

# The biology of Canadian weeds. 118.

## *Artemisia vulgaris* L.

J. N. Barney<sup>1</sup> and A. DiTommaso<sup>2</sup>

<sup>1</sup>Department of Horticulture and <sup>2</sup>Department of Crop and Soil Sciences,  
Cornell University, Ithaca, NY, USA 14853 (e-mail: jnb22@cornell.edu).

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Barney, J. N. and DiTommaso, A. 2003. **The biology of Canadian weeds. 118. *Artemisia vulgaris* L.** Can. J. Plant Sci. **83**: 205–215. *Artemisia vulgaris* L. (mugwort) is an introduced rhizomatous perennial found primarily along roadsides, in waste areas, and in non-containerized nursery crops in eastern regions of Canada and the United States. *Artemisia vulgaris* is rapidly spreading throughout the Northern Hemisphere, and is currently found in nine Canadian provinces, as well as half of the states in the United States. Historically, *A. vulgaris* has been used as an herbal remedy and for flavouring beer, but recently has been identified as a primary pest of nurseries and urban landscapes, largely because of its ability to propagate easily from small rhizome fragments, and because of ineffective control strategies. The recent expansion of the nursery/landscape sector has accelerated the spread of *A. vulgaris* into turfgrass and landscape settings throughout the Northern Hemisphere, but especially westward towards the Pacific Coast. With few effective strategies for control, this aggressive weed has rapidly colonized new areas, often forming dense monospecific stands. Not surprisingly, species diversity of native flora in these habitats has declined following *A. vulgaris* colonization. The mechanisms of interference (e.g., allelopathy and competition) and current strategies for the control of *A. vulgaris* are discussed.

**Key words:** Mugwort, ARTVU, *Artemisia vulgaris*, Asteraceae, Compositae, weed biology

Barney, J. N. et DiTommaso, A. 2003. **Biologie des mauvaises herbes au Canada. 118. *Artemisia vulgaris* L.** Can. J. Plant Sci. **83**: 205–215. *Artemisia vulgaris* L. (armoise) est une vivace rhizomateuse non indigène qui affectionne le bord des routes, les terrains vagues et les pépinières de pleine terre dans l'est du Canada et des États-Unis. L'armoise étend rapidement son aire dans l'hémisphère nord et on la retrouve présentement dans neuf provinces canadiennes et la moitié des États américains. Au fil de l'histoire, l'armoise a été utilisée pour ses vertus médicinales et pour aromatiser la bière, mais ces derniers temps, on s'est rendu compte qu'elle figure parmi les principales adventices dans les pépinières et les aménagements paysagers urbains, surtout parce qu'elle se reproduit rapidement, à partir de fragments de rhizome et parce qu'il n'existe pas de méthode de lutte efficace. La récente expansion de l'industrie des pépinières et de l'aménagement paysager a accéléré la propagation de l'armoise dans les terrains gazonnés et aménagés de l'hémisphère nord, en particulier dans l'Ouest, à mesure qu'on se rapproche du Pacifique. En l'absence de moyens de lutte efficaces, cette adventice agressive colonise vite de nouveaux habitats, engendrant souvent des peuplements très denses d'une seule espèce. On sera donc peu surpris d'apprendre que la flore indigène perd de sa diversité à ces endroits, après colonisation par *A. vulgaris*. Les auteurs passent en revue les mécanismes d'interférence (par ex., allélopathie et concurrence) et les méthodes de lutte actuelles.

**Mots clés:** Armoise, ARTVU, *Artemisia vulgaris*, Astéracées, Composées, biologie des mauvaises herbes

### 1. Name

*Artemisia vulgaris* L.; **mugwort; armoise vulgaire** (Darbyshire et al. 2000); Chrysanthemum weed; felon herb (Uva et al. 1997); green ginger; motherwort; mugweed (Holm et al. 1997); St. John's Plant, herbe Saint Jean (Bouchard et al. 1999); Cingulum Sancti Johannis (Grieve 1972); Carline Thistle; Chiu Ts'ao common mugwort; Douglas mugwort; Sailor's tobacco (Miller 2000). Mugwort, the common name for *A. vulgaris* is thought to have several derivations including from the Greek physician Dioscorides, who believed the plant had the ability to ward off insects, *moughte* (for moth or maggot) with "wort" being an archaic term for a herbaceous plant (Miller 2000). Phillips and Foy (1990) refer to the Old English *mucgwyr*, from "midge" and "wort", which also suggest its use as an insect repellent. Gledhill (1990) indicates that plants within the genus *Artemisia* were named after Queen Artemisia of

Caria, Asia Minor, and the epithet *vulgaris* meaning usual, common, or vulgar. Compositae, Asteraceae, composite family, Composées, Astéracées.

### 2. Description and Account of Variation

(a) *Physical description* — North American specimens of *A. vulgaris* are rhizomatous perennial herbs exhibiting extreme variation in morphology. The **rhizomes** range from a few millimeters to > 1 cm in diameter, typically branching at the nodes, and reaching depths of 7–18 cm in the soil. The **stems** are erect, corrugated lengthwise (< 1 mm), simple or branched, tending to be green to brown towards the lower base, typically 0.25–1.5 cm, while the upper stems are purplish, with some stems hairy. The upper one-third of this 0.5–2.5 m herb is typically branched with densely packed composite **flower heads** found in spike-like clusters at the terminal 1/4 to 1/3 of stems, with the lower 1/3 of the

primary stem turning woody with age. The **flower heads** (2.5–3 mm wide) can be nearly sessile or peduncled, seriate or fascicled, and generally contain 15–30 florets. The complete disk **flowers** are strongly aromatic, greenish yellow in colour, and generally contain a double-branched style and many stamens (Fig. 1). Flowering typically occurs from July to October with sporadic seedling emergence taking place the following spring (Fig. 2). **Seeds** (actually one-seeded fruits known as cypselas) are ridged, brown, oblong with a narrow base (1–2 mm long), and have minute bristles at the apex. The **cotyledons** of *A. vulgaris* seedlings, although rarely seen, are egg-shaped and lack petioles (Fig. 2). *A. vulgaris* has dark green **leaves** 1–10 cm long and 3–7.5 cm wide, with the upper surface being slightly hairy and the lower surface covered with silvery-white woolly hairs (< 1 mm long). The leaves on the lower portion of the stem are coarsely segmented, with each segment further dissected. The middle to upper leaves are smaller, but are more coarsely toothed than primary leaves (Fig. 3). The above description is based on Gleason and Cronquist (1991), Alex (1992), Holm et al. (1997), Uva et al. (1997), and A. Ayeni, personal communication.

The most common ploidy of *A. vulgaris* in Canada and the United States is  $2n = 16$  (Radford et al. 1968; Gleason and Cronquist 1991). European genotypes are dibasic:  $n = 8$  and  $2n = 16$ , while specimens from the high Himalayas, which underwent a period of glaciation, have been found to be exclusively diploids of  $2n = 18$  (Koul 1964). At different elevations in this same region, Koul (1964) also found examples of tetraploid ( $2n = 36$ ) and hexaploid ( $2n = 54$ ) specimens.

Karyological work has been performed on diploid European biotypes of *A. vulgaris*. Oliva and Vallès (1994) found the basic number to be  $n = 8$  for all populations tested, which is the accepted chromosome number. However, biotypes from other regions of the world have been reported to have chromosome numbers of  $2n = 16, 18, 24, 36,$  and  $45$  (Oliva and Vallès 1997).

(b) *Distinguishing features* — Many weedy and ornamental species have similar mature foliage to that of *A. vulgaris*, including common ragweed (*Ambrosia artemisiifolia* L.) and cultivated chrysanthemums (*Chrysanthemum* spp.). However, the lower surface of leaves in both common ragweed and cultivated chrysanthemum lacks the silvery-white woolly hairs. *Artemisia vulgaris* is also commonly confused with other species of the genus *Artemisia*, including *A. absinthium* L., *A. annua* L., *A. ludoviciana* Nutt. and *A. tridentata* Nutt. *A. absinthium* (absinth) is a finer and more branched species, being silvery-silky throughout (Alex 1992). *Artemisia absinthium* is distinguished from *A. vulgaris* by having the silvery-silky hairs on both the upper and lower surfaces of the leaves (Alex 1992). *Artemisia annua* (annual wormwood) can be distinguished from *A. vulgaris* by its lack of underground rhizomes. *Artemisia ludoviciana* (white sage) is a rhizomatous perennial having white-tomentose hairs on both the upper and lower leaf surfaces, or becoming glabrous on the upper side of the leaves (Gleason and Cronquist 1991). Hence, *A. vulgaris* can be distinguished from *A. ludoviciana* by its white-woolly hairs

on the lower leaf surface and the presence of a dense underground rhizome system. *Artemisia tridentata* (big sagebrush) can be distinguished from *A. vulgaris* by its undivided, wedge-shaped leaves, each with three blunt lobes and by its lack of a rhizome system (Whitson et al. 1992). Plants of *A. vulgaris* also exhibit a high degree of within-plant variability in leaf size and shape that is generally lacking in similar species.

(c) *Intraspecific variation* — *Artemisia vulgaris* exhibits extreme morphological and physiological variability in different ecological regions, including North America (Holm et al. 1997). Hwang et al. (1985) reported that several varieties of *A. vulgaris* exist in elevated regions of the Western United States, including California, Montana and Colorado. Morphological variation has been reported in the Himalayan region with diploid individuals typically characterized as small herbs, tetraploid individuals described as having a shrubby base and herbaceous apex, and hexaploid individuals forming large shrubs (Koul 1964). Intraspecific variation in this species has been documented in mountainous glacial areas of the Northern Himalayas (i.e., 3700 m above sea level), parts of Siberia and the former Soviet Georgia, as well as in various cropping systems throughout these regions (Holm et al. 1997). This large morphological and genetic variability suggests that these populations should possibly be classified as different species. Comparative studies of *A. vulgaris* populations in North America have revealed variable: (1) branching habit (branched or non-branched), (2) degree of branching, (3) leaf morphology within an individual and within a population (see Fig. 3) and (4) diameter of rhizomes (hair-like to 1 cm) (Barney et al. 2002). Despite these important variations in the morphology of *A. vulgaris* populations in Québec, Ontario, New Brunswick and New York State, USA, all North American plants are described as small herbs.

(d) *Illustrations* — Figure 1 illustrates habit (A), enlarged leaves (B), panicle (C), flower head (D), flowers (E), and achenes (F). Figure 2 depicts *A. vulgaris* seedlings at (A) 20 d after sowing (DAS), and (B) 26 DAS. Figure 3 illustrates variation in leaf morphology within a single *A. vulgaris* individual. The Canadian and US distributions of *A. vulgaris* are shown in Fig. 4 and Fig. 5, respectively.

### 3. Economic Importance

(a) *Detrimental* — *A. vulgaris* is considered a troublesome weed in nursery and urban landscapes in Canada and the Eastern United States (Henderson and Weller 1985), with the most serious infestations occurring in nursery stock, waste areas, and turfgrass. The US nursery industry considers *A. vulgaris* one of its 10 most serious weeds (Henderson and Weller 1985; Holm et al. 1997). *A. vulgaris* is found in most field-grown ornamental crops; i.e., trees, shrubs, herbaceous ornamentals, but is rarely found in containerized ornamentals in the Southeastern United States (J.C. Neal, personal communication). However, *A. vulgaris* is sold as a containerized ornamental at a garden centre in Victoria, BC (Feb. 2002) for \$7 per plant (P.B. Cavers, personal commu-



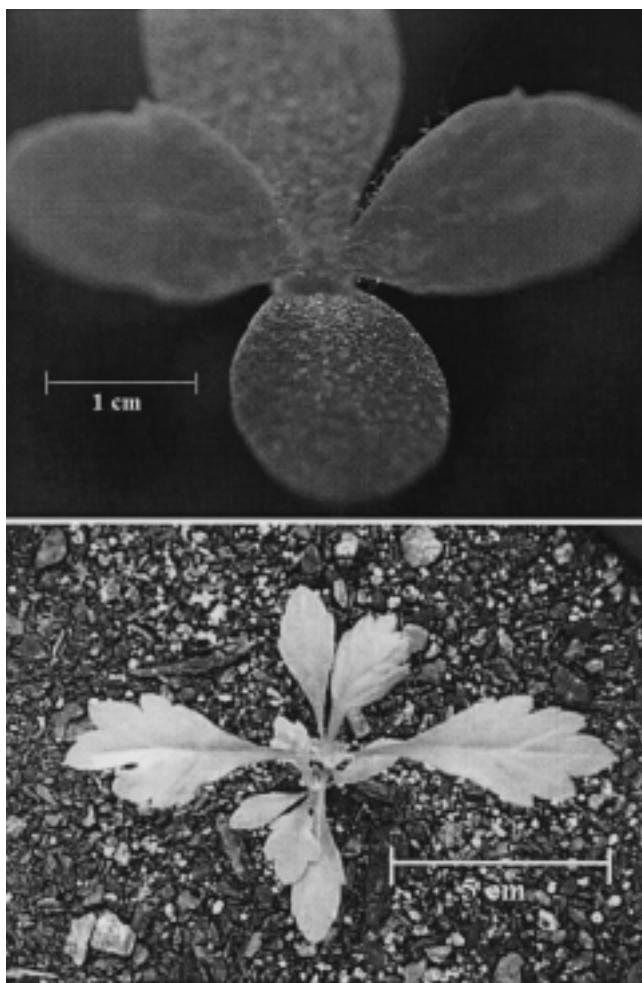
**Fig. 1.** *Artemisia vulgaris* habit (A), enlarged leaves (B), panicle (C), flower head (D), flowers (E), and cypselas (F). The two scales on the left are in centimeters and two scales on the right are in millimeters. (Illustrations reprinted by permission of John Wiley & Sons, from "World Weeds: Natural Histories and Distribution" by Holm et al. 1997.)

nication). The extensive rhizome system and ability to produce allelochemicals (Hale 1982; Inderjit and Foy 1999) make *A. vulgaris* an effective competitor in many plant production systems of Eastern North America, including, non-containerized nursery stock, turfgrass and vineyards. This species is also tolerant to most herbicides, while cultivation and mowing are not effective means of control (Bing 1983).

*Artemisia vulgaris* is commonly found along roadsides of North America (Baldwin 1958; Radford et al. 1968; Catling et al. 1978; Scoggan 1979; Gleason and Cronquist 1991; Holm et al. 1997; Zinck 1998). In Southwestern Québec, the

relatively tall stature and rapid growth of *A. vulgaris* compared with most other roadside species makes more frequent mowing necessary along these rights-of-way (A. DiTommaso, personal observation).

*Artemisia vulgaris* also infests barley and wheat crops in Korea; cereals and horticultural crops in Italy; citrus and maize in the former Soviet Union; tea and vegetables in Indonesia and Soviet Georgia; hazelnuts in Turkey; rangelands and pastures in Japan, Norway, and Sweden; tobacco in the Philippines; vineyards in France; and lucerne in Japan (Soedarsan et al. 1976; Holm et al. 1997).



**Fig. 2.** *Artemisia vulgaris* seedlings at (A) 20 d after sowing (DAS), and (B) 26 DAS.

(b) *Beneficial* — *Artemisia vulgaris* has a well-documented history of herbal uses, including the flavouring of beer before hops were used (Phillips and Foy 1990). The aromatic foliage of *A. vulgaris* is harvested in late spring and early summer. Its extracts are recommended to women for a wide variety of gynecological problems (Chevallier 1996; OnHealth.com 2000). The most common homeopathic use of *A. vulgaris* is for the treatment of irregular menstruation and relief of menopausal ailments (Phillips and Foy 1990; Lee et al. 1998). Different parts of *A. vulgaris* are also used for a multitude of other medicinal purposes including as antibacterial, anti-inflammatory, antiseptic, diaphoretic, emmenagogic, or stimulatory agents (Miller 2000).

The essential oil collected from foliage of *A. vulgaris* is a popular Chinese herbal medicine referred to as “Ai Hao,” which is generally prescribed for moxibustion, hemorrhages, and diarrhea (Misra and Singh 1986). The constituents of this essential oil have been investigated extensively in Asia, with the major compound being a monoterpene (Misra and Singh 1986; Dung et al. 1992). In contrast, the primary constituent of the essential oil from a Cuban biotype was identified as caryophyllene oxide, a

sesquiterpenoid (Pino et al. 1999). A phytotoxic growth inhibitor, collected from *A. vulgaris* foliage was found to reduce seed germination and aboveground growth in alfalfa (LeFevre 1964). Foliar extracts from *A. vulgaris* have also been used in the development of mosquito repellents (Hwang et al. 1985). Interestingly, in the late 1970s, before it was characterized as a problem weed, *A. vulgaris* was evaluated as a forage crop for wildlife in disturbed arid and semi-arid regions of the Midwestern United States because of its excellent tolerance and adaptability to different environmental conditions (Schuman and Howard 1978). *A. vulgaris* had 90% survival in this introduced habitat, as well as being favoured by antelope, deer, and rabbits.

(c) *Legislation* — To date, *A. vulgaris* is listed as a noxious weed only in the province of Manitoba (Anonymous 1996). It is not listed as a federal or state noxious weed in the United States.

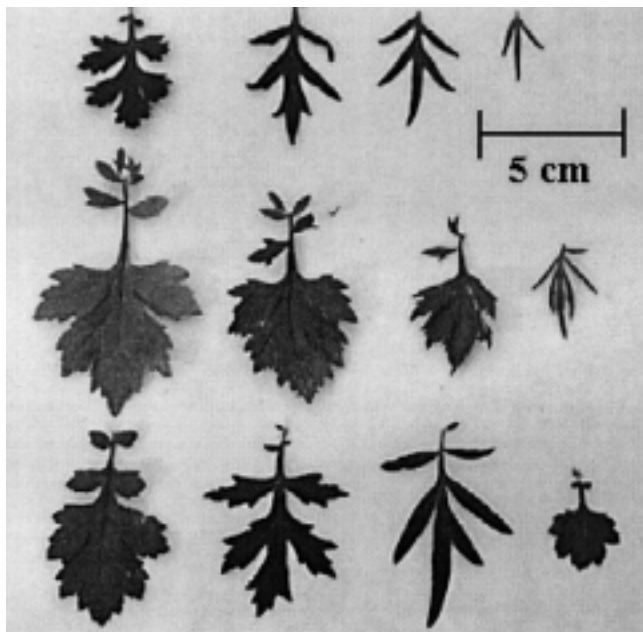
#### 4. Geographical Distribution

*Artemisia vulgaris* is most commonly found in eastern regions of Canada (Fig. 4) and the United States (Fig. 5) (Gleason and Cronquist 1991). The species is most abundant in Ontario and Québec, with populations also present in Newfoundland, Prince Edward Island, Nova Scotia, New Brunswick, Manitoba, Saskatchewan and British Columbia. Worldwide, this weed is currently considered troublesome in 25 crops in 56 countries (Holm et al. 1997). The most common infestations occur in Europe, where it is thought to have originated, but this weed is also found in Southeastern Asia, Australia, and South America (Holm et al. 1997). Populations in all regions exhibit a high degree of morphological variability.

#### 5. Habitat

(a) *Climatic requirements* — Globally, *A. vulgaris* is tolerant of a wide range of climatic conditions and is reported to occur from the high mountainous regions (3700 m) of the Northern Himalayas (Koul 1964) to the warm temperate regions of South America (Holm et al. 1997). The only two continents where *A. vulgaris* has not been documented are Africa and Antarctica. It has been reported that *A. vulgaris* is well adapted to a cool climate, as populations have rarely been found south of latitude 45° (Rousseau 1968). Rousseau (1968) also states that Canadian populations prefer well-drained, gravelly, or sandy soils. However, based on its North American distribution and information from specimen labels (Figs. 4 and 5), *A. vulgaris* has a wide temperature range, but prefers moist soils (J.N. Barney, personal observation). *Artemisia vulgaris* is commonly dispersed by floodwaters in North Carolina, USA, because a large part of nursery stock is based in flood plains that receive relatively frequent flooding (J.C. Neal, personal communication). The ability to survive in contrasting temperature and moisture environments, allows this weed to thrive equally well along cool dry roadsides in Québec and warm moist floodplains in the Southern United States.

(b) *Substratum* — Populations of *A. vulgaris* grow across a range of soil types and pH, from sandy loams, sandy clays



**Fig. 3.** Variation in leaf morphology within a single *A. vulgaris* individual. (Leaf maturity decreases from left to right.)

of pH 5.5–6.8, in both Québec (*A. DiTommaso*, unpublished data) and New Jersey, USA (*A. Ayeni*, personal communication) to sandy, loamy and clay soils of the Southeastern United States (*J.C. Neal*, personal communication). *Rousseau* (1968) states that this species is most common on well-drained gravelly or sandy soils in Québec. The growth of *A. vulgaris* was found to be poor in the presence of low concentrations of lime or magnesium, whereas pH was not found to affect biomass production (*Mathias and Winant* 1983).

(c) *Communities in which the species occurs* — In Canada and the United States, *A. vulgaris* primarily infests roadsides, waste areas, abandoned mines, and horticultural nursery fields (*Holm et al.* 1997; *Uva et al.* 1997). Specimen labels indicate that Canadian *A. vulgaris* populations frequently grow with *A. absinthium* L., *A. campestris* L., *Cirsium arvense* (L.) Scop., and *Solidago canadensis* L. The presence of this weed in field crops has been rare in the Northern Hemisphere, but appears to be increasing in North America, especially in no-till corn and soybean systems (*A. DiTommaso*, personal observation).

## 6. History

Conflicting information on the origin of *A. vulgaris* exists. Most report that *A. vulgaris* is native to Europe and Asia (*Rousseau* 1968; *Catling et al.* 1978; *Scoggan* 1979; *Hinds* 1986; *Gleason and Cronquist* 1991), and *Fogg* (1945) indicates that the herb is native to North America. However, most taxonomists believe this perennial was introduced to North America from Europe. Although there is no documented date of arrival, *Fernald* (1900) states that European explorers travelling along the St. Lawrence River in 1535

may have brought seeds from Europe, and subsequently deposited them along the riverbank. In 1821, it was recorded as common in Montreal (*Rousseau* 1968). However, *A. vulgaris* may have gained entry into the United States from Europe via rhizome fragments contaminating a nursery crop. Once in North America, *A. vulgaris* colonized abandoned areas, wastelands, and field-grown horticultural crops (*Henderson and Weller* 1985; *Holm et al.* 1997).

The earliest known documentation of *A. vulgaris* describes its use as a cushioning material in the sandals of Roman centurions (*Chevallier* 1996). Native Americans were believed to rub the leaves of *A. vulgaris* over their bodies as a means of warding off ghosts (*Miller* 2000). *Phillips and Foy* (1990) describe the wearing of *A. vulgaris* as a talisman against fatigue, disease, and evil spirits. In the Middle Ages, the common name of the species was *Cingulum Sancti Johannis* (*Grieve* 1972) because *A. vulgaris* plants were believed to have been worn by John the Baptist around his neck.

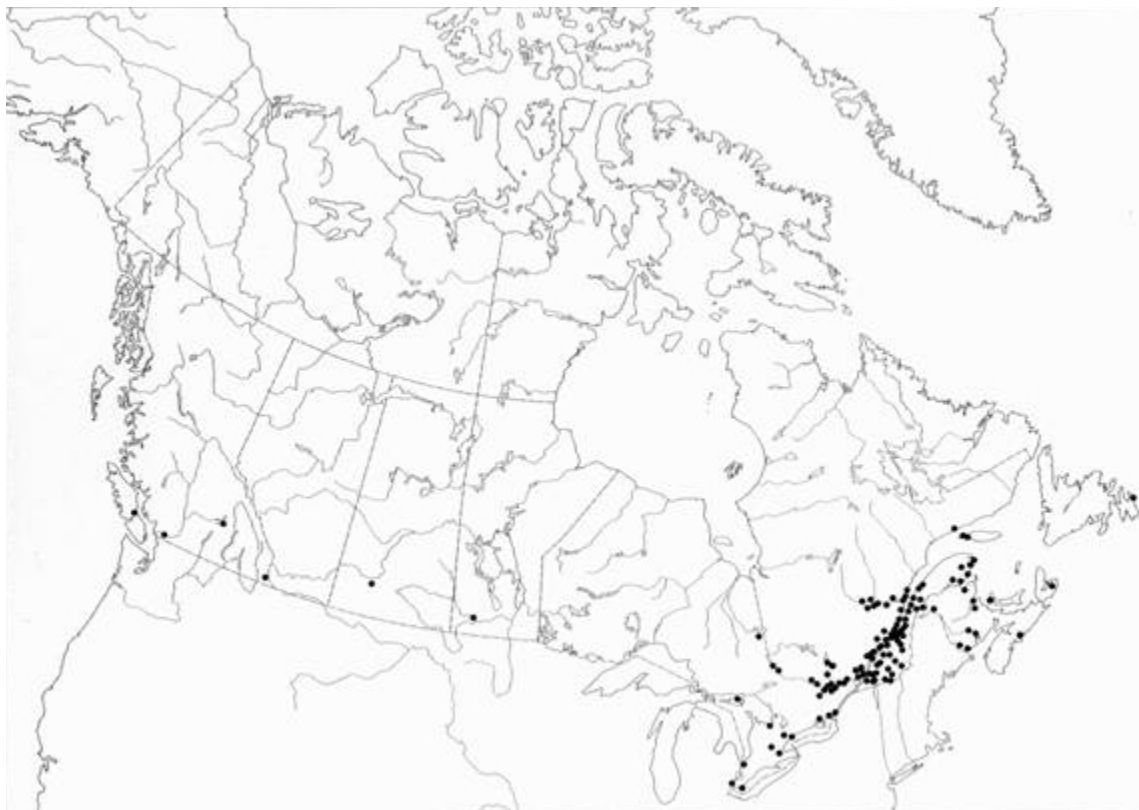
## 7. Growth and Development

(a) *Morphology* — Morphological variation in *A. vulgaris* is known to exist in nearly every location it is found. In some Eastern US populations, plants may be 2 m tall and unbranched, while in other populations, plants may be short and highly branched (*J.N. Barney*, unpublished data). Morphological variation in the underground rhizome system also exists, with plants in some populations having thick (~0.5–1 cm) rhizomes with minimal branching at the nodes, while plants in other populations have a dense fibrous (<0.5 cm diameter) rhizome system (*Barney et al.* 2002). *Koul* (1964) noted that *A. vulgaris* morphology differed with ploidy.

(b) *Perennation* — *Artemisia vulgaris* overwinters as a dense underground rhizome network, and possibly as seeds, which in spring gives rise to numerous leafy shoots. It is possible that seeds can survive the winter and germinate the following spring [Section 8(c)]. The density and vigour of shoots produced depends largely on the density and vigour of the underground rhizome system (*Greenock-Jones* 1986). Leaves and shoots turn a reddish-purple colour with the first frost, but all plant material dies back to ground level over winter in northern regions of its distribution (*J.N. Barney*, unpublished data).

(c) *Physiology* — *Bostock and Benton* (1979) compared the resource allocation strategy of *A. vulgaris* with four other perennials within the Asteraceae, namely *Achillea millefolium* L., *Cirsium arvense* (L.) Scop., *Taraxacum officinale* G.H. Weber ex Wiggers, and *Tussilago farfara* L. Of the five species, *A. vulgaris* allocated the fewest total resources to seed production and vegetative reproductive structures (i.e., rhizomes). In a 2-yr pot and field study, *A. vulgaris* allocated 2.3% of its total resources to seed-related organs and 8.9% of resources to vegetative reproductive structures.

*Artemisia vulgaris* is an excellent competitor for resources, with the production of secondary chemicals possibly playing an important role in the enhancement of its competitive ability (*Hale* 1982; *Inderjit and Foy* 1999).



**Fig. 4.** Distribution of *A. vulgaris* in Canada. Dots represent *A. vulgaris* locations from the following herbaria: ACAD, ALTA, CAN, DAO, LT, NFLD, UBC, UPEI.

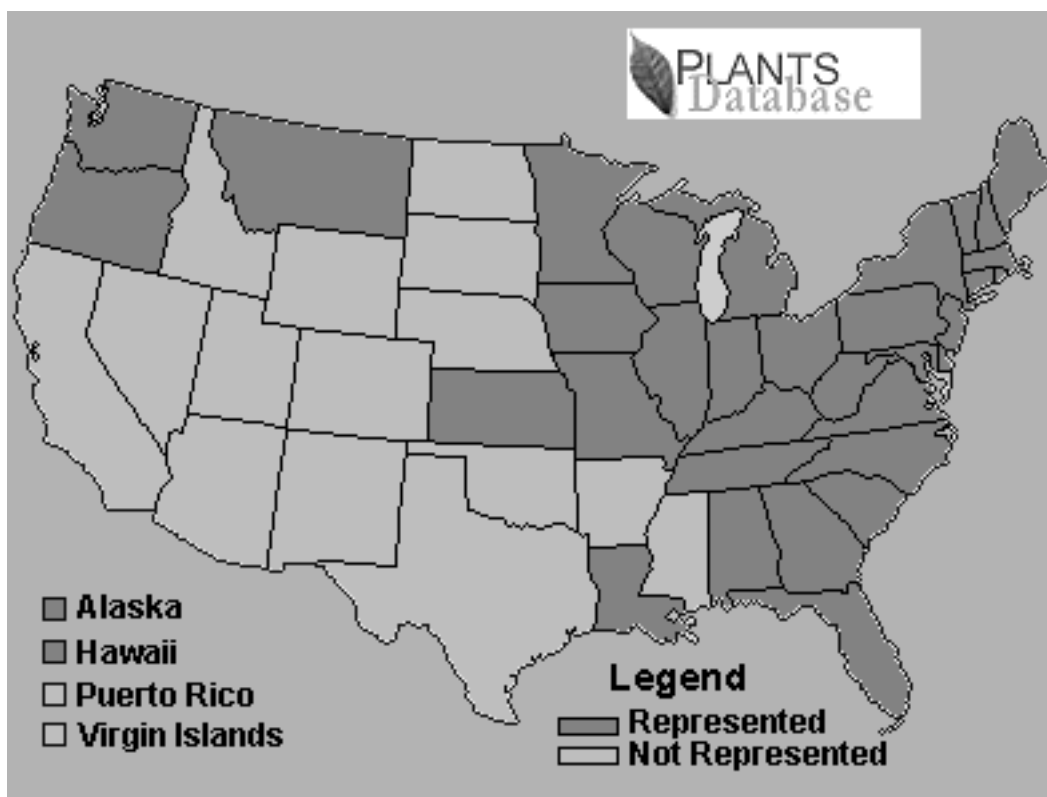
Allelochemical production is thought to occur in both leaf and rhizome tissue. Reductions in red clover (*Trifolium pratense* L. 'Kenland') growth and concurrent changes in soil chemistry have been demonstrated in *A. vulgaris*-amended soils (Inderjit and Foy 1999). Similarly, alfalfa (*Medicago sativa* L.) seed germination was reduced by 25% in soil containing *A. vulgaris* rhizome fragments (Hale 1982). However, in these soils, increased levels of the pathogenic fungus *Pythium myriotylum* Drechs. were also observed. Melkania et al. (1982) bioassayed *A. vulgaris* extracts collected from young developing leaves, old mature leaves, leaf and woody litter, and found the young leaf extracts to be the most inhibitory to Virginia pepperweed (*Lepidium virginicum* L.) and perennial ryegrass (*Lolium perenne* L.). The young leaf extracts of *A. vulgaris* reduced germination of Virginia pepperweed by 95% and perennial ryegrass by 65%.

Foliar extracts of fresh leaves of two *A. vulgaris* populations reduced radicle length in a test species, curly cress (*Lepidium sativum* L.), by 35 and 72% (Barney and Weston 2002). Interestingly, plants of the more inhibitory *A. vulgaris* population were found to be, on average, 5–25 cm shorter and have 30% fewer shoots than plants of the less inhibitory population. Similarly, solvent extraction of *A. vulgaris* dried leaf material ( $0.125 \text{ mg mL}^{-1}$ ) yielded solutions that reduced curly cress radicle length by 35–70%. At  $1.0 \text{ mg mL}^{-1}$ , complete inhibition of cress germination occurred.

The rhizome system in *A. vulgaris* is also a possible source of bioactive secondary metabolites. Agar media prepared with 20% rhizome extracts from each of three morphologically distinct *A. vulgaris* populations reduced curly cress radicle length from 40 to 73% (J.N. Barney, unpublished data). At a 1:1 rhizome extract to water ratio, curly cress germination was completely inhibited. Therefore, the ability of *A. vulgaris* rhizomes to produce allelopathic compounds may provide a competitive advantage to this weed and enhance its invasive potential.

(d) *Phenology* — In North America, *A. vulgaris* vegetative growth occurs from early spring to late autumn with maximum growth taking place in the summer months. Seedlings, or new vegetative shoots, emerge throughout the growing season, but are first observed in early May (J.N. Barney, unpublished data). In the United States, flower heads mature during the late summer months into early autumn (August to October) (Radford et al. 1968; Wofford 1989). The required photoperiod for flower induction was found to be 4–16 h for 4 wk (Henderson and Weller 1985). Woody, brown, necrotic stems last well into the winter months, but flower heads last only a brief time under winter conditions (Uva et al. 1997).

Rogerson and Bingham (1964) characterized the growth habit of *A. vulgaris* over a single growing season and found that rhizome production was initiated 4 wk after rhizome-derived plants 10 cm in height had been transplanted in the



**Fig. 5.** Distribution of *A. vulgaris* in the United States (Map reprinted with permission by USDA, NRCS, National Plant Data Center; © PLANTS.)

field. At 7 wk, plants were 25 cm tall, but remained unbranched, although they had produced, on average, 12 rhizomes reaching soil depths of 10 cm. Rhizomes branched by 9 wk, at which point they also developed secondary ramets. The first flowers were observed at 4 mo. After 24 wk of growth in the field, the aboveground and rhizome fresh weight of single plants were estimated to be 3535 and 5275 kg ha<sup>-1</sup>, respectively, while the total rhizome length was estimated to be nearly 114 km ha<sup>-1</sup>.

(e) *Mycorrhiza* — Information on the presence or absence of mycorrhiza is lacking.

## 8. Reproduction

(a) *Floral biology* — In the Eastern United States, *A. vulgaris* composite flowers were found to be composed of 52% ray flowers and 48% disc flowers, with each of the flower types capable of producing viable seeds (Henderson and Weller 1985).

Garnock-Jones (1986) reported little variation in the specialization of *A. vulgaris* florets for pollen receipt or donation, with 25–50% of the florets in capitula being female. However, some of the florets are highly specialized for pollen reception (female florets) or for pollen donation (hermaphrodite florets).

Garnock-Jones (1986) reports that *A. vulgaris*, which is gynomonocious, is wind-pollinated. However, Garnock-

Jones (1986) also reports *A. vulgaris* flowers being visited by syrphid flies and beetles, suggesting entomophilous pollination. Similarly, the closely related species *A. dracunculus* L., a primarily wind pollinated herb, was reported visited by the syrphid fly, *Melanostoma mellina* (Syrphidae) (Müller 1883).

(b) *Seed production and dispersal* — The number of seeds produced per plant in *A. vulgaris* varies greatly over its habitat range (Holm et al. 1997). There is little published data available on *A. vulgaris* seed production and dispersal as most research has focused on vegetative reproduction. However, *A. vulgaris* has been reported to produce up to 200 000 seeds per plant depending on the growing environment (Pawlowski et al. 1967). Plants within several European *A. vulgaris* populations produced as many as 10 000 capitula per stem, and 450 000 capitula in total (Garnock-Jones 1986). In contrast, some biotypes have been found to produce no viable seeds (Holm et al. 1997). Researchers in Eastern Canada and the United States have observed that seed production in *A. vulgaris* populations does not appear to be a major factor in the spread of this species (J.N. Barney, A. DiTommaso, J.C. Neal, L.A. Weston, personal observations). Seed dispersal in *A. vulgaris* is largely by wind because of its relatively small (~1 mm diameter) light seeds (Garnock-Jones 1986). The mean weight per seed for two *A. vulgaris* populations in the Northeastern United States and Europe were 0.12 and 0.14 mg (J.N. Barney, unpublished data). Holm et al.

(1997) reported the mean weight of 1000 *A. vulgaris* seeds to be 100 mg.

In the Southern United States, *A. vulgaris* is commonly spread by flood waters since most field-grown ornamental trees, where *A. vulgaris* is a dominant weed, are established on flood plains (J.C. Neal, personal communication). Cultivation of *A. vulgaris* infested fields where ornamentals are grown is also a major source of dispersal for this perennial herb. Rhizomes are often fragmented by cultivation equipment, and are then wrapped alongside balled and burlapped ornamentals. These ornamentals are subsequently transplanted into residential settings where *A. vulgaris* can spread further (J.C. Neal and L.A. Weston, personal communication).

(c) *Seed banks, seed viability and germination* — Seed viability in *A. vulgaris* varies widely depending on seed germination environment. Henderson and Weller (1985) reported a seed viability of 25% in an Indiana, USA, population, whereas seed viabilities in other studies have ranged from 0 to 95% (Holm et al. 1997). Dorph-Peterson (1925) found 95% viability of *A. vulgaris* seeds in Denmark, most of which germinated the spring following collection. Possible reasons for these divergent findings in the viability of seeds tested have not been proposed.

Crescini and Spreafico (1953) and Crescini et al. (1956) found that exposing seeds (cypselas) to low intensity light for a short period was sufficient to stimulate germination, but aged seeds became less light dependent and could be germinated under dark conditions. A moist stratification period of 1 wk at 4.5°C was shown to stimulate germination of mature *A. vulgaris* seeds collected the previous season from central US populations (Henderson and Weller 1985). Crescini and Spreafico (1953) and Crescini et al. (1956) reported that freshly harvested *A. vulgaris* seeds attained maximum germination levels when seeds were stored 10–40 d at 1°C. Lauer (1953) found the optimal and minimum temperatures for germination of *A. vulgaris* seeds to be 25°C and 7°C, respectively, with alternating temperatures not affecting germination.

Seeds of *A. vulgaris* recovered from 200-yr-old undisturbed soils were viable and able to germinate (Odum 1965). There is currently no specific information on the presence of transient or persistent seed banks in *A. vulgaris*. However, the findings of Odum (1965) suggest that *A. vulgaris* populations have the potential to develop persistent seed banks.

(d) *Vegetative reproduction* — Whether *A. vulgaris* spreads primarily by rhizomes or from seeds is unclear and appears to be largely dependent on the specific geographic region where populations are located. However, given that few seedlings have ever been observed under field conditions (Uva et al. 1997), it is likely that reproduction in this species occurs principally via rhizomes. Rhizome initiation begins as seedlings approach 4 wk of age, while at 9 wk, lateral branches and secondary shoots are produced (Rogerson and Bingham 1964). Guncan (1982) reported that 75% of rhizome buds produced shoots but no roots in a Black Sea coastal *A. vulgaris* population. Rogerson (1964) found that a

10-cm rhizome fragment had increased to 23 m in length in 4 mo. In undisturbed habitats, *A. vulgaris* allocated more resources to the production of rhizomes when shoots were removed than when plants were left intact (Holm et al. 1997).

Under controlled environmental conditions at a constant temperature of 16°C, *A. vulgaris* can be easily propagated in perlite from 5 to 15 cm rhizome segments collected in winter (Pridham 1963a, b). During one growing season, Henderson and Weller (1985) reported that a rhizome fragment 15 cm in length increased its aboveground dry biomass from 29 to 1490 g, a 50-fold increase.

## 9. Hybrids

No reports exist of hybrids between *A. vulgaris* and other species.

## 10. Population Dynamics

*Artemisia vulgaris* is generally introduced into an area by rhizome fragments. Eventually, these plants give rise to dense monospecific stands that are difficult to manage. *Artemisia vulgaris* biotypes exhibit extreme physical and chemical diversity depending on their growth environment. The ability of *A. vulgaris* to withstand herbicide applications and other human manipulations has allowed this species to thrive in most habitats (Bing 1983). However, there is no information regarding the longevity of *A. vulgaris* plants within a given habitat.

The ability of *A. vulgaris* to produce allelochemicals may contribute to its invasiveness in a variety of habitats. Numerous chemical compounds have been identified from essential oils extracted from the tissue of this plant (LeFevre 1964; Misra and Singh 1986; Dung et al. 1992; Milhau et al. 1997; Pino et al. 1999), but none of the compounds has been evaluated for its allelopathic potential to date.

There are no published reports of auto-inhibition in *A. vulgaris* populations.

## 11. Response to Herbicides and Other Chemicals

Few herbicides provide effective control of *A. vulgaris*, with plants often capable of re-growth. Henderson and Weller (1985) found that efficacy of control using herbicides varied by location, time of application, and plant vigour. Post-emergent applications of glyphosate (2.24 kg a.i. ha<sup>-1</sup>) provided significantly better control than 2,4-D (1.12 kg a.i. ha<sup>-1</sup>) in the Midwestern US, while pre-emergent applications of DPX-F 6025 (46.7 g a.i. ha<sup>-1</sup>) provided better control than dichlobenil (6.72 kg a.i. ha<sup>-1</sup>) and diuron (3.58 kg a.i. ha<sup>-1</sup>) (Henderson and Weller 1985). However, re-growth of *A. vulgaris* plants was observed in all treatment plots later in the season. Repeated applications of 2,4-D + 2,4-DP and three-way combination mixtures of 2,4-D, MCPP, and dicamba resulted in substantial growth reductions (Bing 1983). Repeated spot-treatments with glyphosate provided effective short-term control of *A. vulgaris* in nursery stock (Bing 1983). Foy (2001) found that picloram (0.14 kg ha<sup>-1</sup>) and clopyralid (0.14 kg ha<sup>-1</sup>) provided complete control of *A. vulgaris* 7 wk after treatment, with no re-growth at 21 wk after treatment. Foy (2001) also showed that dicamba (1.12 kg ha<sup>-1</sup>), glyphosate



(1.12 kg ha<sup>-1</sup>) and triclopyr (4.48 kg ha<sup>-1</sup>) were moderately effective in controlling *A. vulgaris* under greenhouse conditions, but re-growth occurred after all herbicide treatments and was determined to be rate-dependent. There is no evidence to suggest that herbicide application stimulates rhizome growth.

No data are available on the efficacy of *A. vulgaris* control using herbicides in Canada.

## 12. Response to Other Human Manipulations

Bing (1983) found that repeated mowing did not control *A. vulgaris*, although the removal of aboveground plant tissue by animals, machinery or hoeing was reported to stimulate rhizome production (Holm et al. 1997). Holm et al. (1997) indicated that *A. vulgaris* might be effectively managed in fields under continuous cultivation.

In 2001, a 3-yr field study was initiated in Central New York, examining the growth habit and reproductive ability of two local *A. vulgaris* populations in a turfgrass and cultivated field setting. Each of the populations was subjected to either a monthly mowing or was not mowed. Mowing had a significant effect on the number of shoots produced in both the cultivated and the turfgrass plots, while population source had a significant effect on the number of shoots produced in the cultivated plots only (Barney et al. 2002). Mowing increased shoot number from 60 to 100% in the cultivated field, and 20–30% in the turfgrass habitat. In the cultivated field, the number of shoots produced differed by about 30% between the two *A. vulgaris* populations.

On the northeastern seaboard of the United States, *A. vulgaris* does not typically infest heavily shaded sites and is much more problematic in areas of infrequent cultivation (A. Ayeni, personal communication). Frequent cultivation fragments the shallow rhizomes, exposing them to desiccating conditions on the soil surface.

Mathias and Winant (1983) examined the effect of fertilization on the growth of *A. vulgaris* within the scope of a project evaluating the suitability of this species as a forage crop in West Virginia, USA. *Artemisia vulgaris* growth was poor in the absence of lime and magnesium, but the growth response to added magnesium was greatest in the absence of lime.

## 13. Responses to Herbivory, Disease and Higher Plant Parasites

### Herbivory

(a) *Mammals* — There is no information on mammalian herbivory of *A. vulgaris* populations. However, Schuman and Howard (1978) examined the possibility using *A. vulgaris* to reclaim disturbed lands, and found that *A. vulgaris* tissue contains nearly 31% protein, which would make it a nutritionally acceptable species for grazers.

(b) *Birds* — There is no information on the consumption of *A. vulgaris* by birds.

(c) *Insects* — Biological control of *A. vulgaris* has shown some promise, although there are currently no biological control programs targeting this weed in Canada. Schmitz

(1999) found 26 strictly monophagous insect species feeding on *A. vulgaris* plants in Central Europe, with nine of these species showing strong suppressive effects. However, due to the strong regenerative ability of this species from underground rhizomes, the biological control of *A. vulgaris* using insects alone may be inadequate.

A survey of *A. vulgaris* roadside populations in Germany revealed 65 species of insects, mites, and spiders residing on this weed (Denys and Schmidt 1998). Among the most abundant species were *Liriomyza* spp., *Bucculatrix noltei*, *Macrosiphoniella artemisiae*, *Trypeta zoe*, and *Macrosiphoniella oblonga*. From surveys in Central Europe, 181 species of arthropods were reported to feed naturally on *A. vulgaris*, 26 of which were exclusively monophagous. The most promising species for use as biological control agents included:

1. *Epiblema foenella* (Tortricidae), which feeds on the medulla of rootstocks. Larvae cause the most damage, although the degree of injury is not known (Schmitz 1999).
2. *Dichrorampha simpliciana*, a rootstock feeder, is considered one of the most promising biological control agents for *A. vulgaris* in the United States (Schmitz 1999).
3. *Oxya parietina*, an arthropod sap feeder found on inflorescence branches of *A. vulgaris* (Groppe 1990; Schmitz 1999).
4. *Bucculatrix noltei* larvae, which cause coleophoroid blotchmines on *A. vulgaris* leaf tissue, may also be a potential biological control agent (Schmitz 1999).
5. *Ametrodiplosis rudimentalis*, *Contrarinia artemisiae*, *Rhopalomyia florum*, *R. magnusi*, and *Blastodiplosis artemisiae* are all host-specific flower bud feeders of *A. vulgaris* (Schmitz 1999).

(d) *Other non-vertebrates* — *A. vulgaris* and other weedy *Artemisia* spp., are plant hosts for *Meloidogyne* nematode species (Bendixen 1988).

### Diseases

(a) *Fungi* — Seventy-nine fungal species have been identified on *A. vulgaris*, ranging from *Allophylaria soederholmii* to *Sphaerotheca fusca* (Anonymous 2001). In British Columbia, *Mycosphaerella tassiana* (de Not) Johans and *Pleospora penicillus* (Schm.) Fckl. has been recorded from *A. vulgaris* (Connors 1967). No information exists on the damage caused by these fungi on *A. vulgaris*.

(b) *Bacteria* — No information is available on bacteria found on *A. vulgaris*.

(c) *Viruses* — No information is available on viruses found on *A. vulgaris*.

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