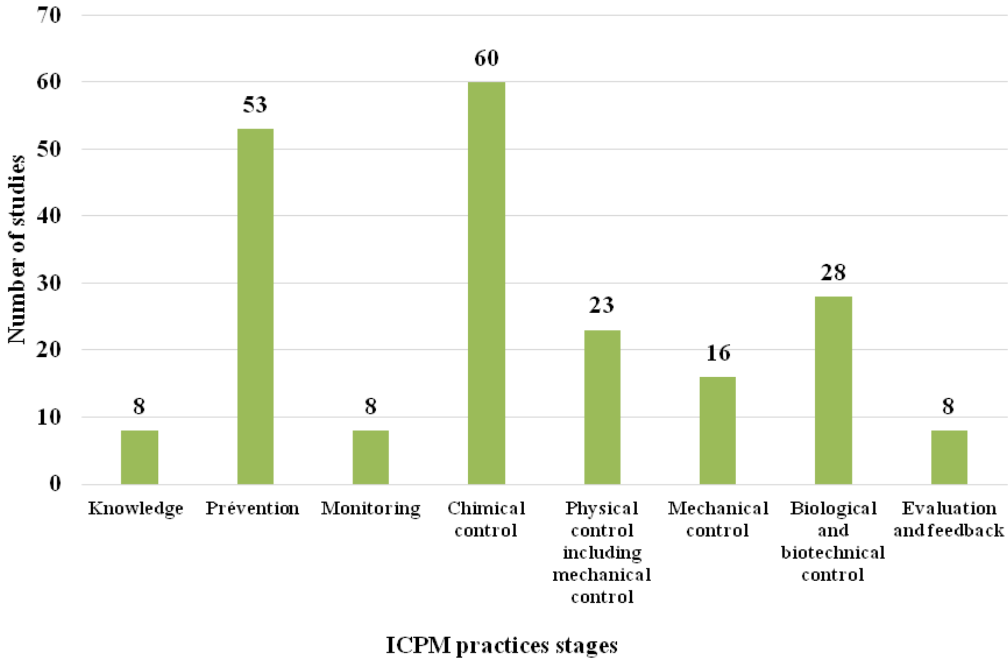
Analysis of the information listed in the tables below reveals that all these five phases defined as follows: are present in the studies reported in this rapid review.

- Knowing crop pests through research and the use of information from expert bodies in the field, such as agricultural advisory services or phytosanitary networks (knowledge stage).
- Using practices that prevent their appearance (prevention stage), such as: choosing cultivars carefully, taking into account their susceptibility to insects and diseases, or rotating with diversified crops that are not hosts to the insects and diseases found in the main crop, choosing pesticides taking resistance into account, choosing seeds that have not been treated with pesticides, sowing fields, using traps from planting onwards ;
- Identify and monitor crop pests (insects, weeds, diseases, etc.) on farms, assess weed pressure by leaving areas untreated, or use intervention thresholds when applying pesticides (herbicides and fungicides) (screening stage);
- Intervene with physical, biological, or chemical controls as appropriate. Using tools such as nets, manual or mechanical weeding for physical control, natural predators and biopesticides for biological control, or spraying fields with herbicides, fungicides and insecticides for chemical control (intervention stage);
- And evaluate and adjust the interventions carried out by archiving phytosanitary, mechanical, biological, and chemical interventions (evaluation and feedback stage). In Canada, for example, this is documented in a

register of phytosanitary interventions. This will make it possible to avoid phytotoxicity problems, assess the quality of previous interventions on farms, improve intervention methods in the future and facilitate their dissemination.

Predominance of chemical control methods in studies

Figure 1 shows that the prevention (53) and intervention by physical including mechanical control (23), biological control (28) or chemical control (60) phases are the most common in studies carried out in Canada and outside Canada. Also, despite the efforts made by farmers to adopt alternative practices to synthetic pesticides, chemical control techniques are very common in the studies selected inside and outside Canada (60).



.Figure 1. Integrated Pest Management Practices found in studies by the MAFFQ' stages
(Source: Authors' construction, 2025)

In this review, practices relating to the evaluation and feedback stages are poorly represented in the studies done in Canada (7) and almost missing in studies outside Canada (1). Indeed, just one of the international studies mentioned the adoption of evaluation and feedback practices. In Canada, few studies have reported on the adoption of evaluation and feedback practices as April et al. (2012), Gauthier (2012), West & Cissé (2014) and Bérubé (2017) etc. The knowledge stage is also not overly mentioned in the literature. Only six (7) Canadian studies mentioned it, while four (1) international studies referred to it. The monitoring stage is not mentioned too much in the literature. Only 8 studies internationally have evoked it.

Table 1. ICMP practices found in research conducted outside Canada according to the MAFFQ typology

Author(s)	Continents/ countries	Types of product(s) and culture(s)	Name of practice(s)	Relevant ICPM Integrated Pest Management stage(s)
Rietra et al. (2022)	Europe	Cereals and horticultural crops	Selection of crop varieties on the farm and crop rotation, pre-crops before wheat, particularly legumes as pre-crops	Knowledge, prevention, intervention (physical, chemical, and mechanical control)
Angus et al. (2015)	Europe	Cereals and wheat	Pest control such as weed management, mechanization and use of technology	Intervention
Preissel et al. (2015)	Spain, Germany, Sweden, France, Denmark, Finland, Great Britain, Poland	Wheat, barley, cereals, grain crop, canola, oats, mustard, flax, legumes, potatoes, lupine, soybeans, faba beans	Crop rotation practices, intercropping, selection of crop varieties, cover crops	Prevention

Bolley (1913)	United States (North Dakota)	Wheat	Crop rotation	Prevention
McAlpine (1904)	Australia (Victoria)	Wheat	Crop rotation	Prevention
Nilsson-Ehle (1920)	Sweden	Wheat	Crop rotation	Prevention
Cook (1981)	North Europe	Wheat	Crop rotation	Prevention
Andert et al. (2016)	North Germany	Wheat, barley, sugar beet, maize, rapeseed	Crop rotation	Prevention
Krupinsky et al. (2004)	United States (Mandan)	Cereal and oilseed crops	Choice of cultivars and crop rotation	Prevention
Liebman & Dyck (1993)	United States	Grain farming	Choice of cultivars and crop rotation	Prevention
Chikowo et al (2009)	France Dijon	Cereals	Crop rotation	Prevention
Lee (1985)		Cereals	Herbicides	Intervention (chemical control)
Zhang et al. (2018)	Germany, Hungary, Italy, Netherlands, Poland, Sweden and United Kingdom	Wheat, corn, sugar beet and rapeseed	Crop rotation, pesticides and insecticides	Prevention and intervention (chemical control)
Macé et al. (2007)	France Dijon	Brome, geranium, cornflower, mustard ball, cornflower, faba bean	Crop rotation, herbicides, mechanical weed control	Prevention, intervention (chemical and mechanical control)
Sarani et al. (2014)	Iran	Safflower and canola	Crop rotation	Prevention
Andert et al. (2016)	Germany	Winter barley, winter wheat, sugar beet, corn, winter rapeseed	Crop rotation, glyphosate and herbicide	Prevention and intervention (chemical control)
Beckie (2011)	United States	Cereals	Glyphosate herbicide	Intervention (chemical control)
Heap & Duke (2018)	United States	Cereals	Glyphosate herbicide	Intervention (chemical control)
Beckie & Harker (2017)	United States	Cereals, oilseeds and legumes	Crop rotation and glyphosate Herbicide	Prevention and intervention (chemical control)
Peterson et al. (2018)	Several countries around the world	Several products	Herbicides	Intervention (chemical control)
Duke & Powles (2008)	Several countries around the world	Several products	Glyphosate	Intervention (chemical control)
Janssen et al. (2019)	Netherland	Wheat	Decontamination of seeds, crop rotation, plowing, resistant cultivar lodging, fungicide use, fungicide use flowering, Resistant cultivar fusarium, biological control, decision support systems	Prevention and intervention (physical, biological, chemical and mechanical control)
Jones et al. (2017)	Portugal	Maize	Genetically modified maize	Prevention
Jussaume et al. (2022)	United States /Arkansas, Iowa, Minnesota, and North Carolina	Corn and soybean	Herbicides and 16 different weed control methods	Prevention and intervention (physical, chemical, biological control)
Khanna et al. (2022)	United States	Several cultures	Digital technologies and artificial intelligence technologies of weed control	Intervention (mechanical control)
Matousek et al. (2022)	Australia	Maize, sugar beet, soybean, potatoes vineyards, vegetables orchards and cereals	Glyphosate and mechanical or chemical alternatives	Prevention, identification, and intervention (physical, mechanical, biological and chemical control)
Kalpna et al. (2022)	Several countries	Grains	Crop rotation, inert materials, harvest time, alternative host, intercropping, storage of unthreshed legumes, cleanliness, vegetable oil resistant varieties, natural control, botanical extracts, chemical and microbial, transgenic approach, cold plasma treatments, chemical insecticides.	Prevention and intervention (physical, chemical, biological control)
Lee et al. (2019)	Europe	Several cultures	Pesticides crop rotation, hygiene, biological measures	Prevention and intervention (chemical and biological control)
Zhang et al. (2019)	United States	Several cultures	Glyphosate	Intervention (chemical control)
Alonso González et al.(2021)	Spain	Several cultures	Pesticides	Intervention (chemical control)

Lamichhane (2017)	Europe	Cereals and horticulture	Pesticides	Intervention (chemical control)
Lamichhane et al. (2018)	Europe	Several cultures	Herbicides, crop rotation, biological control	Prevention and intervention (chemical and biological control)
Kabir et al. (2017)	Bangladesh	Cereals and horticulture	Crop rotation, pesticides	Prevention and intervention (chemical control)
Boudwin et al. (2022)	United States	Several cultures	Good practices, pesticides, physical, chemical, biological controls, crop monitoring documents, and information	Prevention, intervention (chemical and biological control) and Evaluation and feedback
Muneret et al. (2018)	Many countries	Several cultures	Cultural rotation, biological control	Prevention and intervention (biological control)
Lesur-Dumoulin et al. (2017)	17 European countries	37 fruit and vegetable horticultural products	Crop rotation and pesticides	Prevention and intervention (chemical control)
Costa et al. (2019)	Many countries	Horticultural and cereals	Crop rotation, crop diversification, choice of cultivars, mowing nets, suction, traps, corrugated cardboard strips, pits, biopesticides, pheromones, predators, natural, habitat control, identification of enemies insecticide pesticides	Prevention, identification, intervention (physical, mechanical, biological, and chemical control) and monitoring
Vasconcelos et al. (2022)	Europe	Olive	Crop rotation, biological control of natural predators, synthetic organic insecticides, herbicides	Prevention and intervention (biological and chemical control)
Magarey et al. (2019)	United States	Several cultures	Pesticides, neonicotinoids	Intervention (chemical control)
Dara (2019)	United States	Several cultures	Good practices, pesticides, physical, chemical, and biological control, crop monitoring documents and information,	Prevention and intervention (physical, biological, and chemical control)
Pedersen et al. (2019)	Denmark	Several cultures	Pesticides	Intervention (chemical control)
Vryzas et al. (2020)	Europe, United States, Latin America and the Caribbean	Several cultures	Pesticides	Intervention (chemical control)
Deguine et al. (2021)	Europe Asia	Several cultures	Good cultural practices, pesticides, and biological control	Prevention and intervention (chemical and biological control)
LeBude et al. (2017)	United States	Ornamental crops	Monitoring crop pests, fungicides, and herbicides	Prevention, monitoring, and intervention (biological, chemical control)
Wang and Liu (2021)	China	Rice	Pesticides	Intervention (chemical control)
Damalas et al. (2022)	Greece	Several cultures	Pesticides	Intervention (chemical control)
Allmendinger et al. (2022)	Europe	Several cultures	Pesticides, herbicides and Precision weed management technologies	Intervention (chemical and mechanical control)
Thompson et al. (2024)	European Union	Several cultures	Ecological farming practice	Prevention, identification and intervention (physical, mechanical, biological and chemical control)
Areal et al. (2012)	European Union	Maize	Genetically modified herbicide tolerant	Prevention
Arevalo-Vigne (2017)	Australia	Fruit	Area-wide management	Intervention (biological control)
Möhring et al. (2020)	Europe	Several cultures	Pesticides	Intervention (chemical control)
Coon et al. (2020)	United States / Iowa-Missouri border	Cereals	Herbicide application, prescribed fire, and physical removal	Prevention and intervention (chemical and biological control)
David et al. (2021)	France	Several cultures	Pesticides	Intervention (chemical control)
Damalas et al. (2022)	Greece	Cereals	Herbicides	Intervention (chemical control)
Dentzman (2018) and Dentzman et al. (2016)	United States/n Iowa, Minnesota, North Carolina, and Arkansas.	Several cultures	Herbicides resistant seeds	Prevention
Espig and Henwood. (2023)	New Zealand/ Canterbury	Grain	Herbicide	Intervention (chemical control)
Gent et al. (2011)	United States and Australia	Several cultures	Decision support systems and Integrated Pest Management	Intervention (mechanical control)
Goldberger & Lehrer (2016)	United States/California	Walnut and pear	Biological control, minimize factors (e.g., broad-spectrum	Intervention (biological control) and prevention

	and Washington		pesticides) that harm natural enemies, release commercially produced natural enemies, enhance natural enemy habitats (e.g., creating refuges, planting flowering plants or ground covers)	

Source: Authors' construction, 2025.

Table 2. ICPM practices found in research carried out in Canada according to the MAPAQ typology

Authors (s)	Country/City	Types of product(s) and culture(s)	Practices	Relevant ICPM Integrated Pest Management stage(s)
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Attend training activities related to production (symposium, regional information day, field demonstration activity, etc.)	Knowledge of enemies
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Use of information from organizations such as agricultural advice	Knowledge of enemies
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Use of information from specialized guides from ministries or private organizations	Knowledge of enemies
Belzile & Li (2014)	Canada	Straw cereals, Corn soya, horticulture	Use of information from experts	Knowledge of enemies
Belford (1899)	Canada (Manitoba)	Wheat	Crop rotation	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Choosing pesticides considering resistance	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Choose cultivars considering susceptibility to insects and diseases	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Rotations including crops that are not hosts for insects and diseases found in the main crop.	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Time of day to apply a pesticide if fields are sprinkler irrigated	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Choose pesticides considering the risk to beneficial insects	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Mowing at the edge of dikes or ditches	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Silting of fields	Prevention

April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Seeding the dikes with a mixture of non-invasive plants for cultivation	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	After harvest, chopping and burial of crop debris	Prevention
Nicol & Kennedy (2008a)	Canada/British Colombia	Tree fruit, berry, and grape.	Adjust watering times, adjust planting times, use plant disease-resistant varieties	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Use of traps right from planting	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Choose seeds not treated with insecticides	Prevention
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Scout for weeds	Prevention Monitoring
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Screen for diseases	Monitoring
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Insect detection	Monitoring
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Use of action thresholds (if they exist) when applying an insecticide or fungicide	Monitoring
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, Apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale, and grass.	Assessment of weed pressure and species present by leaving areas untreated	Monitoring
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato	Chemical control Herbicide treatment on the entire surface	Intervention (chemical control)
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato	Physical or mechanical control Weeding mechanically or manually	Intervention (physical and mechanical control
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato	Chemical control Reduces the use of herbicides (localized application, reduced doses or in strips)	Intervention (chemical and mechanical control
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato	Biological control Use means other than chemical insecticides and fungicides (predators, biopesticides, parasitoids, trap crops, etc.) and adjustment of insecticide sprayers.	Intervention (biological and chemical control)

April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato	Chemical control Application of pesticides in a localized manner	Intervention (chemical control)
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato	Cover crops in aisles or between cultivation beds	Prevention
Nicol and Kennedy (2008)	Canada/British Colombia	Tree fruit, berry, and grape.	Use sterile or predator insects	Intervention (biological control)
Beckie et al. (2020)	Canada Saskatchewan, Manitoba Alberta	Several cultures	Glyphosate	Prevention and intervention (chemical control)
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Use of a phytosanitary intervention register	Evaluation and feedback
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Information entered in the register: pesticide applications	Evaluation and feedback
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Information entered in the register: weather conditions during applications (winds, temperature)	Evaluation and feedback
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Information recorded in the register: effectiveness of treatments carried out	Evaluation and feedback
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Information entered in the register: phytosanitary interventions (mechanical or biological)	Evaluation and feedback
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Information entered in the register: screening information	Evaluation and feedback
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Using register data to plan the next production season	Evaluation and feedback
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Use of personal protective equipment when preparing porridge	Pesticides management
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Using a tractor equipped with a cabin with a pesticide filter	Pesticides management
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, Vegetable crops, Field crops, Ornamental nurseries, small fruits, apple, Potato, Oats Wheat Canola, Hay but Barley Soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Use of personal protective equipment when applying a pesticide (if the tractor is not fitted with a cabin with a pesticide filter)	Pesticides management
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, Vegetable crops, Field crops, Ornamental nurseries, small fruits, apple, Potato, Oats Wheat Canola, Hay but Barley Soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Cleaning Personal Protective Equipment (if used)	Pesticides management

April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Sprayer Rinsing	Pesticides management
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Triple Rinse or Rinse Empty Pesticide Containers	Pesticides management
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Move pesticide containers safely or return them to suppliers	Pesticides management
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Use of anti-drift nozzles	Pesticides management
April et al. (2012); Bérubé (2017); Gauthier (2012); West & Cissé (2014); Belzile & Li (2014); Belzile & West (2015); Belzile et al. (2015)	Canada	Cranberry, vegetable crops, field crops, ornamental nurseries, small fruits, apple, potato, oats wheat canola, hay but barley soya + horticultural commodities of alfalfa, mustard, millet, triticale and grass.	Use of a windbreak hedge to prevent pesticide drift	Pesticides management

Source: Authors' construction, 2025.

CONCLUSION

This rapid literature review, based on 71 scientific documents, identified a range of alternative practices to the use of synthetic pesticides in Canada and other countries that could be implemented in Quebec to achieve the *PAD 2020–2030* objectives. The review also classified Integrated Crop Pest Management (ICPM) practices according to the typology developed by the Ministry of Agriculture, Fisheries and Food of Quebec (MAFFQ). The findings indicate that ICPM practices related to physical, biological, biotechnical, and chemical (herbicidal, fungicidal, insecticidal) controls are the most widely applied by producers in Canada and in countries with comparable agroeconomic characteristics.

Preventive practices aimed at reducing pest emergence remain crucial and should not be neglected by producers wishing to minimize reliance on synthetic pesticides. Curative approaches, such as physical, mechanical, biological, and biotechnical control methods, are also applied to limit pest damage while reducing pesticide use. Nevertheless, synthetic pesticides continue to be widely used, even though they should constitute a last-resort measure within ICPM frameworks.

The principles of integrated crop pest management (insects, weeds, diseases) encourage the adoption of environmentally sound practices designed to prevent damaging levels of pests and minimize the need for curative solutions. Despite their critical importance, these practices have advantages (environmental protection, improved human and animal health, and biodiversity preservation) and disadvantages (risks related to loss of returns, economic risks, etc.) that encourage farmers to resort to pesticides. This rapid review has shown that even if farmers are interested in adopting integrated pest management practices, especially those in the first and fourth stages of the MAFFQ's typology, particularly preventive methods and intervention without using pesticides (information on pests and practices, crop diversification, crop rotation, choice of cultivars, physical, mechanical, biological, and biotechnical control, biopesticides, windbreak hedges), they face constraints. Several reasons are mentioned by the authors in the studies, notably the poor access and availability of information on crop pests to agricultural producers, the limited knowledge of crop pests, social norms imposed on agricultural producers, time loss suffered by producers, the complexity of certain integrated pest management practices (mechanical weeding, biological control), the perception of economic risks, and the difficulty of assessing intervention thresholds.

Regarding the results on the constraints to the adoption of alternative pesticide practices, it is important that the governments of the countries considered in this study implement policies that facilitate access to information for agricultural producers, develop practices that are less complex to use and require less labor, consider the importance of psychosocial factors (social norms, perception of practices, perception of economic, health, or environmental risk) in the adoption of alternative pesticide practices, and disseminate research results to producers on the economic risks they face when they decide to adopt an integrated pest management practice. It is also important to provide information to producers on intervention thresholds.

The results obtained also show that practices related to knowledge, monitoring, evaluation, and feedback stages are poorly represented in the studies. Based on these findings, agricultural policies that encourage the adoption of these practices at these stages would facilitate pesticide reductions in agriculture in Canada and the other countries considered in this rapid review.
Given the results regarding pest management practices adopted by producers according to the ICPM stages, it would be relevant for the countries considered in this study, and Canada in particular, to apply the MAFFQ's typology in the future. It can indeed facilitate the development of agricultural policies specific to each phase of the ICPM. This classification of practices allows for faster identification of the stages best understood and adopted by agricultural producers. This typology provides a clear idea of the phases and alternative practices that governments must pay particular attention to develop relevant policies for the reduction of synthetic pesticides in agriculture.
Our review has limitations. Geographically, it is limited to Canada and some countries with similar agroeconomic characteristics. Therefore, it would be relevant in future rapid reviews to expand the geographical scope (for example, by including countries in Asia, Africa, or other parts of the Americas) in order to identify both integrated pest management practices like those found in this review and those that differ depending on the agroeconomic contexts of these countries. This would allow for more comprehensive research results. From a methodological perspective, it would also be interesting to conduct scoping reviews, systematic reviews, or meta-analyses on the same topic to identify or compile more comprehensive assessments of ICPM practices and thus obtain more robust results. Our review does not also highlight the impacts or effects of adoption of alternative pesticide practices on farm yields and costs. Future reviews should certainly take this into account. The time allocated to carrying out this review is a little insufficient and could suggest a non-exhaustive nature of our research results.
Despite the limitations mentioned above, it should be noted that this review has mainly highlighted the importance of classifying integrated crop pest management practices according to a typology (that of the MAFFQ in particular) when carrying out studies in this area in order to facilitate the development of more appropriate agricultural policies.

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