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Connecting plant species and natural products from the Canadian prairie ecological zone to biomedical knowledge

Layla Molina¹, Haley K. Allard¹, Sophie M. Kernéis², and Roy M. Golsteyn^{1*}

1. Natural Product Laboratory, University of Lethbridge, Lethbridge, AB, T1K 3M4 Canada

2. Microbial Research Laboratory, Lethbridge College, Lethbridge, AB, T1K 1L6 Canada

*Corresponding author:

Roy M. Golsteyn

Natural Product Laboratory,

Department of Biological Sciences,

University of Lethbridge, Lethbridge, Alberta, T1K 3M4 Canada

Tel. 403-332-4553

E-mail: roy.golsteyn@uleth.ca

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Abstract

Natural products from plants in Canadian ecological zones are understudied. There are, however, sound scientific arguments to justify investigation of natural products from plant species found within these zones. We review a broad range of scientific and local literature describing the features of the Canadian prairie ecological zone and the Asteraceae taxonomical family. Species from Asteraceae are well represented in the prairie ecological system, although very few have been investigated for natural products with bio-medical properties. Data from a range of sources that address ecological interactions, abiotic features, and Traditional Knowledge provide a foundation for future scientific studies of plant natural products found within Canadian borders. We draw from discoveries of the Asteraceae family and one of its major classes of secondary metabolites, sesquiterpenes, to stimulate research of Asteraceae species in Canada.

Keywords

Alberta

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Asteraceae natural products as sources of bioactive molecules

Plants from the taxonomical family, Asteraceae, are historically and scientifically recognized as sources of beneficial natural products (metabolites), such as treatments for malaria (*Artemisia annua* L.) (Septembre-Malaterre et al., 2020), respiratory diseases (*Echinacia spp.*) (Barrett, 2003), use as sweeteners (*Stevia spp.*) (Soejarto et al., 2019), or wellness (*Achillea millefolium* L.) (Benedek and Kopp, 2007). Primary metabolites are essential for growth and include well known chemical families such as proteins, carbohydrates, lipids, chlorins (chlorophylls), and nucleic acids. Secondary metabolites, such as flavonoids, alkaloids, or terpenoids, including sesquiterpenes, are not thought to have vital roles; instead they act as supportive metabolites that evolved from ecological pressures (Hartmann, 1996). Secondary metabolites may be critical for defensive strategies against herbivores or pathogens, plant-plant competitions, or beneficial interactions for plants such as the attraction of pollinators or symbionts. They may also have protective roles against abiotic stressors such as changes in temperature, light intensity, UV exposure, among others (Pavarini et al., 2012). It is noteworthy that the precise boundaries of primary and secondary metabolites are becoming blurred (Erb and Kliebenstein, 2020).

The Asteraceae, also known as Compositae family, is the largest family of flowering plants containing 32,913 species in 1,911 genera distributed around the world except for Antarctica (Garden, 2013). It was taxonomically divided into 11 subfamilies and 35 tribes by Panero and Funk (2002) after analysis of DNA sequence data of chloroplasts genes. It is a monophyletic family characterized by a special type of inflorescence called pseudanthium, flower head, or capitulum, where disc and ray florets are arranged on a receptacle centripetally and are surrounded by bracts that form the involucre. This family presents anthers fused in a ring with the pollen pushed out by the style, and achenes (cypselas) usually with a pappus (Figure 1). There is a large morphological variation among its members, existing annual and perennial herbs, shrubs, vines, or trees, and

although they are more common in open areas, they can be found in almost every type of habitat from forests to high elevation grasslands (Panero and Funk, 2002).

Several Asteraceae species are well known because they contribute to our diets, such as lettuce (*Lactuca sativa* L.), chicory (*Cichorium intybus* L.), and artichoke (*Cynara cardunculus* var. *scolymus* L.). Within the category of medicinal plants, *Artemisia annua* from Asteraceae, is the source of artemisinin and its derivatives artesunate and dihydroartemisinin are major antimalarial drugs. The discovery that *A. annua* was able to inhibit malarial parasite growth and the subsequent isolation of the sesquiterpene lactone artemisinin is attributed to Dr. Tu Youyou (Miller and Su, 2011). For this discovery, Dr. Youyou was awarded the Nobel Prize in 2015 (Youyou, 2016). The best-known species of this family in the prairie ecological zone is the sunflower (*Helianthus annuus* L.).

We consulted natural product related databases (Sorokina and Steinbeck, 2020), including National Center for Biotechnology Information (PubMed, PubChem), Google Scholar, VASCAN, as well as numerous limited print publications that are cited herein. Scientific information about the biological and medical potential of prairie plant species, including those from Asteraceae is limited. We review information from a diverse set of sources that support continued investigation of Asteraceae species from the prairie ecological zone for natural products, especially secondary metabolites such as sesquiterpene lactones. Members of the Asteraceae family produce a wide range of other secondary metabolites including: monoterpenes, diterpenes, triterpenes, sesquiterpenes, polyacetylenes, flavonoids, phenolic acids, benzofurans, and coumarins (Zdero and Bohlmann, 1990). They do not produce major classes of alkaloids, only pyrrolizidine alkaloids are found in Senecioneae and Eupatorieae tribes. The accumulation of lactonized sesquiterpenes and polyacetylenes, as well as the presence of many highly oxidized compounds, have been

recognized as unique chemical signatures for most of the members of this family (Zdero and Bohlmann, 1990). Therefore, these compounds may be responsible for the unique medicinal uses that have been attributed to this family.

Vascular plants in Canada have been enumerated using provincial boundaries. The province of Alberta, which overlaps with much of the prairie ecological zone, has 1636 native vascular plant species belonging to 123 families (Kershaw and Allen, 2020). A widely used taxonomical key developed by Packer and Moss (1983) reported 1475 native plant species in Alberta. It is reported that 55% of the species present in Alberta (661,848 km²) can be found in Waterton Lakes National Park (505 km²), which is nestled in the south west corner of the province but only covers 0.08% of the provincial surface area (Kuijt, 1982).

Documents of the Flora of North America have recorded 2413 Asteraceae species and 418 genera for the United States and Canada (Committee, 1993). The Database of Vascular Plants of Canada (VASCAN) currently reports 691 species of the Asteraceae family from 163 genera and 19 tribes of the 4 subfamilies Asteroideae, Cichorioideae, Carduoideae, and Mutisioideae distributed across the ecological zones (Brouillet et al., 2010). It includes plants having one or more of five statuses. The status of *native* is given when a taxon is present in a region as a result of natural processes and not human intervention. Taxa are considered *introduced* if they were established after European colonization for accidental or deliberate human activity. The status of *ephemeral* refers to taxa that recur in the wild in a near-annual basis, usually from cultivation, but is not permanent. The VASCAN database catalogues a taxon as *excluded* when it has been reported from a region but it is not established, or it was erroneously determined, and as *extirpated* if it was native to the region but it is now considered eradicated (Brouillet et al., 2010). From these 691 species, 332 are present in the prairie region (provinces of Alberta, Saskatchewan, and Manitoba)

from 106 genera and 18 tribes. 245 species are native to this region, 58 introduced, 27 excluded, and 2 ephemerals. In Alberta, which includes the prairie ecological zone, there are 270 species from 91 genera and 16 tribes from the Asteraceae family: 207 natives, 51 introduced, 11 excluded, and 1 ephemeral. **Table 1** lists the Asteraceae species present in the prairies and their status in this region. Presence can refer to either Alberta, Saskatchewan, Manitoba, or combinations thereof. It is striking that only 9 of these species are described in Health Canada's NHPD monographs, and of those, only 3 are native plants (**Table 2**). The biotic and abiotic conditions of the prairies as well as association with Traditional Knowledge provide support for investigation of the biomedical properties of this family.

The prairie ecological zone

The prairie ecological zone is one of the fifteen zones of Canada. It extends from the western edge of Alberta to the eastern edge of Manitoba and has its base in the Canada-United States border, comprising the northern extension of the Great Plains of North America (Marshall et al., 1999). It is characterized by relatively little topographic relief, grasslands, limited forests, and a sub-humid to semiarid climate (Figure 2). Despite a strong presence of agricultural activity, little research has been done regarding the potential biological activities of its native flora. Similar to other ecological zones in the biosphere, Asteraceae is one of the major botanical families in the prairies.

Secondary metabolites and the prairie ecological herbivory

Secondary metabolism in plants may have evolved to interact with molecular targets that affect physiological functions in competing organisms (e.g. microorganisms, non-host plants, animals) (Wink, 2003). These organisms, in turn, can develop adaptive responses constituting plant-animal interactions. This coevolutionary adaptation process has contributed to the multitude of bioactive

compounds found in plants (Wöll et al., 2013). We focus on the prairie ecological zone because it is a region in which vascular plants and grazing herbivores have co-existed since the Eocene Epoch (45,000,000 years ago) (Stebbins, 1981). In modern times, the prairies were occupied by vast herds of *Bison bison* (American bison, also known as buffalo), which are herbivores that weigh between 400-1,000 kg as adults. The bison were extirpated from Alberta by 1879 (Adams et al., 2004) and replaced immediately by domestic cattle. In 1880-1882 the number of cattle imported in Alberta increased from 1,352 to 16,282 with nearly 104,000 cattle registered by 1886 (Evans, 1978). There has been a nearly continuous grazing by herbivores on prairie grasslands (Mijaljica et al., 2012).

The bison had major effects upon prairie flora and contributed to patch dynamics, in which they reduce plant height, decrease grass numbers, and increase forb numbers (Myser, 2011). Grazing by large mammalian herbivores does reduce reproductive success and abundance yet increases diversity of prairie plant species (Spotswood et al., 2002, Bakker et al., 2006). Although much less studied, it was reported that below-surface organisms such as nematodes and mammals (*Cynomys ludovicianus*; prairie dogs) may be the largest contributor to herbivory in the United States grasslands (Ingham and Detling, 1984, Myser, 2011). It is not reported if the major below-surface mammal in Canadian prairies, the ground squirrel, *Urocitellus richardsonii*, impacts below-surface herbivory.

Detailed examples of plant toxins affecting animal grazing are not common; the possum (*Trichosurus vulpecula*, a marsupial) alters its foraging behaviour relative to the concentration of plant toxin, eucalyptus oil, a terpene (Nersesian et al., 2011). The concept of adaptive plant-herbivore behaviour in the prairie ecological zone is largely based on empirical data with little supportive experiment data to this day (Laycock, 1978, Briske, 1996). It would stand to reason

that plants in grassland communities have developed significant secondary metabolites that affect animal physiology leading to avoidance (Briske, 1996). Some secondary metabolites produced by plants have a toxic effect in grazing animals. Grazing domestic animals are known to be at risk to intoxication by secondary metabolites from plant species within the prairie ecological zone, such as *Thermopsis rhombifolia* Nutt. ex Pursch (Fabaceae; buffalo bean) (Keeler et al., 1986, Keeler and Baker, 1990) or *Delphinium nuttallianum* Pritz. ex Walp. (Ranunculaceae; Larkspur) (Pfister et al., 1996). To support the agricultural development of the prairies, native plant species on the prairies have been investigated for toxicity at the whole animal level. In the province of Alberta, 42 native plant species from forbs to trees have been identified as toxic to livestock (Majak et al., 2008). A document circulated by the Government of Alberta lists 133 introduced and native plant species or genera that are toxic to humans and livestock of which the greatest number were members of Asteraceae (Government of Alberta, 1995). Although the type of secondary metabolite and its toxic dose have been frequently identified, the mechanism of action (host target receptor) is usually not known.

More recently, in European grasslands (not North American prairie), it has been proposed that at low concentrations certain secondary metabolites may benefit grazing herbivores by providing antioxidant or anti-parasite properties (Poutaraud et al., 2017). Some grazing animals in North American ecological zones display a preference for a plant species over another. In studies of deer (*Odocoileus*) and their consumption of prairie Fabaceae species, *Dalea purpurea* Vent. was consumed in preference relative to *Amorpha canescens* Pursh. (Nisi et al., 2015). Changes in plant defenses over a period of 39 years were observed in the investigation of aphids and *Arabidopsis thaliana* L. (Brassicaceae) interactions in Europe (Züst et al., 2012). Albeit a study of insect herbivore, it provides biological evidence of an interaction that is consistent with the

notion of similar outcomes with mammalian herbivores. The possibility of relationships between animals and plants likely harbouring secondary metabolites is supported by an investigation of foraging habits of pygmy rabbits (*Brachylagus idahoensis*) and plants of *Artemisia* spp (Sagebrush) (Ulappa et al., 2014). The presence of secondary metabolites negatively influenced the selection of foraging by this small herbivore.

There are several examples of co-evolution between diverse organisms in the prairie ecological zone that are astonishing in their specificity and reside under a theme of connectivity in biology. The monarch butterfly (*Danaus plexippus*) feeds on the toxic prairie plant, milkweed (*Asclepias incarnata* L. (Apocynaceae)) which protects the butterfly against parasites, such as *Ophryocystis elektroscirrha* (Smilanich and Nuss, 2019). An example of a vertebrate (avian) and Asteraceae species relationship in the prairie setting is shown with the sage grouse (*Centrocercus urophasianus*) and the silver sagebrush (*Artemisia cana* Pursh.) (Adams et al., 2004). The sage grouse is a silver sagebrush obligate, with 100% of its food requirement in winter provided by this plant. The plant also provides nesting sites and cover from mammalian predators. The *Artemisia* spp. are poisonous to livestock and humans (Alberta Agriculture, 1995) but the phytochemical relationship between sage-grouse and *Artemisia* spp. has not been identified. Secondary metabolites from the sesquiterpene lactone class that are assigned to defense mechanisms may also have roles in tissue specific development in seedlings, moving them to a primary metabolite role (Padilla-Gonzalez et al., 2016, Spring et al., 2020).

Secondary metabolites and prairie abiotic features

The abiotic features of an ecological zone impact the secondary metabolites that can be isolated from plants within that zone. The prairie ecological zone of Canada has a dramatic range of abiotic

features. Over a 30-year period at a central site (Lethbridge, AB) in the prairies, the maximum daily average temperature was calculated to be 26.1°C, with the extreme of 39.4°C. In the same period, the minimum daily average was -12.1°C with the extreme -42.8°C, a temperature range of 81°C (Government of Canada, 2021). The temperature range varies per year, as does the number of days per year with temperatures above -5°C during the past 50 years; ranging between 141 to 213 days. Similar wide variations are observed with season precipitation in the form of snow and rain. Over a 50-year period, the amount of precipitation ranged between 111 to 554 mm. The mean daily insolation is 3.7-5.1 Wh/m², the highest of the fifteen Canadian ecozones, with the greatest intensity occurring in June (Government of Canada, 2021b). The 20-year average of direct normal irradiation is 1,900 Wh/m² in the prairie zone, in contrast to 1,300 Wh/m² for most other ecological zones at the similar latitude. Abiotic conditions are known to affect secondary metabolite concentrations (Rodziewicz et al., 2014). It is likely that plants in the prairie ecological system vary their secondary metabolite concentrations and have co-evolved means to stabilize metabolite concentrations in response to abiotic variation. There are reports, however, of how abiotic features such light intensity affects the concentration of sesquiterpene lactones in the prototype prairie Asteraceae, (*Helianthus annuus* L.) (Spring et al., 1986) and that flavonoid synthesis correlates with latitude of the host plant (Jaakola and Hohtola, 2010).

Prairie plants with medical and wellness properties

As a result of connections to ecological systems plants may synthesize metabolites that are structurally similar to animal metabolites, such as hormones, signal transduction ligands, or neurotransmitters, and may affect human physiology due to the resemblance in potential target sites (Briskin, 2000). Natural products can potentially modulate cellular responses that are of interest in biological research or drug development. Furthermore, because some natural products

have evolved to modify animal physiology, they have inherent medicinal properties, which contributes to their success as medicines (Newman and Cragg, 2020).

Indigenous Knowledge and prairie plants

The prairie ecological zone in Canada and the United States has been home since time immemorial to members of North American First Nation communities. One of these, known as the Niitsitapi People (Blackfoot Confederacy), uses prairie plant species for medicinal purposes. The Niitsitapi hold an oral tradition and exchanges with scientific communities are not frequent, but some information has been made available publicly for all communities. A regional publication from 1987 lists 185 species of plants that are recognized from Traditional Knowledge as having medicinal properties (Johnston, 1987). A publication from 1974 lists 100 plant species with medicinal properties used by two of the Niitsitapi tribes, the Kainai and the Pikanii, who are located in southern Alberta (Hellson, 1974). Some information about medicinal plants from the Kainai tribe has been shared in a website (Galileo Network Website, 2016), which provides recorded audio and written information about 61 plants.

Several plant species that are found in the prairies are also distributed in other ecological zones and are recognized as medicinal plants by First Nations from those regions. The Asteraceae family was well represented amongst the medicinal plants known to First Nation communities across North America (Shemluck, 1982). This listing included 474 species, of which it is noteworthy that scientifically well known *Achillea* and *Artemisia* species (Asteraceae) were widely used by different tribes for a large number of ailments; whereas other listed species, some which are found in the prairies such as *Hymenopappus filifolius* Hook (Asteraceae) are not described in biomedical literature. Medicinal plants from the boreal plain ecological zone in central and

northern Alberta that are known to Cree peoples were reviewed in 1982 by an Elder, Dr. Anne Anderson (Anderson, 1982). The information collected by Dr. Anderson was further studied and described in a MSc thesis (Wood, 1996). Kindscher (1992) reported an ethnobotanical study of 203 prairie plant species present in the prairie ecological system of the United States (Kindscher, 1992). Other regions outside of the prairie ecological zone, but which harbour plant species that are established in the prairies are part of Traditional Knowledge from the Thompson First Nations (Central British Columbia) (Turner et al., 1990) and Wood Cree First Nations (Central Saskatchewan) (Leighton, 1985), and the First Nation communities of boreal forests in western Canada (Marles et al., 2012). An encyclopedic reference of 3000 plant species known in Traditional Knowledge to First Nation communities of North America, which includes the prairie zone and the Blackfoot Confederacy is described by Moerman (2009). A survey of the information about prairie plants reveals several themes about western scientific and Traditional Knowledge:

1. The majority of plant species are not described as Traditional medicine in printed sources. It is noteworthy that the information about medicinal plants in different public sources are only partially overlapping, suggesting that much knowledge remains to be shared or exchanged between western scientific and First Nation communities.
2. There are relatively few references to cancer treatments, consistent with the difficulty of detecting internal tumours (Moerman, 2009). For example, there are 523 references to treatment for eye afflictions compared to 55 for cancer.
3. Specifically to Traditional Knowledge of Niitsitapi communities, very few plant species with medicinal properties have been investigated by Western scientific methods.
4. Asteraceae species that are globally distributed such as *Achillea millefolium* (Yarrow) or *Helianthus annuus* (Sunflower) have also been identified by distant cultures in Europe and

Asia and by Niitsitapi communities for their medicinal properties (Johnston, 1987, Moerman, 2009, Laws, 2015).

The relationship between Traditional Knowledge and Western biomedical information has been recognized in the investigation of natural products globally. It has been reported that inclusion of Traditional Knowledge in western scientific studies increases the success of finding pharmacologically important compounds (Balick, 1990). Incorporating Traditional Knowledge has not been widely used in investigation of plant species in the Prairie ecological zone (Kindscher, 1992), although there are a small number of studies performed in other zones. Uprety et al. (2012) analyzed 49 publications related with the medicinal uses of North American Aboriginal people, including Canada's First Nations, Metis, and Inuit, and reported 546 medicinal plant taxa used by Aboriginal people of the Canadian boreal forest. The anti-diabetic properties of plants known to the Cree First Nations led to the isolation of several compounds including those with specific enzyme targets in glucose metabolism (Muhammad et al., 2012, Nistor Baldea et al., 2011, Shang et al., 2015, Downing et al., 2019). A study comparing anti-fungal activity of plants in Eastern Canada revealed a greater activity in extracts prepared from species identified by Traditional Knowledge when compared to those selected without ethnobotanical information (Jones et al., 2000). Examples of considering North American ethnobotanical knowledge to find anticancer activity screening include testing 29 plants used by the Gwich'in First Nation (Northwest Territories and Yukon) (Deeg et al., 2012), and testing of two plants used by Indigenous Peoples in New Mexico USA (Daniels et al., 2006). The exchange of Aboriginal Traditional Knowledge to western scientific knowledge remains incomplete in Canada. Currently, there are no studies published in which Canadian Niitsitapi Traditional Knowledge of prairie plants was incorporated into a western scientific study.

In countries other than Canada, Indigenous Traditional Knowledge has contributed to the discovery of anti-cancer compounds from a variety of chemical scaffolds (Khadem and Marles, 2011). Comparison of the success of drug screening programs using either unbiased selection of plant materials to ethnobotanical biased selection favours the inclusion of ethnobotanical knowledge. Kindscher and colleagues tested published medicinal plants and were able to detect anti-cancer activity in tests *in vitro*. Similar trends were observed in studies of bioactive plants from rainforests (Balick, 1990), midwestern regions of United States (Lewis and Elvin-Lewis, 1995), and British Columbia (McCutcheon et al., 1992, McCutcheon et al., 1995). The increase in successful discovery of active compounds might be due to Traditional Knowledge about the best harvest conditions which would include time of year, which part of the plant, and which plant within a population. Traditional Knowledge from other cultures, such as from Chinese Traditional medicine, was used to guide the investigation of 15 plant species that are distributed in both Canadian and Chinese ecological zones (Ramirez-Erosa et al., 2007). In this study, the plants collected in Canada were found to have similar properties to those reported for plants collected in China.

The best methods to exchange western scientific and Traditional Knowledge have yet to be established, although notable progress has been made. Guidelines to promote equitable knowledge exchange are proposed by Canadian Tri-Council research agencies and by public Canadian universities, including the University of Lethbridge, which is situated in the prairies and Treaty 7 ancestral lands. In addition to these guidelines, our laboratory has chosen to only investigate a Traditional Knowledge perspective of a plant if a member of a First Nations community performs experiments in the laboratory.

The majority of cancer drugs are derived from plant natural products

A study of drugs from 1981 to 2019 revealed the leading contribution of natural products for drug development (Newman et al., 2000). If biologics and vaccines are removed from the 247 agents approved for anticancer therapy, 75% of the agents are natural small molecules, derivatives of them, or synthetic products that were developed to mimic natural products. Even if the synthetic mimics of natural products are not counted, 41% of the approved anticancer small molecules are natural products or their derivatives. Examples from this list include the anticancer agents and their derivatives: camptothecin, isolated from the tree *Camptotheca acuminata* Decne (Nyssaceae) (Wall and Wani, 1996); the *Vinca* spp. alkaloids, vinblastine and vincristine, from the periwinkle *Catharanthus roseus* L. (Apocynaceae); paclitaxel, isolated from the bark of the Pacific Yew tree *Taxus brevifolia* Nutt. (Taxaceae) (Cragg, 1998). Plant natural products have had an enormous impact in the discovery of anti-cancer drugs, as paclitaxel and its derivatives, and by inspiring cell cycle targets for new anticancer drugs (Newman et al., 2000).

The majority of plants species have not been investigated for biomedical properties

Only a small percentage of plants have been investigated for their bioactive properties. It is estimated that there are 383,671 vascular plant species identified in the biosphere (Lughadha et al., 2016), of which 10,636 vascular plant species are restricted geographically to North America (USA and Canada) (Ulloa Ulloa et al., 2017). Miller (2011) estimates that between 540 to 23,490 new drugs remain to be found from all plants in the biosphere (Miller, 2011). This estimate considers that discovery of 135 natural drugs resulted from the only 2,000 plant species that were chemically described are from about 60,000 species that had been screened. An uncertainty on these estimates is whether all species have additive potential to synthesize new compounds or

whether they are somewhat chemically redundant. However, most plant screenings are conducted for one bioactivity and other uses are not investigated (Miller, 2011). Moreover, this estimation is only taking into account natural products approved for medicinal purposes.

There are arguments that suggest a sufficient number of plant species have been characterized to identify phytochemicals and further investigation is unlikely to discover new chemicals. There is a compelling example to suggest otherwise: the discovery of docetaxel, a natural product isolated from the English yew, *Taxus baccata* L. (Taxaceae) (Potier et al., 1994). Docetaxel is a member of the taxane class of natural products that has become one of most widely used anti-cancer treatments. Its discovery was inspired by the isolation of paclitaxel from the Pacific yew, *T. brevifolia*, whose distribution is limited to western Canada and the Northwestern United States (Goodman and Walsh, 2001, Potier, 2001). *T. baccata*, whose toxic properties have been known since antiquity, is restricted to the European continent and the perimeter of the Mediterranean Sea (Iszkuło et al., 2016). The two species are closely related yet distinct. Each produces taxanes that are also closely related but distinct and individually have improved the lives of millions of cancer patients (Figure 3). The two natural products bind to the same protein (tubulin) and inhibit cell proliferation (Schiff et al., 1979, Ringel and Horwitz, 1991) but they affect cancer cell lines differently (Verweij et al., 1994), have different pharmacokinetic profiles in patients (Kearns, 1997), and have different drug costs (Clegg et al., 2002). It is difficult to comprehend the magnitude of possibilities of natural products from plants, but as exemplified by paclitaxel and docetaxel, all natural products may need to be studied for their potential to affect human physiology or provide a benefit.

The biomedical properties of many of the vascular plants geographically restricted to North America and Alberta are not well studied. By contrasting examples, the species *Achillea*

millefolium, which is present in Alberta prairies and globally distributed, was the topic of 679 publications referenced in the National Center for Biotechnology Information (NCBI/PubMed) as of January 2021. Whereas the species, *Arnica fulgens* Pursh (Asteraceae, Foothills arnica), a member of the well known *Arnica* genus and is abundant but geographically restricted to prairies, is not described in any biomedical publications.

Sesquiterpene lactones

The Asteraceae family is known for the production of a class of secondary metabolites called sesquiterpene lactones (Seaman, 1982). Sesquiterpene lactones (SLs) are compounds with a 15-carbon backbone that includes a lactone group. Its biosynthesis starts from the union of three isoprene units, which are 5-carbon derivatives of the mevalonic acid, creating an acyclic farnesyl pyrophosphate (FPP), the simplest sesquiterpene structure.

Sesquiterpene lactones have been isolated from many plant families such as Apiaceae, Magnoliaceae, Acanthaceae, Solanaceae, Araceae, Euphorbiaceae, amongst others (Chadwick et al., 2013), but they can be found almost ubiquitously in the Asteraceae family. SLs are found predominantly in tissues attractive to herbivores, such as leaves, phyllaries, and achenes, and stored in glandular trichomes or laticifers to be secreted in the surface of these organs (Chadwick et al., 2013). A range of biological activities has been attributed to them, from allelopathy, insect feeding deterrent, antibiotic, antifungal, and antiparasitic, to allergenic, toxic, and antiproliferative effects in animal and human cells.

Sesquiterpene lactones have been shown to have cytotoxic effects in cancer cells (Picman, 1986, Ghantous et al., 2010) ; however, little research has been done regarding their mechanism of action leading to cell death. Our laboratory collected the information about previous research made with SLs reporting a cell cycle arrest and a compilation can be found in the review from

Bosco & Golsteyn (2017). Strikingly, all sesquiterpene lactones with described anti-mitotic activity to date were isolated from species from the Asteraceae family. We have identified and characterized seven species from the Asteraceae family that are predominant in the prairie ecosystem and have anti-mitotic activity (Bosco, 2017, Molina, 2018, Molina et al., 2021, Bosco et al., 2021). We believe that the anti-mitotic activity of SLs present in Asteraceae species is understudied and that more chemicals and plants need to be investigated. Table 1 provides a list of Asteraceae species for launching these studies. It is likely that this argument can be applied to other plant families and Canadian ecological zones for other biomedical activities, hinting at the vast potential of natural products that remain to be discovered.

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Contributors' statement:

LM: Investigation, Writing

HKA: Investigation, Writing

SMK: Conceptualization, Investigation, Writing

RMG: Conceptualization, Supervision, Funding acquisition, Writing

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Figure Legends

Figure 1. Botanical description of Asteraceae flower heads.

A. The key morphological features that characterize the flower heads of members of the Asteraceae taxonomical family are shown as a side view.

B. A side view of the flower from *Gaillardia aristata* Pursh (Blanket flower), which is a striking flower present in the prairie ecological zone that contains bioactive sesquiterpene lactones. Scale bar is shown.

C. A top view of the flower from *G. aristata*. Scale bar is shown.

Figure 2. The prairie ecosystem in Alberta, Canada.

This is an image of the prairie ecosystem in Alberta taken at 49°05 N and 112°28 W (approximately 100 km East of the Rocky Mountains and 15 km North of the Canadian-American border). The worn path around the boulder was made by grazing mammals and is a testimony to the herbivory that occurs in this region. The boulder is an erratic, deposited during the last ice age. It measures approximately 1.5 metres across. Although not visible, there are at least ten forb species that are present and blooming at time the photo was taken. Very few of these species have been investigated for the biomedical properties of their secondary metabolites.

Figure 3. The two best anti-cancer drugs are from two closely related plant species.

The chemical structures of paclitaxel (Taxol®, left) and docetaxel (Taxotere®, right) are shown. The arrows point to functional groups that differ between the two natural products. Paclitaxel was first isolated from the plant species *Taxus brevifolia* (Pacific yew), which is distributed throughout British Columbia and present in Waterton National Park, Alberta. Docetaxol was first isolated

from *Taxus baccata* (English yew) in France. The chemical structures are found in the National Center for Biotechnology Information website:
<https://pubchem.ncbi.nlm.nih.gov/compound/taxol> and
<https://pubchem.ncbi.nlm.nih.gov/compound/Docetaxel>.

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Table 1. Asteraceae family members in Canada according to the database of vascular plants (VASCAN). The status within the Prairie region is indicated in parenthesis as follows: native (N), introduced (I), ephemeral (EP), or excluded (EX).

Subfamily	Tribe	Genus	Species
Asteroideae	Anthemideae	<i>Achillea</i>	<i>A. alpina</i> L. (N), <i>A. borealis</i> L. (N).
		<i>Anthemis</i>	<i>A. arvensis</i> L. (1753) (I), <i>A. cotula</i> L. (I).
		<i>Arctanthemum</i>	<i>A. arcticum</i> (L.) Tzvelev (N).
		<i>Artemisia</i>	<i>A. abronatum</i> L. (I), <i>A. absinthium</i> L. (I), <i>A. biennis</i> Willd (I), <i>A. borealis</i> Pall (N), <i>A. campestris</i> L. (N), <i>A. cana</i> Pursh (N), <i>A. dracunculus</i> L. (N), <i>A. frigida</i> Willd. (N), <i>A. hyperborea</i> Rydberg (N), <i>A. longifolia</i> Nutt. (N), <i>A. ludoviciana</i> Nutt. (N), <i>A. michauxiana</i> Bess. (N), <i>A. norvegica</i> Fr. (N), <i>A. pontica</i> L. (N), <i>A. tilesii</i> Led. (N), <i>A. tridentata</i> Nutt. (N), <i>A. vulgaris</i> L. (I).
		<i>Cota</i>	<i>C. tinctoria</i> L. (I).
		<i>Leucanthemum</i>	<i>L. vulgare</i> Lam. (I).
		<i>Matricaria</i>	<i>M. chamomilla</i> L. (I), <i>M. discoidea</i> DC.(I).
		<i>Tanacetum</i>	<i>T. balsamita</i> L. (I), <i>T. bipinnatum</i> L. Sch. Bip. (N), <i>T. parthenium</i> L. Sch. Bip. (I), <i>T. vulgare</i> L. (I).
		<i>Tripleurospermum</i>	<i>T. inodorum</i> L. Sch. Bip. (I).
	Astereae	<i>Almutaster</i>	<i>A. pauciflorus</i> (Nutt.) A. Löve & D. Löve (N).
		<i>Aster</i>	<i>A. alpinus</i> L. (N).
		<i>Boltonia</i>	<i>B. asteroides</i> (L.) L'Hér. (N).
		<i>Canadanthus</i>	<i>C. modestus</i> (Lindl.) G.L. Nesom (N).
		<i>Dieteria</i>	<i>D. canescens</i> Nutt. (N).
		<i>Doellingeria</i>	<i>D. engelmannii</i> (D.C. Eaton) Semple, Brouillet & G.A. Allen (N), <i>D. umbellate</i> Nees (N).
		<i>Ericameria</i>	<i>E. nauseosa</i> Pall. ex Pursh G.L. Nesom (N).
		<i>Erigeron</i>	<i>E. acris</i> L. (N), <i>E. annuus</i> L. (N)), <i>E. aureus</i> Greene (N), <i>E. caespitosus</i> Nutt. (N), <i>E. canadensis</i> L. (I), <i>E. compositus</i> Pursh (N), <i>E. divergens</i> Torr. A. Gray (N), <i>E. elatus</i> Greene (N), <i>E. evermannii</i> Rydb. (EX), <i>E. flagellaris</i> A. Gray (N), <i>E. formosissimus</i> Greene (EX), <i>E. glabellus</i> Nutt. (N), <i>E. glacialis</i> (Nutt.) A. Nelson (N), <i>E. grandiflorus</i> Hook. (N), <i>E. humilis</i> Graham (N), <i>E. hyssopifolius</i> Michx. (N), <i>E. lackschewitzii</i> G.L. Nesom W.A. Weber (N), <i>E. lanatus</i> Hook. (N), <i>E. lonchophyllus</i> Hook. (N), <i>E. nivalis</i> Nutt. (N), <i>E. ochroleucus</i> Nutt. (N), <i>E. pallens</i> Cronquist (N), <i>E. peregrinus</i> Greene (N), <i>E. philadelphicus</i> L. (N), <i>E. pumilus</i> Nutt. (N), <i>E. radicans</i> Hook. (N), <i>E. speciosus</i> (Lindl.) DC. (N), <i>E. strigosus</i> Muhl. ex Willd (N), <i>E. trifidus</i> Hook. (N), <i>E. arthurii</i> B. Boivin (N).

		<i>Eucephalus</i>	<i>E. engelmannii</i> (D.C. Eaton) Greene (N).
		<i>Eurybia</i>	<i>E. conspicua</i> (Lindl.) G.L. Nesom. (N), <i>E. sibirica</i> (L.) G.L. Nesom. (N).
		<i>Euthamia</i>	<i>E. graminifolia</i> L. Nutt. (N).
		<i>Grindelia</i>	<i>G. hirsutula</i> Hook. Arn. (N), <i>G. paysonorum</i> H. St. John (EX Quebec), <i>G. squarrosa</i> (Pursh) Dunal (N).
		<i>Gutierrezia</i>	<i>G. sarothrae</i> Pursh Britt. Rusby (N).
		<i>Heterotheca</i>	<i>H. villosa</i> (Pursh) Shinnars (N).
		<i>Machaeranthera</i>	<i>M. tanacetifolia</i> (Kunth) Nees (N).
		<i>Pyrrocoma</i>	<i>P. lanceolata</i> (Hook.) Greene (N), <i>P. uniflora</i> (Hook.) Greene (N).
		<i>Solidago</i>	<i>S. altissima</i> L. (N), <i>S. bellidifolia</i> Greene (EX), <i>S. bernardii</i> B. Boivin (N), <i>S. bicolor</i> L. (EX), <i>S. canadensis</i> L. (N), <i>S. gigantea</i> Aiton (N), <i>S. glutinosa</i> Nutt. (N), <i>S. hispida</i> Muhl. ex Willd (N), <i>S. jejunifolia</i> E. S. Steele (N), <i>S. juncea</i> Aiton (N), <i>S. lepida</i> DC. (N), <i>S. lutescens</i> Lindley ex DC (N), <i>S. missouriensis</i> Nutt. (N), <i>S. mollis</i> Bartl. (N), <i>S. multiradiata</i> Aiton (N), <i>S. nemoralis</i> Aiton (N), <i>S. ptarmicoides</i> (Torr. & A. Gray) B. Boivin (N), <i>S. riddellii</i> Frank ex Riddell (N), <i>S. rigida</i> L. (N), <i>S. simplex</i> Kunth (EX), <i>S. uliginosa</i> Nutt. (N).
		<i>Stenotus</i>	<i>S. armerioides</i> Nutt. (N).
		<i>Symphyotrichum</i>	<i>S. ascendens</i> (Lindl.) G.L. Nesom (N), <i>S. boreale</i> (Torr. & A. Gray) Á. & D. Löve (N), <i>S. campestre</i> (Nutt.) G.L. Nesom (N), <i>S. chilense</i> (Nees) G.L. Nesom (EX), <i>S. ciliatum</i> (N), <i>S. ciliolatum</i> (Lindl.) Á. & D. Löve (N), <i>S. cordifolium</i> (L.) G.L. Nesom (N), <i>S. cusickii</i> (A.Gray) G.L. Nesom (N), <i>S. eatonii</i> (A. Gray) G.L. Nesom (N), <i>S. ericoides</i> (L.) G.L. Nesom (N), <i>S. falcatum</i> (Lindl.) G.L. Nesom (N), <i>S. firmum</i> (Nees) G.L. Nesom (N), <i>S. foliaceum</i> (Lindl. ex DC.) G.L. Nesom (N), <i>S. laeve</i> (L.) Á. & D. Löve (N), <i>S. lanceolatum</i> (Willd.) G.L. Nesom (N), <i>S. lateriflorum</i> (L.) Á. & D. Löve (N), <i>S. novae-angliae</i> (L.) G.L. Nesom (N), <i>S. novi-belgii</i> (L.) G.L. Nesom (EX), <i>S. praealtum</i> (Poir.) G.L. Nesom (EX), <i>S. puniceum</i> (L.) Á. & D. Löve (N), <i>S. robynsianum</i> (J. Rousseau) Brouillet & Labrecque (N), <i>S. sericeum</i> (Vent.) G.L. Nesom (N), <i>S. spathulatum</i> (Lindl.) G.L. Nesom (N), <i>S. subspicatum</i> (Nees) G.L. Nesom (N).
		<i>Tonestus</i>	<i>T. lyallii</i> (A. Gray) A. Nelson (N).
		<i>Townsendia</i>	<i>T. condensata</i> Parry ex A. Gray (N), <i>T. exscapa</i> (Richardson) Porter (N), <i>T. hookeri</i> Beaman (N), <i>T. parryi</i> DC. Eaton (N).
	Bahieae	<i>Hymenopappus</i>	<i>H. filifolius</i> Hook. (N).
		<i>Picradeniopsis</i>	<i>P. oppositifolia</i> (Nutt.) Rydb. (I).
	Calendulae	<i>Calendula</i>	<i>C. arvensis</i> (Vaill.) L. (EX).
	Chaenactideae	<i>Chaenactis</i>	<i>C. douglasii</i> (Hook.) Hook. & Arn. (N).

	Coreopsidaeae	<i>Bidens</i>	<i>B. amplissima</i> Greene (I), <i>B. beckii</i> Torr. ex Spreng. (N), <i>B. cernua</i> L. (N), <i>B. frondosa</i> L. (N), <i>B. tripartita</i> L. (N), <i>B. vulgata</i> Greene (N)
		<i>Coreopsis</i>	<i>C. tinctoria</i> Nutt. (N).
		<i>Thelesperma</i>	<i>T. subnudum</i> A. Gray (N).
	Eupatorieae	<i>Ageratina</i>	<i>A. altissima</i> (L.) R.M. King & H. Rob. (EX).
		<i>Brickellia</i>	<i>B. grandiflora</i> (Hook.) Nutt. (N).
		<i>Conoclinium</i>	<i>C. coelestinum</i> (L.) DC. (EP).
		<i>Eupatorium</i>	<i>E. perfoliatum</i> L. (N).
		<i>Eutrochium</i>	<i>E. maculatum</i> (L.) E.E. Lamont (N), <i>E. purpureum</i> (L.) E.E. Lamont (EX).
		<i>Liatris</i>	<i>L. aspera</i> Michx. (EX), <i>L. ligulistylis</i> (A. Nelson) K. Schum. (N), <i>L. punctata</i> Hook. (N).
	Gnaphalieae	<i>Anaphalis</i>	<i>A. margaritaceae</i> L. (N).
		<i>Antennaria</i>	<i>A. alpina</i> (L.) Gaertn. (N), <i>A. anaphaloides</i> Rydb. (N), <i>A. aromatica</i> Evert (N), <i>A. corymbosa</i> E. Nels. (N), <i>A. dimorpha</i> Nutt. (N), <i>A. friesiana</i> (Trautv.) Ekman (EX), <i>A. howellii</i> Greene (N), <i>A. lanata</i> (Hook.) Greene (N), <i>A. luzuloides</i> Torr. & Gray (N), <i>A. media</i> Greene (N), <i>A. microphylla</i> Rydb. (N), <i>A. monocephala</i> DC. (N), <i>A. neglecta</i> Greene (N), <i>A. parlinii</i> Fern. (N), <i>A. parvifolia</i> Nutt. (N), <i>A. plantaginifolia</i> (L.) Richards (EX), <i>A. pulchella</i> Greene (EX), <i>A. pulcherrima</i> (Hook.) Greene (N), <i>A. racemosa</i> Hook. (N), <i>A. rosea</i> Greene (N), <i>A. umbrinella</i> Rydb. (N).
		<i>Gamochaeta</i>	<i>G. purpurea</i> (L.) Cabrera (N).
		<i>Gnaphalium</i>	<i>G. palustre</i> Nutt. (N), <i>G. uliginosum</i> L. (I).
		<i>Logfia</i>	<i>L. arvensis</i> L. (I).
		<i>Pseudognaphalium</i>	<i>P. macounii</i> (Greene) Kartesz (N), <i>P. thermale</i> (E. E. Nelson) G. L. Nesom (N).
		<i>Psilocarphus</i>	<i>P. brevissimus</i> Nutt. (N), <i>P. elatior</i> Gray (EX).
	Helenieae	<i>Gaillardia</i>	<i>G. aristata</i> Pursh (N), <i>G. pulchella</i> Foug. (I).
		<i>Helenium</i>	<i>H. autumnale</i> L. (N).
		<i>Hymenoxys</i>	<i>H. richardsonii</i> (Hook.) Cockerell (N).
		<i>Tetraneuris</i>	<i>T. acaulis</i> (Pursh) Greene (N).
	Heliantheae	<i>Ambrosia</i>	<i>A. acanthicarpa</i> Hook. (N), <i>A. artemisifolia</i> Meyen & Walp. (N), <i>A. psilostachya</i> DC. (I), <i>A. trifida</i> L. (N).
		<i>Balsamorhiza</i>	<i>B. sagittata</i> (Pursch) Nutt. (N).
		<i>Cyclachaena</i>	<i>C. xanthiifolia</i> Nutt. (N).
		<i>Echinacea</i>	<i>E. angustifolia</i> DC. (N).
		<i>Galinsoga</i>	<i>G. parviflora</i> Cav. (I), <i>G. quadriradiata</i> Ruiz & Pav. (I).

		<i>Helianthus</i>	<i>H. annuus</i> L. (N), <i>H. giganteus</i> L. (EX), <i>H. laetiflorus</i> Pers. (EX), <i>H. maximiliani</i> Schrad. (N), <i>H. nuttallii</i> Torr & A. Gray (N), <i>H. pauciflorus</i> Nutt. (N), <i>H. petiolaris</i> Nutt. (N), <i>H. tuberosus</i> L. (N).
		<i>Heliopsis</i>	<i>H. helianthoides</i> L. Sweet (N).
		<i>Iva</i>	<i>I. axillaris</i> Pursh (N).
		<i>Ratibida</i>	<i>R. columnifera</i> (Nutt.) Wooton & Standl. (N).
		<i>Rudbeckia</i>	<i>R. laciniata</i> L. (N), <i>R. hirta</i> L. (N).
		<i>Xanthium</i>	<i>X. spinosum</i> L. (EP), <i>X. strumarium</i> L. (N).
	Inuleae	<i>Inula</i>	<i>I. helenium</i> L. (N).
	Madieae	<i>Arnica</i>	<i>A. angustifolia</i> Vahl (N), <i>A. chamissonis</i> Less. (N), <i>A. cordifolia</i> Hook. (N), <i>A. fulgens</i> Pursch (N), <i>A. gracilis</i> Rydb. (N), <i>A. lanceolata</i> Nutt. (N), <i>A. latifolia</i> Bong. (N), <i>A. lonchophylla</i> Greene (N), <i>A. longifolia</i> D.C. Eaton (N), <i>A. louiseana</i> L. 1753 not Boehm. 1760 (N), <i>A. mollis</i> Hook. (N), <i>A. ovata</i> Greene (N), <i>A. parryi</i> Gray (N), <i>A. rydbergii</i> Greene (N), <i>A. sororia</i> Greene (N).
		<i>Madia</i>	<i>M. glomerata</i> Hook. (I).
	Senecioneae	<i>Erechtites</i>	<i>E. hieraciifolius</i> (L.) Raf. ex DC. (EX).
		<i>Jacobaea</i>	<i>J. vulgaris</i> Gaert (I).
		<i>Packera</i>	<i>P. aurea</i> (L.) A. & D. Löve (N), <i>P. cana</i> (Hook.) W.A. Weber & A. Löve (N), <i>P. contermina</i> (Greenm.) Bain (N), <i>P. heterophylla</i> (Fishc.) Wieb. (N), <i>P. hyperborealis</i> (Greenm.) A. & D. Löve (EX), <i>P. indecora</i> (Greene) A. & D. Löve (N), <i>P. pauciflora</i> (Pursch) A. & D. Löve (N), <i>P. paupercula</i> (Michx.) A. & D. Löve (N), <i>P. plattensis</i> (Nutt.) W.A. Weber & A. Löve (N), <i>P. pseud aurea</i> (Rydb.) W.A. Weber & A. Löve (N), <i>P. streptanthifolia</i> (Greene) A. & D. Löve (N), <i>P. subnuda</i> (DC.) D.K. Trock & T.M. Barkely (N), <i>P. tridenticulata</i> (Rydb.) W.A. Weber & A. Löve (EX).
		<i>Petasites</i>	<i>P. frigidus</i> (L.) Fries (N).
		<i>Senecio</i>	<i>S. eremophilus</i> Rich. (N), <i>S. fremontii</i> Torr. & A. Gray (N), <i>S. hydrophiloides</i> Rydb. (N), <i>S. integerrimus</i> Nutt. (N), <i>S. lugens</i> Rich. (N), <i>S. megacephalus</i> Nutt. (N), <i>S. triangularis</i> Hook. (N), <i>S. viscosus</i> L. (I), <i>S. vulgaris</i> L. (I).
		<i>Tephrosieris</i>	<i>T. palustris</i> (R.Br.) DC. (N).
	Tageteae	<i>Dyssodia</i>	<i>D. papposa</i> Cav. (I).
Carduoideae	Cardueae	<i>Arctium</i>	<i>A. lappa</i> L. (I), <i>A. minus</i> (Hill) Bernh. 1800 not Schkuhr 1803 (I), <i>A. tomentosum</i> Mill. (I).
		<i>Carduus</i>	<i>C. nutans</i> L. (I).
		<i>Carthamus</i>	<i>C. tinctorius</i> L. (I).
		<i>Centaurea</i>	<i>C. cyanus</i> L. (I), <i>C. diffusa</i> Lam. (I), <i>C. solstitialis</i> L. (I), <i>C. stoebe</i> L. (I).

		<i>Cirsium</i>	<i>C. arvense</i> (L) Scop. (I), <i>C. discolor</i> (Muhl. ex Willd.) (N), <i>C. drummondii</i> Torr. & A. Gray (N), <i>C. flodmanii</i> (Rydb) Arthur (N), <i>C. foliosum</i> (Hook.) DC. (N), <i>C. hookerianum</i> Nutt. (N), <i>C. muticum</i> Michx. (N), <i>C. scariosum</i> Nutt. (N), <i>C. undulatum</i> (Nutt.) Spreng. (N), <i>C. vulgare</i> (Savi) Ten. (I).
		<i>Echinops</i>	<i>E. sphaerocephalus</i> L. (EP).
		<i>Onopordum</i>	<i>O. acanthium</i> L. (EX).
		<i>Rhaponticum</i>	<i>R. repens</i> L. Hidalgo. (I).
		<i>Saussurea</i>	<i>S. amara</i> L. (EX), <i>S. americana</i> D.C. Eaton. (N), <i>S. angustifolia</i> , Willd. DC (N). <i>S. nuda</i> Ledebour. Icon. (N).
		<i>Silybum</i>	<i>S. marianum</i> L. Gaertn. (I).
Cichorioideae	Cichorieae	<i>Agoseris</i>	<i>A. glauca</i> (Pursh) Raf. var. <i>agrestis</i> (Osterh.) (EX), <i>A. aurantiaca</i> (Hook.) Greene (N), <i>A. glauca</i> (Pursh) Raf. (N), <i>A. parviflora</i> (Nutt.) D. Dietr. (EX).
		<i>Askellia</i>	<i>A. elegans</i> (Hook.) W.A. Weber, 1984 (N), <i>A. pygmaea</i> W.A. Weber (N).
		<i>Cichorium</i>	<i>C. endivia</i> L. (EX), <i>C. intybus</i> L. (I).
		<i>Crepis</i>	<i>C. atribarba</i> A. Heller (N), <i>C. capillaris</i> (L.) Wallr. (I), <i>C. intermedia</i> A. Gray (N), <i>C. modocensis</i> E. Greene (EX), <i>C. occidentalis</i> Nutt. (N), <i>C. runcinata</i> (James) Torr. & A. Gray (N), <i>C. tectorum</i> L. (I).
		<i>Helminthotheca</i>	<i>H. echiioides</i> (L.) Holub (I).
		<i>Hieracium</i>	<i>H. albiflorum</i> (Hook.) F.W. Schultz & Sch. Bip. (N), <i>H. scouleri</i> F.W. Schultz & Sch. Bip. (N), <i>H. umbellatum</i> L. (N).
		<i>Krigia</i>	<i>K. biflora</i> (Walter) S.F.Blake 1915 (N).
		<i>Lactuca</i>	<i>L. canadensis</i> L. (EX), <i>L. floridana</i> (L.) Gaertn. 1791 (N), <i>L. ludoviciana</i> (Nutt.) Riddell 1835 (N), <i>L. sativa</i> L. (EX), <i>L. serriola</i> L. (I), <i>L. virosa</i> L. 1753 not Thunb. 1800 nor Luce nor Hablitz (EX).
		<i>Lapsana</i>	<i>L. communis</i> L. (I).
		<i>Lygodesmia</i>	<i>L. juncea</i> (Pursh) D. Don ex Hooker (N).
		<i>Microseris</i>	<i>M. nutans</i> (Hook.) Sch. Bip. (N).
		<i>Mulgedium</i>	<i>M. pulchellum</i> (Pursh) G. Don (N).
		<i>Nabalus</i>	<i>N. alatus</i> Hook. (1833) (N), <i>N. albus</i> (L.) Hook. (N), <i>N. racemosus</i> (Michx.) Hook (1833) (N), <i>N. sagittatus</i> (A. Gray) Rydb. (1900) (N).
		<i>Nothocalais</i>	<i>N. cuspidata</i> (Pursh) Greene (N).
		<i>Pilosella</i>	<i>P. aurantiaca</i> (L.) F.W. Schultz & Sch. Bip. (I), <i>P. caespitosa</i> (Dumort) P.D. Sell & C. West (I), <i>P. tristis</i> (Willd. ex Spreng.) F.W. Schultz & Sch. Bip. (N).
		<i>Shinnersoseris</i>	<i>S. rostrata</i> (A. Gray) Tomb (N).
		<i>Sonchus</i>	<i>S. arvensis</i> L. (I), <i>S. asper</i> (L.) Hill 1769 (I), <i>S. oleraceus</i> L. 1753 not Wall. 1831 (I).

		<i>Stephanomeria</i>	<i>S. runcinata</i> Nutt. (N), <i>S. tenuifolia</i> (Torrey) H.M. Hall (N).
		<i>Taraxacum</i>	<i>T. ceratophorum</i> (Ledeb.) Schinz ex Thellung (N), <i>T. erythrospermum</i> Andrz. ex Besser (I), <i>T. lapponicum</i> Kihlman ex Handel-Mazzetti (EX), <i>T. officinale</i> (L.) Weber ex F.H.Wigg. (I), <i>T. scopulorum</i> (A. Gray) Rydb. (N).
		<i>Tragopogon</i>	<i>T. dubius</i> Scopoli (I), <i>T. porrifolius</i> L. (I), <i>T. pratensis</i> L. (I).
	Vernonieae	<i>Vernonia</i>	<i>V. fasciculata</i> Michx. (N).
Mutisioideae	Mutisieae	<i>Adenocaulon</i>	<i>A. bicolor</i> Hook (N).

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Table 2. Asteraceae species present in the Prairie region which appear in Health Canada's NHPD monographs.

Species	Status	Traditional Uses	Active phytochemical(s)	Phytochemical Reference
<i>Arctium lappa</i> L.	Introduced	Diuretic and pain relief	Arctigenin and onopordopicrin	(Hyam et al., 2013, de Almeida et al., 2012)
<i>Artemisia vulgaris</i> L.	Introduced	Stimulates bile secretion and appetite, aids digestion	Apigenin	(Omar et al., 2019)
<i>Cichorium intybus</i> L.	Introduced	Prebiotic and digestive health aid	Chicoric acid	(Street et al., 2013)
<i>Echinacea angustifolia</i> DC.	Native	Relief of upper respiratory tract infections and sore throat	Echinacoside and cynarine	(Linde et al. 2006)
<i>Helianthus annuus</i> L.	Native	Cholesterol management	Oleic and linoleic acids, phytosterols	(Adeleke and Babalola, 2020)
<i>Helianthus tuberosus</i> L.	Native	Relieves digestive irregularity	Inulin	(Srinameb et al., 2015)
<i>Matricaria chamomilla</i> L.	Introduced	Relief of mouth/throat irritation and inflammation	Apigenin-7-glucoside and luteolin-7-O-B-D-glucoside	(Haghi et al., 2014)
<i>Silybum marianum</i> L. Gaertn.	Introduced	Hepatoprotectant and relief of indigestion	Silymarin	(Bijak, 2017)
<i>Tanacetum parthenium</i> L. Sch.-Bip	Introduced	Digestive aid and migraine relief	Parthenolide and other sesquiterpene lactones	(Pareek et al., 2011)

Figure 1

Figure 2

Figure 3