

# The biology of Canadian weeds. 117. *Taraxacum officinale* G. H. Weber ex Wiggers

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Stewart-Wade, S. M., Neumann, S., Collins, L. L. and Boland, G. J. 2002. **The biology of Canadian weeds. 117. *Taraxacum officinale* G. H. Weber ex Wiggers.** Can. J. Plant Sci. **82**: 825–853. *Taraxacum officinale* G. H. Weber ex Wiggers (dandelion, pissenlit officinal) is a perennial weed occurring in parks, gardens, pastures, orchards, roadsides, vegetable gardens, agricultural crops and horticultural crops. A common weed worldwide, it was originally introduced from Eurasia and now occurs in every province of Canada. It is an aesthetic problem during flowering and seed production, interrupting turfgrass uniformity and density; it reduces yields of agricultural crops; it causes slower drying of hay; its pollen is allergenic; and it acts as an alternative host for several pests and diseases. A number of herbicides are available for its control. Mechanical removal of *T. officinale* plants has limited success, due to the regenerative capacity of the long taproot. Insects, fungi, sheep and geese have been considered as biological control agents for dandelion.

**Key words:** *Taraxacum officinale*, dandelion, weed biology, Canada.

Stewart-Wade, S. M., Neumann, S., Collins, L. L. et Boland, G. J. 2002. **Biologie des mauvaises herbes au Canada. 117. *Taraxacum officinale* G. H. Weber ex Wiggers.** Can. J. Plant Sci. **82**: 825–853. *Taraxacum officinale* G. H. Weber ex Wiggers (pissenlit officinal, dandelion) est une adventice vivace qui peuple les parcs, les jardins, les champs, les vergers, le bord des routes, les potagers, les grandes cultures et les cultures horticoles. Cette mauvaise herbe, qu'on retrouve partout sur la planète, nous vient d'Eurasie et a désormais colonisé toutes les provinces du Canada. Elle pose un problème d'esthétisme lors de la floraison et de la production des graines, jetant une note de discordance dans le vert des pelouses et diminuant la densité des peuplements. Cette adventice réduit le rendement des cultures et ralentit le fanaage du foin. Son pollen est allergène et la plante sert d'hôte de rechange à plusieurs ravageurs et maladies. Il existe divers herbicides pour la combattre. L'extraction des plants de *T. officinale* à la machine n'a qu'une efficacité restreinte à cause de la capacité de régénération de la longue racine pivotante. Les insectes, les champignons, les ovins et les oies figurent parmi les agents de lutte biologique contre le pissenlit.

**Mots clés:** *Taraxacum officinale*, pissenlit officinal, biologie des mauvaises herbes, Canada

## 1. Names

*Taraxacum officinale* G. H. Weber ex Wiggers — **dandelion; pissenlit officinal** (Darbyshire et al. 2000), dandelion officinal, dent-de-lion, dent-de-lion commun, florion d'or, pissenlit dent-de-lion, pissenlit (Ferron and Cayouette 1975); blowball, faceclock, dumble-dor (in Newfoundland), lion's tooth, yellow gown, priest's crown, pee-a-bed, wet-a-bed (Jackson 1982). Asteraceae, composite (daisy) family, tribe Cichoriae.

The first scientific classification of *T. officinale* was by Linnaeus in 1753 as *Leontodon taraxacum* (Jaeger 1955). Wiggers (1746–1811) described the genus *Taraxacum*, and Georg Heinrich Weber created the current classification in

1780 (Britton and Brown 1970). The origin of the name *Taraxacum* is uncertain but Holm et al. (1997), Jenniskens (1984) and Mitich (1989) have reviewed possible sources. *Taraxacum* is thought to originate from the Arabic name for the dandelion “tarachakum” (meaning wild cherry), “tarakhshaqun” (meaning wild chicory), “tharachschaquh”, “talkh chakok” or “tarashqun” meaning “bitter herb” (Dwyer 1977; Jenniskens 1984; Mitich 1989). In another explanation, the name was derived from the Greek words “taraxis”, an eye disease, “tarassen” or “tarasos” meaning disorder, “trogimon” meaning edible and “akeomai” or “akos” meaning to cure or remedy (Powell 1972; Jenniskens 1984; Mitich 1989). *Officinale* means medicinal or capable of producing medicine (Schmidt 1979), or “of the shops”, meaning it was sold as a remedy for man's illnesses (Dwyer 1977; Holm et al. 1997).

The common name for dandelion is an alteration of “dent de lion”, a phrase thought to be based on the Welsh “Dant y Llew” of the thirteenth century (Hedrick 1972), meaning “tooth of the lion”. This name may have evolved because of the shape of the immature seeds (Lovell and Rowan 1991),

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the jagged shape of the leaves (Jackson 1982), the appearance of the yellow florets of the inflorescence (Angier 1980), or the strong white taproot (pulling it from a lawn is like trying to extract a lion's tooth) (Dwyer 1977). The French name, pissenlit, is attributed to the diuretic activity of the plant parts (Lovell and Rowan 1991).

## 2. Description and Account of Variation

(a) *Description.* *Taraxacum officinale* is an almost stemless, lactiferous, perennial herb. The stems are acaulescent, only 1–2.5 cm in length, with extremely short internodes at or below the soil surface (Gier and Burress 1942; Holm et al. 1997). The leaves form a basal, radial rosette in which every sixth leaf overlaps (Holm et al. 1997). The leaves are highly variable in shape, ranging from lobeless to toothed edges to highly incised and, when lobed, the lobes point to the leaf base. The runcinate-pinnatifid or lobed oblanceolate leaves have glabrous to sparsely pubescent lower surfaces, are generally 5–40 cm in length and 0.7–15 cm in width, and taper to a winged, petiolar base (Gleason 1963; Holm et al. 1997). The prominent midrib of the leaves ranges in colour from pale yellow-green to deep red-brown (L. L. Collins, unpublished data, University of Western Ontario, London, ON). The thick, branched taproot can be up to 2–3 cm in diameter and grow up to 1–2 m in length (von Hofsten 1954; Solbrig 1971). The lateral roots are arranged in two rows that wind clockwise downward in a loose spiral around the root and are distributed more or less regularly along its length (Gier and Burress 1942).

The basal rosette gives rise to one to numerous glabrous, hollow, cylindrical scapes (peduncles), 5–50 cm tall, decreasing in diameter along their length from base to tip. Each scape bears a terminal capitulum (inflorescence) of 2–5 cm diameter (Gier and Burress 1942; Gleason 1963; Holm et al. 1997). Each capitulum is subtended by an oval-cylindrical involucre with lanceolate-obtuse, green to brownish, herbaceous bracts, in two rows of phyllaries, with the outer phyllaries shorter and wider than the inner phyllaries (Holm et al. 1997). The inner phyllaries are of uniform length and one-serrate, while the outer ones are unequal, one-third to one-half as long as the inner bracts and many-serrate. All bracts are reflexed at maturity, with a convex, minutely pitted receptacle, without paleae (Holm et al. 1997).

The capitulum is composed of up to 250 ligulate, perfect, yellow florets (Holm et al. 1997). Each floret has a corolla of five united petals with one side prolonged, strap-shaped, and five-notched at the tip. Each floret contains five stamens fused into a tube with a sagittate base, filiform basal lobes and an obtuse apex (Holm et al. 1997). The warty spherical pollen grains are 30 µm in diameter (Gier and Burress 1942). In each floret, the inferior ovary contains one basal, inverted ovule with a single integument. A single style branches into two stigmatic arms, which are 1–1.5 mm in length and 0.06 mm in diameter, and covered with fine hairs (Gier and Burress 1942; Sood and Sood 1992; Holm et al. 1997). Each ovule gives rise to a pale grey-brown to olive-brown, narrowly obovoid-oblong, rough-surfaced cypsela (seed), 3–4 mm in length and 1 mm width. Each cypsela is 5–8 ribbed on each side with upwardly pointed teeth at the beaked apex

and with a white pappus composed of numerous hairs, 3–4 mm in length, mostly white, persistent and fused at the base (Gleason 1963; Holm et al. 1997). In the remainder of this review, for the sake of simplicity, the following terms will be used: scape to describe a peduncle, inflorescence to describe a capitulum and seed to describe a cypsela.

*Taraxacum officinale* ranges in ploidy level from diploid to hexaploid ( $x = 8$ ), possessing 16 to 48 individual chromosomes (Richards 1973). North American individuals of this species are generally triploid ( $x = 8$ ,  $3x = 24$ ), and sexual reproduction is rare or may even be absent (Solbrig and Simpson 1974; Lyman and Ellstrand 1984). Of the 2000 reported micro-species in Europe, approximately 90% are polyploids that reproduce asexually by obligate agamospermy. The majority of the remaining 10% are diploid species that reproduce sexually and are obligate outcrossers. However, a small number of more primitive forms are capable of self-fertilization (Hughes and Richards 1985).

(b) *Morphological characters.* *Taraxacum officinale* has similarities with other *Taraxacum* and related species. The red-seeded dandelion, *Taraxacum laevigatum* (Willd.) DC., reported throughout southern Canada, is similar to *T. officinale*, however, it is more slender, and its leaves are very deeply incised for their whole length (Gleason 1963). Leaf lobes of *T. laevigatum* are generally narrower than those of *T. officinale* and, unlike *T. officinale*, the terminal leaf lobe is seldom larger than lateral leaf lobes. Unlike seeds of *T. officinale*, seeds of this species become bright red to reddish purple at maturity (Gleason 1963). *Taraxacum officinale* is more difficult to distinguish from *T. ceratophorum* (Ledeb.) DC., which is found in northern mountainous regions of Canada (Gleason 1963). *T. ceratophorum* is generally less robust, has more broadly lobed petioles, leaves with fewer lobes, and smaller inflorescences than *T. officinale* (Gleason 1963).

The marsh dandelion, *Taraxacum palustre*, found in southern and eastern Ontario and western Québec, is very similar to *T. officinale*. Originally reported as *T. turfosum* (Brunton 1989), it has since been placed in the well-defined species, *T. palustre* (Oldham et al. 1992). *T. palustre* can be distinguished by its erect, narrow, remotely serrate leaves and very dark, broad, and strongly appressed exterior involucre bracts (Brunton 1989; Oldham et al. 1992).

There are also many native species of *Taraxacum* in North America, which mostly occur in the Arctic and eastern Canada. For example, *T. lyratum* (Ledeb.) DC. occurs throughout much of the Yukon territory as well as in Labrador and Newfoundland (Cody 2000). Other rare native species, such as *T. latilobum* and *T. laurentianum*, are found in eastern Québec, Newfoundland and Labrador, and these could be confused with *T. officinale* (J. Cayouette, personal communication, Agriculture and Agri-Food, Canada, Ottawa, ON).

*Taraxacum officinale* is also morphologically similar to other members of the Asteraceae. *Chondrilla juncea* L., skeleton-weed, overlaps in range with *T. officinale* in the interior of British Columbia (R. S. Cranston, personal communication, BC Ministry of Agriculture, Fisheries and Food, Abbotsford, BC). While the basal rosette of *C. juncea*

is similar to that of *T. officinale*, *C. juncea* produces branched stems bearing linear cauline leaves, and sessile inflorescences containing 11 florets each (Gleason 1963). Members of the genus *Crepis* L., hawk's beard, have inflorescences bearing florets that are yellow, ligulate, and perfect. However, the inflorescences occur in small to large groups in an open, corymbiform or paniculiform arrangement. Basal leaves of *Crepis* species are also less lobed than those of *T. officinale* (Gleason 1963). Members of the genus *Prenanthes* L., white lettuce, have basal leaves that could be mistaken for the leaves of *T. officinale*. However, *Prenanthes* species also exhibit cauline leaves, scaled scapes and corymbiform, paniculiform, thyrsoïd, or subracemiform inflorescences with ligulate and tubular florets, which are absent in *T. officinale* (Gleason 1963). The inflorescence of *Tussilago farfara* L., coltsfoot, is very similar to that of *T. officinale*, but flowering in this species occurs prior to the development of the leaves in the spring, while *T. officinale* produces inflorescences well after the establishment of leaves (Gleason 1963). *Taraxacum officinale* may also be confused with members of the genus *Hypochoeris* L., cat's-ear, as well as with *Leontodon autumnalis* L., fall dandelion, due to the similarities of the bright yellow inflorescences of these species. Aarssen (1981) provided a key to distinguish these species.

(c) *Intraspecific variation.* The taxonomy of *T. officinale* is complex and requires more extensive study (Small and Catling 1999). As *Taraxacum* species exhibit extremely variable biology and morphology, the genus is treated as many micro-species in Europe; however, it is treated as one species exhibiting considerable phenotypic plasticity in North America (Richards 1973). This extensive variation may be somewhat unexpected since North American populations are generally considered to be apomictic and so do not exchange genes (Solbrig and Simpson 1974; Taylor 1987). There are differences of opinion regarding the extent to which the observed variation is due to phenotypic plasticity versus genotypic differentiation arising from multiple introductions of European microspecies (Taylor 1987). Janzen (1977) suggested that there is very little genetic variation among populations, while Abbott (1979) argued that this assumption is premature. Taylor (1987) stated that intrapopulation morphological variation was as great as or greater than inter-population variation and, therefore, morphological variation was largely due to phenotypic plasticity. However, Kennison (1978) found that in populations from Washington State, variation among populations was consistently greater than variation within populations.

Ford (1981a) observed that agamospecies growing in particular habitats differed from site to site in characters such as population flux, survivorship and fecundity. Furthermore, agamospecies represent ecologically highly specialized population units, relevant to a fine scale of heterogeneity of habitat, and two or more agamospecies can coexist in a broad habitat (Ford 1981b, 1985). Small and Catling (1999) provide an excellent summary of variation in this species in Canada. King (1993) used restriction enzyme analysis of ribosomal DNA and chloroplast DNA to assess the relative

contribution of hybridization and mutation as sources of genotypic variation in dandelions of North America. She found that multiple hybridization events in populations (prior to their introduction to North America) were a more important source of genotypic variation than mutation in populations.

(d) *Illustrations.* The morphology of a seedling at the three-leaf stage and a mature *T. officinale* plant are shown in Fig. 1. Details of one floret and one cypsela (seed) are shown in Fig. 2. A number of internet sites exist which contain photos or illustrations of *T. officinale* including

<http://www.rce.rutgers.edu/weeds/weed.asp?pname=dandelion>

[http://www.biologie.uni-hamburg.de/b\\_online/thome/band4/tafel\\_146.html](http://www.biologie.uni-hamburg.de/b_online/thome/band4/tafel_146.html)

<http://clay.agr.okstate.edu/alfalfa/images/weeds/composite/non-thistle.htm>

<http://www.agry.purdue.edu/turf/weeds/dandelion/dandelion.htm>

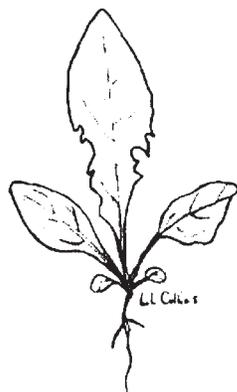
<http://elib.cs.berkeley.edu/cgi/img-query?where-genre=plants&where-taxon=Taraxacum+officinale>

### 3. Economic Importance

(a) *Detrimental.* *Taraxacum officinale* infests terrestrial habitats worldwide and is especially adapted to pastures, lawns, orchards, hay fields, roadsides and other areas of occasionally disturbed vegetation (Holm et al. 1997). It has become a problem weed in golf courses, municipal parks, home gardens, athletic fields, agricultural crops, vegetable gardens and horticultural crops such as strawberries (Witty and Bing 1985; Riddle et al. 1991; Holm et al. 1997). *T. officinale* plants are an aesthetic problem during flowering and seed production periods, interrupting turfgrass uniformity and density (Riddle et al. 1991). It is an increasing problem in annual cereal and oilseed crops in western Canada (Derksen and Thomas 1997), and was ranked the sixth most important weed occurring in corn, soybean and winter wheat fields in southwestern Ontario, being found in more than 25% of 593 fields examined (Frick and Thomas 1992). It was the sixth most abundant weed species in reduced and no tillage fields and the tenth most abundant species in conventionally tilled fields (Frick and Thomas 1992). *Taraxacum officinale* may have been more common in fields with reduced or no tillage because its control was facilitated by intensive tillage or because the increased crop residue in these fields aided in trapping wind-borne seeds (Frick and Thomas 1992). The brilliantly coloured inflorescences give fields a weedier appearance than is really the case (Holm et al. 1997).

In the USA, corn yields were drastically reduced by *T. officinale*, especially when the previous crop was corn rather than soybeans (Hartwig 1990). It has also been reported as one of the most dominant weed species in wheat fields in Pakistan (Ahmad 1993). When present in dense populations, *T. officinale* can cause slower drying of hay because of its high water content, and can be a potential seed source for other parts of the farm (Tardif 1997). Doll (1984) found that forage from an alfalfa crop with a *T. officinale* infesta-

(A)



(B)

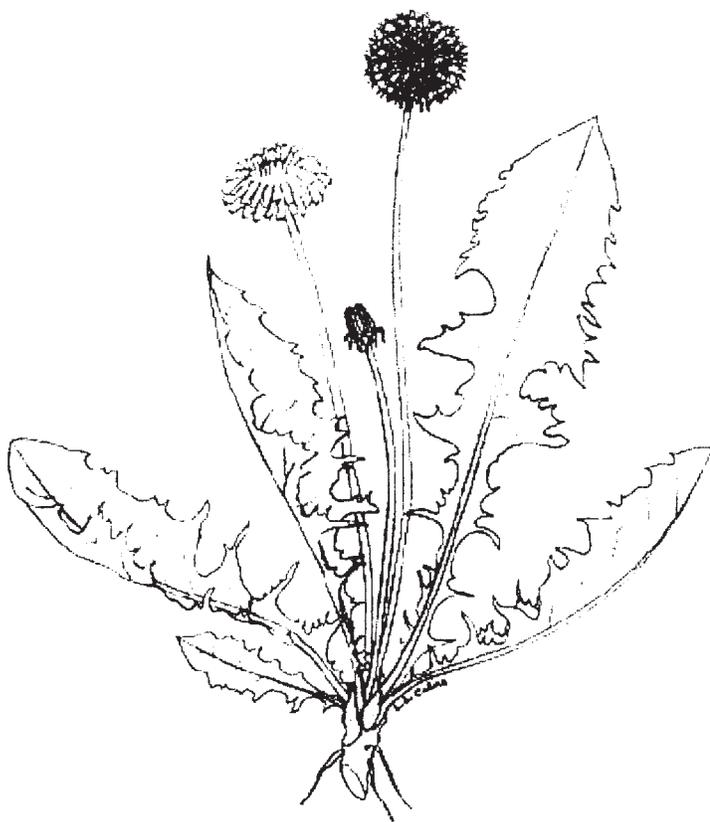
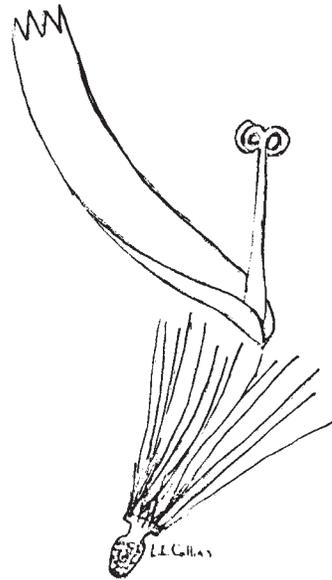


Fig. 1. (A) seedling at three-leaf stage ( $\times 1/2$ ); (B) mature plant ( $\times 1/2$ ).

tion of 13–31% dry weight required an additional day to dry to the same level as forage free of *T. officinale*. Leaves of *T. officinale* dried faster than stems or ribs and this can cause a loss in dry matter yield during mechanical haymaking (Isselstein and Ridder 1993).

*Taraxacum officinale* also occurs as a weed in national parks (Tyser and Worley 1992) and in peppermint fields in the USA (Carda et al. 1992). It may also act as an alternative host for boll weevils (Haynes and Smith 1992), cabbage looper, yellow-striped armyworm (Dussourd and Denno

(A)



(B)

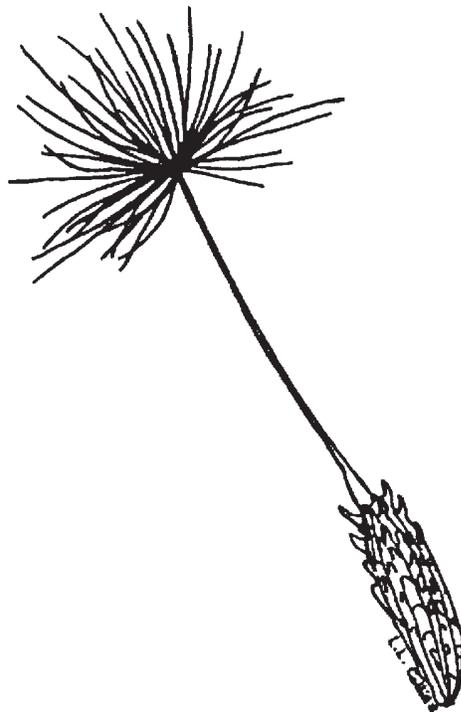


Fig. 2. (A) floret ( $\times 4$ ); (B) cypselus (seed) ( $\times 7$ ).

1994), green peach aphid (Kaakeh and Hogmire 1991), *Pseudomonas viridiflava*, which causes bacterial streak and bulb rot of onion (Gitaitis et al. 1998), and numerous viruses (Brcák 1979; Mountain et al. 1983).

*Taraxacum officinale* is used as a medicinal plant (see section 3b), however, overindulgence may render the liver inactive and cause various unpleasant symptoms (Jackson 1982). The pollen of *T. officinale* has been identified as an

allergen in honey (Helbling and Wuethrich 1987) and can cause allergic contact and photoallergic contact dermatitis (Mark et al. 1999). *Taraxacum officinale* inflorescences in orchards are perceived as a serious competitor to flowering apple and pear trees for honeybee visits, and much time and expense is spent mowing to remove them. However, a study in Ontario showed that apple pollen accounted for >90% of the pollen collected, even when the ratio of dandelion to apple inflorescences was 28:1; and mowing had no effect on the percentage of pollen collected (Lavery and Hiemstra 1998). Similarly, a study in Hungary found that *T. officinale* inflorescences were scarcely visited by honeybees compared to flowering pear trees (Benedek et al. 1998).

(b) *Beneficial.* *Taraxacum officinale* has been used for medicinal purposes for centuries to treat a myriad of conditions (Culpeper 1826; Powell 1972), including to improve liver function, lower cholesterol, lower blood pressure (Mattern 1994), decrease body weight in obese patients, treat gall bladder ailments (Dalby 1999) and as a diuretic (Rácz-Kotilla et al. 1974). Matol Botanical International Ltd. produces and distributes a health tonic sold under the brand name MATOL in Canada (Km in the USA) that contains 14 medicinal-plant extracts, including an extract from roots of *T. officinale* (Michaud et al. 1993). Leaves of *T. officinale*, mixed with other plant material, have been used therapeutically for liver, kidney, skin and even cancerous diseases (Neamtu et al. 1992). Dandelion infusion has a beneficial effect on urolithiasis (kidney stones) that can be attributed to some disinfectant action, and tentatively, to the presence of saponins (Grases et al. 1994).

The feed value of *T. officinale* is high, with only trace amounts of essential oils and a low amount of tannin that might affect quality or palatability (Falkowski et al. 1990). The plant can contain as much protein as white clover (Bockholt et al. 1995) and is a valuable feed, based on its fat and carbohydrate content (Spatz and Baumgartner 1990). Bergen et al. (1990) found that *T. officinale* had protein and mineral contents high enough to exceed the established requirements for cattle, and that cattle consumed dandelion as readily as, or sometimes in preference to, grass pasture. However, Falkowski et al. (1990) reported that it was not eaten readily by most domestic animals because of its bitterness.

*Taraxacum officinale* has been tested as a soil amendment for organically grown herbs, but it was not as useful as some other weeds (Li 1996). It also possesses allelopathic properties and can suppress some fungal pathogens, such as *Fusarium oxysporum* f. sp. *radicis-lycopersici* Jarvis & Shoemaker, and nematodes (Jarvis 1989; Falkowski et al. 1990; Alvarez et al. 1998). Fresh aboveground material of *T. officinale* lowered population densities of infective, second-stage juveniles of the nematode *Meloidogyne hapla* Chitwood and, therefore, increased carrot yield in the greenhouse (Alvarez et al. 1998).

*Taraxacum officinale* is commonly used as a salad green. In Toronto alone, 155 tonnes of leaves (valued at Can\$595 000.00) were marketed in 1988 and 1989 (Letchamo and Gosselin 1995). Recently, a program was initiated in Québec to introduce organic production of *T.*

*officinale* for commercial processing of the roots (Letchamo and Gosselin 1995). Extracts from *T. officinale* have been used in cheese preparation, due to its milk clotting and proteolytic properties (Akuzawa and Yokoyama 1988). *Taraxacum officinale* plant parts are used in soups, main courses, desserts and beverages, including tea, wine, beer and a coffee substitute (using dried roots that have been roasted and ground) (Gail 1994; Dalby 1999; Khan 2001). The inflorescences are also an excellent source of nectar for honey; however, the nectar is more commonly used by beekeepers in the brood nest for spring colony build-up (Gail 1994; Dalby 1999).

*Taraxacum officinale* is a good indicator of environmental pollution and is often used as a biomonitor because it is an abundant, widely distributed plant, and the leaves and roots accumulate metals, including As, Br, Cd, Co, Cu, Cr, Hg, Mn, Pb, Sb, Se and Zn (Kuleff and Djingova 1984; Djingova et al. 1986; Simon et al. 1996). Recently it was used to evaluate trace metal bioavailability in abandoned industrial sites, community gardens and parks in urban Montréal, QC (Marr et al. 1999). With increasing levels of pollution, traits such as the length and weight of seeds decrease, but the number of seeds increases, as an adaptation to survive unfavourable conditions (Savinov 1998).

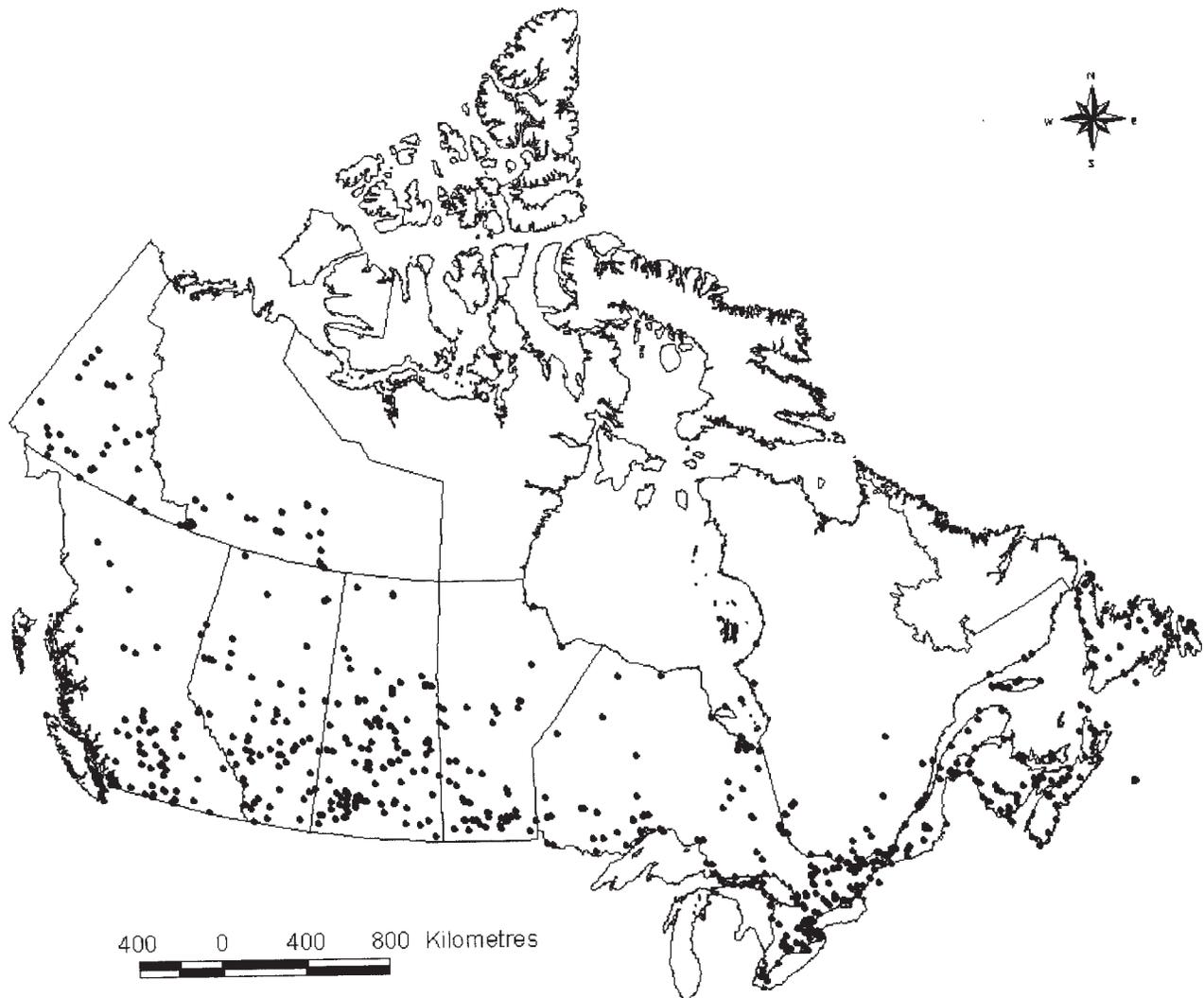
*Taraxacum officinale* is also useful as an experimental subject in classroom practical work. As it is very common, easily recognizable and perennial, it is easy to obtain and is ideal for studying germination, gravitropism, auxin effects, water potential measurement, polarity of root sections, morphological variation and plant cell structure (Oxlade and Clifford 1999) (See also Section 7c).

(c) *Legislation.* *Taraxacum officinale* is listed as a noxious weed in Saskatchewan (Anonymous 1984) and in Québec, where it is considered noxious when it is found growing on roadside verges, along railways and electrical energy transmission lines, in ditches and fields, and in unoccupied lots (Anonymous 1977). *Taraxacum officinale* is designated as a nuisance weed in Alberta (Anonymous 1991) and is in the schedule of weeds that may be declared noxious by the Lieutenant Governor in Council in Manitoba (Anonymous 1981). *Taraxacum officinale* is not listed in any other provincial weed control acts.

#### 4. Geographical Distribution

More than 1000 herbarium samples and records were examined to determine the distribution of *T. officinale* in Canada and ca. 900 records were included in the final distribution map (Fig. 3). The availability of samples and records often did not reflect the prevalence of the species within a particular area but this is often the case with common species. The correct identity of the samples and records was not verified, primarily due to the taxonomic uncertainty of many species within this genus. Only samples and records that were determined as *T. officinale* were included in the distribution map and analysis.

The geographical distribution of *T. officinale* in Canada is summarized in Fig. 3. *Taraxacum officinale* has been reported from all provinces and territories of Canada, including



**Fig. 3.** Canadian distribution of *Taraxacum officinale*. Information was gathered from specimens and records in the following herbaria: ACAD, ALA, APM, CAFB, CAN, DAL, DAO, DAS, LRS, MALA, NFLD, NFO, NSAC, NSPM, OAC, OLDS, PMAE, QFA, QK, QSA, SASK, SCFQ, SCS, SSMF, TRT, TRTE, TUP, UBC, UNB, UQTR, WAT, WIN, WINDM, and WLU [herbarium abbreviations as in Holmgren et al. (1990), as presented in <http://www.nybg.org/bsci/ih/ih.html>].

the Northwest, Yukon and Nunavut Territories (Rousseau 1968; Scoggan 1979). This species is widely distributed within Canada and records were also found from almost all isolated regions, including Sable Island, Anticosti Island, Vancouver Island, Queen Charlotte Islands, and Akimiski Island (James Bay).

*Taraxacum officinale* is distributed within Canada from 41°42' N (Ontario) to 64°48' N (Yukon Territory) latitude, and from 49°37' W (Newfoundland) to 139°50' W (Yukon Territory) longitude. In Alaska, records were found as far north as 67°06' N latitude, and as far west as 176°45' W longitude. *Taraxacum officinale* is also found in over 60 countries worldwide (Holm et al. 1997).

## 5. Habitat

(a) *Climatic requirements.* *Taraxacum officinale* can tolerate a broad range of climatic conditions (Simon et al. 1996)

and is distributed in almost every temperate and subtropical region of the world (Holm et al. 1997). Established *T. officinale* plants are very resistant to drought, while young plants are very sensitive and have a limited chance of invading coarse-textured or rapidly drying soils (von Hofsten 1954). *Taraxacum officinale* shows a wide range of adaptability to light, being able to grow vigorously in full sunlight, or in diffused light in the shade of trees or buildings (when leaves are usually thinner and more tender) (Longyear 1918). It may grow at sea level or up to an elevation of 3350 m, where it can be found associating with one or more sub-alpine or alpine native species (Longyear 1918).

(b) *Substratum.* *Taraxacum officinale* can grow in a wide range of soils (Simon et al. 1996) but it flourishes best in moist, good-quality loam (Jackson 1982). Soil moisture determines its local distribution, with well-watered areas of

lawns being especially favourable for its growth (Longyear 1918). However, it has been recorded pushing up through concrete, hanging from eaves troughs of houses, and growing from cracks in old stone walls (Jackson 1982). It grows in soils ranging in pH from 4.8 to more than 7.6, but does not thrive on shallow and drought-sensitive soil (von Hofsten 1954, P. B. Cavers, personal communication, University of Western Ontario, London, ON). In hilly terrain, *T. officinale* occurs more often on ridges than in hollows but this may be due to differential herbivory (e.g., slugs, rodents, grasshoppers) on the gradient, rather than differential effects of competition (Reader 1992).

(c) *Communities in which the species occurs.* *Taraxacum officinale* occurs in lawns, gardens, waste ground, roadsides, fields (forage fields such as alfalfa) and their margins, and no-till crop production systems in agricultural crops (Lovell and Rowan 1991; Hamill 1997). Interestingly, it is one of the predominant species in black-tailed prairie dog towns in North Dakota (Stockrahm et al. 1993) and is the favourite food of pocket gophers in Utah, USA (Ellison and Aldous 1952).

*Taraxacum officinale* occurs in grassland communities and, after renovation, meadows and pastures are often invaded rapidly (Haugland 1993). Nitrogen levels had limited effects on competition patterns between grass swards and *T. officinale*, but competition among roots affected shoot dry weight much more than competition among shoots (Haugland 1993). Shading increased leaf length and specific leaf area, which made *T. officinale* less susceptible to competition for light (Haugland 1993). Shoot competition reduced root dry weight and increased the shoot:root ratio, which, in turn, may have reduced plant survival (Haugland 1993).

Establishment and performance of *T. officinale* in grass vegetation is dependent on the height and cutting frequency of the grass (Molgaard 1977). This Danish study found that with increasing grass height, the density of *T. officinale* decreased, at least partly due to shading (Molgaard 1977). Also, the reproductive morphology of *T. officinale* in alfalfa fields was different, facilitating colonization of open areas, compared to the reproductive morphology on undisturbed sites with a high density of grass (Welham and Setter 1998).

## 6. History

Many botanists believe that *T. officinale* originated in Greece, or perhaps the Northern Himalayas, and spread across temperate areas to Europe and Asia Minor (Richards 1973; Schmidt 1979; Gail 1994). *Taraxacum officinale* has a fossil record that goes back to glacial and interglacial times in Europe (Godwin 1956) and it is thought to have colonized the Americas post-Pleistocene via Beringia (Richards 1973). Later introductions of *T. officinale* to North America are obscured in conflicting claims (Gail 1994). The earliest claim is that it arrived on the east coast with the Vikings about 1000 AD; others say it first came on the Mayflower; while others claim the introduction was by later settlers who brought it as a garden plant or a pot herb for medicinal purposes (Schmidt 1979; Jackson 1982; Gail 1994). The earliest recorded observation of *T. officinale* in North America was in the New England area in 1672

(Rousseau 1968). The Cree, Digger, Apache and Mohican Indians soon became aware of its virtues and used it as a medicinal herb (Jackson 1982; Dalby 1999). It is likely that there have been multiple introductions from many sources (Gail 1994). The plant is thought to have spread to the west coast with loggers and settlers (Schmidt 1979). The first Canadian collection of *T. officinale* was made in Montréal, QC, in 1821, where it was observed as a common species (Rousseau 1968).

## 7. Growth and Development

(a) *Morphology.* Phenotypic variability in *T. officinale* increases its ability to colonize a wide range of habitats. In cool or dry weather, or in closely mown lawns, the leaves usually spread flat against the surface of the ground to form an almost prostrate rosette (Longyear 1918; Lovell and Rowan 1991). In warmer weather or in areas where it is crowded by taller vegetation, the leaves stand in more or less erect tufts (Longyear 1918). The rosette enables it to survive mowing, grazing and competition with grasses (Baker 1974). The possession of toothed leaves, which resemble those of thistles, and the bitter white latex, are thought to be adaptations to deter grazing animals (Richardson 1985).

*Taraxacum officinale* displays a wide range of leaf shapes, from a smooth rounded (juvenile) form to a deeply incised runcinate (adult) form (Sánchez 1971). The length:breadth ratio decreases as the leaf number increases (Sánchez 1971) and the ratio and depth of incisions in the runcinate form are influenced by light, mediated by the phytochrome system (Wassink 1965; Sánchez 1967). Therefore, leaf shape can be regulated by light intensity and quality, with rounded blades developing at low light energy values and runcinate blades developing at high light energy values (Sánchez 1967; Slabnik 1981). An increase in light intensity increases the degree of lobing and decreases the length:breadth ratio (Slabnik 1981).

The species possesses a deep tap root that can extend below the level of competing grass roots (Loomis 1938), and make it difficult to remove plants manually (Lovell and Rowan 1991). The root system can be widely branched and surmounted by a crown, which can divide to form numerous (up to 22) crown branches, depending on the degree of crowding by other plants and plant age (Roberts 1936). The roots are also highly regenerative, capable of producing shoots and roots within 1–2 wk from very small segments (Longyear 1918; Warmke and Warmke 1950; Mann and Cavers 1979). When cut off below the crown, the root usually produces several new shoots so that a cluster of new plants is formed (Longyear 1918). At the end of the growing season, the root shortens and draws the crown slightly into the soil, where it is better protected from adverse conditions (Longyear 1918). The ease of regeneration is reportedly related to the ability of the parenchymatous cells of the secondary phloem and xylem in the root to readily dedifferentiate and develop into new shoots and roots (Higashimura 1986).

During the development of the inflorescence, the growth rate and georesponse of the scape varies (Clifford and

Oxlade 1989). The scape elongates to bloom, then bends down close to the ground while the seeds mature, where it can escape injury from lawnmowers or grazers (Longyear 1918; Richardson 1985). When seeds are nearly mature, the scape elongates again up to 75 cm, maximizing its height for effective dispersal of the wind-blown seeds (Longyear 1918; Jackson 1982; Richardson 1985). Therefore, the scape grows upright (negatively orthogeotropic) when extension growth is rapid, as it is prior to flowering and during formation of the inflorescence (Oxlade and Clifford 1981). However, between these stages, when extension growth is minimal and the inflorescence is closed, the scape can grow parallel to the ground (diageotropic) for some or most of its length (Oxlade and Clifford 1981). The outer tissue layers of *T. officinale* scapes are held in a state of longitudinal tension by internal stem tissues, which are held in a reciprocal state of compression (Niklas and Paolillo 1998).

Fasciation has been recorded in *T. officinale* in two forms, confined to the reproductive tissues of the plant (Dekker and Dekker 1987). In plants with multiple scapes, the central scapes can be fused together to form one broad (1–2 cm) scape; or inflorescences (2–4) can be fused at their base to form a longitudinal floral structure (Dekker and Dekker 1987).

(b) *Perennation*. *Taraxacum officinale* overwinters as seed or it retains a reduced basal rosette under snow cover (Cyr et al. 1990).

(c) *Physiological data*. *Taraxacum officinale* leaves are rich in fibre, potassium, iron, calcium, magnesium, phosphorus, vitamins A and C, the B vitamins thiamine and riboflavin, and protein (Schmidt 1979; Jackson 1982; Gail 1994). Gail (1994) reported that they are also nature's richest vegetable source of  $\beta$ -carotene at 0.84 mg g<sup>-1</sup> tissue compared to carrots (*Daucus carota* L.) at 0.61 mg g<sup>-1</sup> tissue. They rank above broccoli (*Brassica oleracea* L.) and spinach (*Spinacia oleracea* L.) in overall nutritional value (Haytowitz and Matthews 1984), and Minnich (1983) ranked them out of all vegetables (including grains, seeds and greens) as tied for ninth best, higher than lettuce (*Lactuca sativa* L.). Also, the roots of *T. officinale* are rich in iron, copper and other trace elements (Dwyer 1977). The most prominent therapeutic property of *T. officinale* is the diuretic activity, which is based on the high potassium content of the plant (Hook et al. 1993). It is superior to other diuretics because it reduces the likelihood of hypokalaemia, a common side-effect of many diuretics (Houghton 1995).

The major and trace element content of *T. officinale* alters with growth stage (Müller and Kirchgessner 1972). In a Finnish study, the vitamin C content was lowest, while dry matter, soluble solids and mineral content were highest in late summer (Kuusi et al. 1982). Dandelion mineral content was investigated by van der Kley (1956) to assess the suitability of this species as feed for livestock. The high amounts of protein and  $\beta$ -carotene, favourable mineral composition, and low nitrate content throughout the growing season in Poland provided a high value feed (Falkowski et al. 1990). In UK studies, the availability of these elements

was equivalent to that in perennial ryegrass (*Lolium perenne* L.), a popular forage species (Wilman and Derrick 1994). *Taraxacum officinale* also had a lower proportion of cell walls in dry matter than perennial ryegrass (Derrick et al. 1993). The true dry matter digestibility was as high as that of ryegrass, but the *in vivo* digestibility was lower (Derrick et al. 1993).

The qualitative and quantitative distribution of carotenoids in *T. officinale* inflorescences did not change, regardless of the year, season or location of sampling (Tóth and Szabolcs 1970). Pollen of *T. officinale* contained carotenoids, leucoanthocyanidins, flavonols and ascorbic, chlorogenic, triterpene, palmitic, stearic, linoleic and linolenic acids (Bandyukova et al. 1983). Bandyukova et al. (1989) found the amino acid composition of pollen to be similar to that of pollen of other plants. The pollen contained a low concentration of ct-ABA (*cis trans* abscisic acid) and a high concentration of proline, which serves several functions including drought and cold resistance (Lipp 1991).

Callus development, and leaf and root formation, occurred in tissue cultures isolated from secondary thickened roots of *T. officinale* (Bowes 1970). Tissue cultures produced the same spectrum of compounds as intact plants and, in actively growing suspension cultures, volatile metabolites with an apple-like odour (Hook et al. 1991; Hook 1994). The application of nitrogen (as potassium nitrate) promoted the growth of roots and shoots (Khan 1975). Auxins and cytokinins are also likely to be involved in the hormonal control of regeneration and are necessary for growth and organogenesis (Booth and Satchuthanathavale 1974a, b). In a British laboratory study, the addition of gibberellin to *T. officinale* leaf discs retarded their senescence and delayed the decline in levels of chlorophyll, protein and RNA (Fletcher and Osborne 1966). The level of endogenous gibberellins in leaf tissue was high during leaf growth and expansion but declined progressively during senescence (Fletcher et al. 1969). Aging of leaves was associated with a deficiency of endogenous gibberellins (Fletcher et al. 1969).

Undifferentiated cultured cells of *T. officinale* produced oleanolic and ursolic acids as major triterpenoids, in addition to triterpenols composed mainly of  $\alpha$ - and  $\beta$ -amyrins (Akashi et al. 1994). Regenerated and wild plants contained additional triterpenols, including taraxasterol and lupeol, but negligible quantities of triterpene acids (Akashi et al. 1994). High squalene synthase activity was detected at the late logarithmic growth stage of suspension-cultured cells that produced triterpenoids, since squalene is an intermediate in sterol and cyclic triterpene biosynthesis (Komine et al. 1996). *Taraxacum officinale* accumulated the serine proteinase taraxalisin in latex but this latex did not contain cardenolides, which are cardioactive compounds found in the latex of some other weeds (Sady and Seiber 1991; Rudenskaya et al. 1998).

*Taraxacum officinale* is a C<sub>3</sub> species (Kemp et al. 1977). In US studies, plants from different altitudes showed no significant differences in enzyme activity, net photosynthesis, dark respiration, photorespiration, transpiration rates or temperature responses of gas exchange (Kemp et al. 1977;

Oulton et al. 1979). This is in disagreement with earlier US reports, which indicated that there were differences in the photosynthetic Hill reaction and enzyme activity among the same altitudinally diverse populations (May and Villarreal 1974; May 1976). Activity of the enzyme invertase, which was only present in the petiole and central midrib of the developing leaf, was correlated with leaf growth rate and its level was controlled by light (Slabnik 1981).

Various chemicals and cellular structures play roles in the geotropic behaviour of *T. officinale*. UK studies showed that elevated levels of endogenous ethylene were associated with the diageotropic behaviour and reduced extension growth after flowering (Clifford and Oxlade 1989). There were significant differences in indol-3-yl-acetic acid (IAA) levels across the scape after geostimulation, indicating a role for auxin in geotropism (Clifford et al. 1985). In an earlier British study, Clifford and Barclay (1980) showed that amyloplasts (colourless plastids that form starch granules) in the cells of scapes sediment much faster than previously reported and were involved in the initiation of geotropism in *T. officinale*.

In other Canadian studies, it was found that amino acids accumulated in the roots as fall senescence progressed in the aerial parts of the plant, and declined in spring when regrowth occurred, with large fluctuations in the amides asparagine and glutamine (Cyr and Bewley 1990a). An 18 kDa protein increased in *T. officinale* roots during the fall months, suggesting that it has a role as a storage compound (Cyr and Bewley 1990b). The same protein was also found in inflorescences, the stem and seeds (Cyr and Bewley 1990b).

Plants exposed to elevated levels of CO<sub>2</sub> grew faster, exhibited more deeply incised leaf margins and had relatively more slender leaf laminae than those exposed to ambient levels (Thomas and Bazzaz 1996; Staddon et al. 1999). These effects were most pronounced when *T. officinale* plants were grown individually, but detectable differences were also found in plants grown at high density (Thomas and Bazzaz 1996). This supports the hypothesis that leaf carbohydrate levels play an important role in regulating heteroblastic leaf development, although elevated CO<sub>2</sub> may also affect leaf development through direct hormonal interactions or increased leaf water potential (Thomas and Bazzaz 1996).

A US study showed that the leaf size of *T. officinale* plants decreased linearly with increasing elevation and a corresponding decline in nocturnal infrared irradiation from the sky (Jordan and Smith 1995). Differences in plant leaf structure and physiology traditionally associated with daytime sun exposure may also be influenced by nighttime sky exposure and susceptibility to frost (Jordan and Smith 1995). Red light and far-red light influenced the water exchange of epidermal cells of *T. officinale* and phytochrome appeared to be involved (Carceller and Sánchez 1972).

Environmental factors, such as temperature, photoperiod and rainfall, were studied in Finland for their effect on the bitterness of *T. officinale* (Kuusi and Autio 1985). It was found that increasing temperature and photoperiod and decreasing rainfall were correlated with an increase in bitterness. However, morphological characters such as leaf

shape, main nerve breadth and colour of petiole base were not correlated with bitterness (Kuusi and Autio 1985). Growth phase and season had a strong influence on bitterness, with plants being less bitter in spring before flowering than in late summer (Kuusi and Autio 1985). Bitterness in leaves was caused by sesquiterpene lactones, such as taraxinic acid and its glucoside, as well as triterpenoids, such as cycloartenol (Houghton 1995). Kuusi et al. (1985) identified four bitter compounds: p-hydroxyphenylacetic acid,  $\beta$ -sitosterol, 11,13-dihydrotaraxine acid 1'-O- $\beta$ -D-glucopyranoside and taraxine acid 1'-O- $\beta$ -D-glucopyranoside [also identified as an allergen (von Hausen 1982)]. The following triterpene alcohols have been isolated from roots of *T. officinale*: taraxol, taraxerol,  $\psi$ -taraxasterol, taraxasterol,  $\beta$ -amyirin, stigmasterol and  $\beta$ -sitosterol; along with phenolic acids related to caffeic acid and  $\beta$ -fructofuranosidases (Burrowes and Simpson 1938; Rutherford and Deacon 1972; Houghton 1995). Caffeoyltartaric acids, cinnamic acids, coumarins and flavonoids have also been isolated from *T. officinale* tissues, including leaves (Williams et al. 1996; Budzianowski 1997).

A UK study showed that sterol levels in leaves of *T. officinale* fluctuated with season, probably due to temperature (Westerman and Roddick 1981). Free 4-demethyl sterols were maximal during the winter months and levels were correlated negatively with sunshine and temperature (Westerman and Roddick 1981). Sitosterol ester and cycloartenol ester showed the opposite response, with levels correlating positively with sunshine and temperature (Westerman and Roddick 1981). The scapes contained predominantly  $\beta$ -sitosterol and  $\beta$ -amyirin (Aexel et al. 1967).

*Taraxacum officinale* possesses allelopathic properties that can reduce germination of other plant species (Falkowski et al. 1990). In addition, phenolic compounds produced by *T. officinale* are considered responsible for allelopathic biological control of *Fusarium oxysporum* f. sp. *radicis-lycopersici* in greenhouse tomato plantings in Canadian experiments (Kasenberg and Traquair 1988). Satisfactory control of this pathogen was achieved when residues of *T. officinale* were incorporated into sterilized greenhouse soil. The mode of action is unknown but it may act directly by secretion of allelochemicals or promotion of antagonistic microflora (Jarvis 1989).

An anti-fungal toxin was inducibly produced by *T. officinale* leaves treated with cupric chloride but production was depressed under oxygen deficient conditions (Mizutani 1989). This compound was identical to lettucenin A, which has been isolated from lettuce infected with *Pseudomonas cichorii* (Takasugi et al. 1985). Lettucenin A is a stress-induced antifungal sesquiterpenoid that was present in sufficient quantity to suppress invasion of a pathogen in vivo (Hanawa et al. 1995). It was found that lettucenin A production started at an early stage of fungal infection, before the appearance of symptoms, and ended soon after the death of the pathogen (Hanawa et al. 1995).

Carbohydrate and nitrogen reserves in the roots of *T. officinale* fluctuate with the season (Loomis 1938). The roots remained viable during the winter and acted as a source of nutrients to facilitate the resumption of growth in

early spring (Cyr et al. 1990). Fructans, storage carbohydrates such as inulin and inulo-n-ose, were synthesized in roots by the enzyme fructan-fructan fructosyl transferase (Lüscher et al. 1993; Ernst et al. 1996). This synthesis of inulin was practically unaffected by the height of competing grass vegetation (Molgaard 1977). High inulin content in roots resulted in high nitrogenase activity (Vlassek and Jain 1976), which could enrich the soil with nitrogen through asymbiotic nitrogen fixers such as *Azotobacter* and *Clostridium* species (Vlassek and Jain 1978). Fructan hydrolysis occurred during late autumn and provided simple sugars as a readily accessible carbon pool (Cyr et al. 1990). Nitrates, free amino acids and soluble proteins were important vehicles for nitrogen storage (Cyr et al. 1990). Storage reserves remained at peak levels throughout winter and declined prior to the resumption of growth in spring, when inulin was metabolized to provide a high content of mobile fructose and sucrose to enable extensive vegetative growth and flowering (Molgaard 1977; Cyr et al. 1990). At the time of fruiting, nitrogen reserves were at their lowest concentration (Loomis 1938). Toward the end of summer, these reserves were restored and the cycle began again (Rutherford and Deacon 1974).

*Taraxacum officinale* was identified as a valuable source of the essential linolenic acid, apigenin-7-glucoside, lecithin, and cholin (Houghton 1995; Letchamo and Gosselin 1995). Unsaturated hydroxy fatty acids such as linolenic acid are important in the chilling-resistant properties of *T. officinale* (Imai et al. 1995).

(d) *Phenology*. Generally, during the first season of growth, *T. officinale* seedlings produce only leaves, usually in rosettes (Longyear 1918). In the spring of the second season, and each season thereafter, inflorescences are produced (Longyear 1918). However, under favourable conditions, some seedlings can bloom in their first year (von Hofsten 1954; Listowski and Jackowska 1965). The first bud may appear at various times and cannot be correlated to leaf index, although the plant has to have formed at least 20 leaves and enlarged its tap root to store the required energy (Listowski and Jackowska 1965; Solbrig 1971). The time of first flowering is partly dependent on the surrounding plant community and, in undisturbed communities, a plant may not flower until its fourth season (Gorchakovskii and Abramchuk 1996).

In *T. officinale*, flowering occurs over a wide range of photoperiods and light intensities. Studies on seasonal variation in flowering of *T. officinale* in Kentucky, showed that plants flowered throughout the year, with most plants flowering in April when the average daily air temperature was 16°C and day length was about 13 h. A secondary peak occurred in September and October, with an average of 21°C and 12–13 h day length (Gray et al. 1973). Therefore, *T. officinale* can be classified as a day-neutral plant (Listowski and Jackowska 1965; Gray et al. 1973), although Solbrig (1971) classified it as a short-day plant due to limited flowering during long summer days. Individual plants that bloom in spring may also bloom again in fall (Listowski and Jackowska 1965). Bud formation in these plants occurs

during a period of decreasing daylight, when the differentiation of new leaves is limited and existing leaves show symptoms of premature aging (Listowski and Jackowska 1965). The time course of the main spring flowering period may vary in different years, partly due to differences in microclimate, such as the amount of sunshine and soil temperature (von Hofsten 1954; Sterk and Luteijn 1984). The number of times the inflorescences open and close, the length of time that the inflorescences remain open each day, and the length of time that the inflorescences remain closed before opening into mature heads, vary with time of year (Gray et al. 1973).

The development of buds requires approximately 1 wk (Solbrig 1971). A scape is formed between the base of the bud and the tip of the shoot in about 48 h (Solbrig 1971). On average, inflorescences open during 2 or 3 successive days, after which they remain closed until the seeds mature (Longyear 1918; Gray et al. 1973). The scape and the inflorescence flatten to the ground and, after a couple of days, the scape straightens and the involucre bracts surrounding the closed inflorescence open to reveal seeds (Solbrig 1971). The time required from the first day of blooming until the seeds ripen and the bracts open to release them, is about 9–12 d (Longyear 1918; Beach 1939; Gray et al. 1973).

A study in Japan showed that at low temperatures, inflorescences opened in response to increasing temperature (thermonasty), whereas at higher temperatures, they opened in response to light (photonasty) (Tanaka et al. 1988). The minimum temperature for photonastic opening was 13°C and inflorescences remained open for 13–14 h (Tanaka et al. 1988). At temperatures of 13–18°C, plants were in full bloom and this was most favourable for nectar secretion, pollen production and bee activity (Kremer 1950). In Michigan, USA, inflorescences were reported to close when the temperature was over 21°C or during adverse weather, and could remain closed for several days and then re-open when climatic conditions were favourable (Kremer 1950). Once closed, however, they did not open again on the same day (Kremer 1950).

Seeds produced in the spring during the peak flowering period mostly emerged that same spring or did not emerge at all (Collins 2000). However, seeds produced at other times during the year produced seedlings throughout the year. Seedlings produced in the fall produced seeds in the spring of the following year. Chepil (1946) found that seedlings emerged in most months of the year in Canada and for up to 4 yr after sowing. Collins (2000) collected ripe, viable seeds from a single population on the University of Western Ontario campus, London, ON, on the following dates in 1999: 1, 17, 27 May; 10 June; 20 August; 14, 21 September; 4, 20 October; 5, 22 November; and 13 December. At least 58% of the seeds collected on each date germinated. P. Cavers (personal communication, University of Western Ontario, London, ON) has collected ripe seeds in every month of the year, but not every month in a single year. He concluded that if there is a January or February thaw that lasts for at least a week, then flowering and seed production can occur.

The survival and regeneration of root fragments vary seasonally (Mann and Cavers 1979). Minimum survival of fragments occurred at the time of maximum flowering of the source plants and maximum survival of fragments occurred in the second growing season (Mann and Cavers 1979).

(e) *Mycorrhiza*. *Taraxacum officinale* forms mycorrhizal associations (Truszkowska 1951; Hawker et al. 1957). Two vesicular-arbuscular mycorrhizal fungi, *Glomus mosseae* (Nicol. & Gerd.) (Gange et al. 1994) and *Pythium ultimum* Trow. (Hawker et al. 1957), have been reported on *T. officinale*. Infection by *G. mosseae* conferred some degree of resistance in *T. officinale* roots to larvae of the black vine weevil *Otiorynchus sulcatus* (Fab.) (Gange et al. 1994). There have been some recent studies on the mycorrhizal interactions of *T. officinale*, including the effect of elevated CO<sub>2</sub> levels on mycorrhizal function (Staddon et al. 1999); the effect of non-host and host plants on mycorrhizal colonization (Fontenla et al. 1999); and the effect of *T. officinale* on mycorrhiza inoculum potential, soil aggregation and yield of maize (Kabir and Koide 2000).

## 8. Reproduction

(a) *Floral biology*. As *T. officinale* is an apomict (the embryo develops without fertilization) and a triploid of hybrid origin, most pollen grains are abortive and sterile, and cannot form pollen tubes (Solbrig 1971; Jenniskens 1984). Generally, in the Asteraceae, ligulate or ray-florets are sterile, and tubular or disc-florets are fertile. However, in *T. officinale*, there is no distinction between ray- and disc-florets, either in appearance or function, with all florets being ligulate and equally fertile (Roberts 1936). The ligulate florets are surrounded by inner and outer involucre bracts that close at night, in overcast weather, when the relative humidity is above 97% or when the temperature is less than 9.4°C. Opening of the inflorescences is inhibited by rain and accelerated by high light intensity (Percival 1955; Jenniskens et al. 1984).

In the Peace River region of Alberta, Szabo (1984) found an average daily production of 59.2 inflorescences m<sup>-2</sup>, which is equivalent to 592 700 inflorescences ha<sup>-1</sup> d<sup>-1</sup> and, over a 25-d blooming period, represented a potential production of 14 792 500 inflorescences ha<sup>-1</sup>. On a sunny day, inflorescences opened between 0800 and 0900, reached a peak at 1100 to 1200 and closed gradually from 1500 to 2100; but the whole period was shorter on dull days since high light intensity accelerates inflorescence opening (Percival 1955, Szabo 1984). A UK study found that *T. officinale* presented its pollen from 0900 to 1500, with the peak period from 1000 to 1100 (Percival 1955). Most inflorescences (89%) opened for 2 consecutive days, some (7%) for 1 d and some (4%) for 3 d (Szabo 1984). Quantity and concentration of nectar were significantly higher in inflorescences 2 d old than in those 1 d old (Szabo 1984). Larger inflorescences produced more nectar, and the nectar-sugar concentration and sugar value increased with increasing temperature (Szabo 1984). High nectar-foraging activity by honeybees coincided with peak nectar-sugar production (Szabo 1984), and anthers dehisced over a period of 1–7 d (Percival 1955).

(b) *Seed production and dispersal*. Although stamens and pistils are present and pollen is produced regularly, the seed of *T. officinale* develops without fertilization (Roberts 1936). Originally, it was thought that seeds were primarily produced by allogamy, and insects such as honeybees and flies were pollinators (Longyear 1918). However, it has been suggested by UK investigators that insect visitors, attracted by the bright yellow inflorescences, may be needed to trigger seed set (Williams et al. 1996). In a heavily infested area in Canada, the average number of seeds produced by *T. officinale* was 60 000 m<sup>-2</sup>, equivalent to about 600 000 000 seeds ha<sup>-1</sup> (Roberts 1936). Under near optimal conditions, the number of inflorescences/plant ranged from 48 to 146, with an average of 93, while the number of seeds/inflorescence ranged from 130 to 412, with an average of 252 (Roberts 1936). This provides an average of 23 436 seeds/plant (Roberts 1936).

In UK studies on the reproductive success of *T. officinale*, Bostock and Benton (1979) found that of 185.5 ovules produced/inflorescence, 181.7 seeds were produced, and 178.1 were dispersed. As well, an average of 12.2 inflorescences/plant were observed, resulting in approximately 2170 seeds/plant being produced during the growing season. Ford (1981b) found that the number of inflorescences/plant, number of seeds/inflorescence and, therefore, the number of seeds/plant varied with the habitat in which *Taraxacum* agamospecies were found. The number of inflorescences/plant was 7.7 for plants on denuded roadsides, 1.7 for plants on non-denuded roadsides, and only 0.6 for plants in upland sites. Similarly, the number of seeds/inflorescence was 151 for plants growing in denuded roadside sites, as compared to 119 in non-denuded roadside sites, and only 62 in upland sites. Similarly, a US study found that the number of inflorescences/plant and florets/inflorescence depended on the size and vigour of the plant (Longyear 1918). Small stunted plants growing in dry soil may produce only a single inflorescence with 30 florets/inflorescence; while large clumps of plants along roadsides may produce 50 or more inflorescences at once with more than 200 florets/inflorescence (Longyear 1918).

After flowering, *T. officinale* scapes elongate significantly, allowing enhanced wind dispersal of seeds (Radosevich and Holt 1984). The seeds have pappi that further aid in dispersal by wind (Lovell and Rowan 1991). The seed settling velocity may be a useful surrogate for the measurement of dispersal ability (Andersen 1992) and the average settling velocity of seed-pappus units of *T. officinale* is 2.37 km h<sup>-1</sup> (Andersen 1993). Sheldon and Burrows (1973) found that the distance travelled by seed-pappus units of *T. officinale* increased with increasing wind speed. Wind speeds of 5.47, 10.94, and 16.41 km h<sup>-1</sup> resulted in distances travelled of 0.76, 1.52, and 2.27 m, respectively. Von Hofsten (1954) estimated the dissemination distance of seeds was 200–500 m. Seeds are also dispersed in the excreta of animals such as cattle, horses and birds (Salisbury 1961), and by water, especially via irrigation ditches (Salisbury 1961; Radosevich and Holt 1984). Seeds can survive in water for up to 9 months (Comes et al. 1978).

Collins (2000) found that the mean mass (mg) per seed in the UWO collection ranged from 0.33 mg in an August collection to 0.68 mg in a late October collection. At the peak of flowering in May, it ranged between 0.43 and 0.49 mg. The seeds produced in late October and early November were significantly ( $P = 0.05$ ) heavier than those produced at other times of the year. UK reports of seed weights vary, with Salisbury (1961) stating an average weight of 0.8 mg, Bostock (1978) reporting an average seed weight of 0.583 mg, while Sheldon (1974) reported the average seed weighed 0.0549 mg; one-tenth as much as in any other report. Also, the average seed was reported as 10.25 mm in length, with a pappus diameter is 6.94 mm (Sheldon 1974).

(c) *Seed banks, seed viability and germination.* Very large populations of *T. officinale* seeds can be found in soil. For example, in the UK, Champness and Morris (1948) found 1 575 000 seeds  $\text{ha}^{-1}$  in the top 13 cm of soil in a grassland area, and 2 350 000 seeds  $\text{ha}^{-1}$  in the top 18 cm of an arable field.

At least 7 d must elapse after the opening of the inflorescence before most seeds of *T. officinale* are mature enough to germinate (Longyear 1918). Therefore, if all inflorescences, including those that have closed to ripen the seeds, are removed from the plant (e.g., by mowing), the germination of seeds from the dried inflorescences that have ripened after cutting is only 13% (Longyear 1918; Roberts 1936). Fully mature seeds of *T. officinale* lack primary dormancy and are able to germinate almost as soon as they leave the plant (Longyear 1918; Martinková and Honěk 1997). However, the proximity of the seeds to each other influences germination. In a US study, seeds placed singly or in groups of 5, 10 or 25 had germination percentages of 68, 64, 54 and 41%, respectively. This significant decrease in germination with increasing density may be a population-regulating mechanism (Linhart 1976).

The germination capacity of *T. officinale* seeds is generally 80–90% (Falkowski et al. 1989), and Martinková and Honěk (1997) reported 94% germination on moist filter paper, 28 d after collection. Most seeds germinate within 1.5 mo after dispersal (Ogawa 1978). However, von Hofsten [quoted by King (1966)] estimated that, of 10 000–20 000 seeds  $\text{m}^{-2}$  dispersed into a meadow, only 50–125 would establish successfully. Germination is impaired after passage through the digestive tracts of cattle, with germination of 52%, 31% and 22% after retention in faeces for 5 h, 24 h and 48 h, respectively (Falkowski et al. 1989, 1990). Germination is also influenced by individual seed weight (Tweney and Mogie 1999). There is variation in the weight of seeds produced in a single inflorescence and the heavier seeds have a greater probability of germination (Tweney and Mogie 1999).

Seeds of *T. officinale* germinate over a wide range of temperatures, from 5–35°C (Mezynski and Cole 1974; Washitani 1984), with less germination at higher temperatures (Martinková and Honěk 1997). Most reports indicate that seeds of *T. officinale* germinate best under alternating temperatures and light. Collins (2000) found 85–94% of seeds, from two populations from London, ON, germinated under the following regimes: 15°C/5°C with 9 h light,

25°C/10°C with 14 h light, 35°C/20°C with 15 h light and 25°C/10°C in total darkness. However, other temperature regimes in total darkness led to reduced germination, with only 75% at 35°C/20°C and 43% at 15°C/5°C. Cross (1931) found 75–76% of seeds, collected from Ottawa, ON, germinated in alternating temperatures of 30°C/20°C, while only 60–65% germinated at a constant temperature of 18–20°C. Mezynski and Cole (1974) reported maximum germination of fresh seeds, collected from Maryland, USA, at an alternating temperature of 20°C for 16 h and 10°C for 8 h (while seeds stored for 30 d germinated best at 20°C/15°C). Maguire and Overland (1959) found that 92% of seeds, collected from Washington State, USA, germinated at alternating temperatures (30°C/20°C) in alternating light and darkness, but when kept in darkness, there was only 72% germination. Also, at a constant temperature of 15°C in dark, only 4% germination was recorded, but when alternating light and dark was added to the same constant temperature, 96% germination was observed. Two British studies (Thompson 1989; Williams 1983) reported similar results. Seed germination was greater, faster and more uniform in light than in dark (Isselstein 1992; Letchamo and Gosselin 1996). In a Swedish study, Noronha et al. (1997) used cold, dark stratification to show that seeds of *T. officinale* have an inducible light requirement for germination. Ecologically, this inducible light requirement is important for preventing the germination of buried seeds in conditions unfavourable to seedling development (Noronha et al. 1997).

There are varying reports of the viability of seeds of *T. officinale* after storage. Following burial of *T. officinale* seeds for varying time periods, a small number of seeds (1%) were still viable for up to 9 yr after burial (Burnside et al. 1996). Typically, 1–6% of *T. officinale* seeds remained viable 4 yr after burial in soil, and soil storage for 5 yr or longer resulted in little detectable viability (Chepil 1946; Roberts and Neilson 1981). Seeds remained viable longer in the soil (up to 20–30 yr) than when dry-stored indoors (von Hofsten 1954). Depth of seed burial was negatively correlated to establishment success (Bostock and Benton 1983). Storage of seeds at room temperature decreased seed viability, compared to storage at 4°C (Letchamo and Gosselin 1996). Mezynski and Cole (1974) reported that percentage germination decreased during 30 d storage of seeds at –15°C or 22°C, compared to fresh seeds. Al-Hially (1991) found that the rate of germination increased after 90 d storage.

The position of *T. officinale* seeds affects germination, with greatest germination occurring when there is good contact between the substrate and the scar of attachment of the seed, allowing water uptake (Sheldon 1974). The hygroscopic pappus can move to alter the seed position as humidity changes and, in high humidity, the pappus closes hygroscopically (Sheldon 1974). The backward-pointing hairs and teeth of the seed may play a role in firmly anchoring it during seedling establishment (Sheldon 1974). Increasing soil compaction decreases seed germination, radicle penetration and seedling establishment, partly due to removal of microsites (Sheldon 1974).

The endosperm of *T. officinale* is cellular and the uninucleate cells have meagre cytoplasm. At the globular stage of

the embryo, the endosperm shows endospermous haustoria at its middle and chalazal portions, which perhaps act to draw nourishment from the adjoining tissue to cope with the increasing nutritional need of the growing embryo, leading to increased seed set (Sood and Sood 1992).

(d) *Vegetative reproduction.* The regenerative capacity of *T. officinale* roots has been examined by Naylor (1941) and Khan (1973). Vegetative propagule weight was positively correlated to establishment success (Bostock and Benton 1983). Root segments that were 1.25 mm in diameter had to be at least 6–10 mm in length to regenerate, and segments as short as 2 mm could regenerate only if they were more than 4 mm in diameter (Warmke and Warmke 1950). The minimum length for shoot regeneration was 1.5 mm and for root regeneration 2 mm (Khan 1969). More shoots and roots regenerated from longer root segments than from shorter ones (Khan 1969). Regenerative capacity decreased as fragment volume decreased (down the length of the root) (Mann and Cavers 1979). Planting cuttings in an inverted or horizontal plane, rather than the normal planting orientation resulted in a decline in regeneration and survival, and an increase in regeneration time (Mann and Cavers 1979). Planting depth did not consistently influence regenerative capacity or timing (Mann and Cavers 1979). Root fragments were highly vigorous and capable of producing new plants even when covered by 5–10 cm of soil (Falkowski et al. 1989, 1990). This may be due to their high sugar content (~11% of dry matter) (Falkowski et al. 1990).

## 9. Hybrids

Although sexual reproduction is rare or absent in North America (Solbrig and Simpson 1974), natural hybrids have been reported to occur between *T. officinale* and *T. platycarpum* in Japan (Watanabe et al. 1997). More than 90% of the plants classified as *T. officinale* had alleles introduced from *T. platycarpum* and were morphologically intermediate between the two species with respect to the number of marginal hairs in the outer involucre bract, the length of corniculate appendages on the outer involucre bract, and the size of the seed (Watanabe et al. 1997).

## 10. Population Dynamics

In a study in West Virginia, the finite rate of increase for an entire population was largest in fall and declined throughout the rest of the year (Vavrek et al. 1997). The age of *T. officinale* plants can be determined by counting the annual growth-rings in the principal roots and plants that are 10–13 yr old are common (Roberts 1936; von Hofsten 1954). Reader (1991a) found that a significantly greater number of seedlings emerged on ridges than in hollows in vegetated plots, but the experimental removal of ground cover increased seedling emergence more in hollows than on ridges. Genetically variable individuals of *T. officinale*, known as biotypes, have been identified by their polymorphic isozyme patterns. Some biotypes of *T. officinale* are able to outcompete others under certain conditions (Solbrig and Simpson 1977). For example, two biotypes grown in garden plots were left undisturbed, or subjected to artificial

disturbance by defoliation or removal of the entire plant by tilling (Solbrig and Simpson 1977). In undisturbed plots, biotype D accounted for 85% of the plants whereas in disturbed plots, biotype D only accounted for 7–9% of the plants (Solbrig and Simpson 1977). These population differences were a direct response to differences in disturbance (Solbrig and Simpson 1974).

The strong competitive ability of *T. officinale* is due to several properties, including the tap root, which penetrates more deeply to reach moisture and nutrients than roots of most other plants (Jackson 1982). In addition, plants release ethylene, which can inhibit the growth of other plants nearby (Dwyer 1977; Jackson 1982). The variable growth habit of *T. officinale*, from thick, wide-spreading rosettes of leaves that suppress plants, to erect elongated leaves among denser growth, is of competitive advantage (Jackson 1982). Developing seed heads droop towards the ground where they are protected and seeds are formed without the need for fertilization (Jackson 1982). Finally, each inflorescence releases hundreds of seeds, which are effectively wind-dispersed due to the pappi (Jackson 1982). Seed burial experiments established that seedlings of *T. officinale* emerge nearly year-round, peaking in May and again in September, with this pattern continuing for up to 3 yr after planting (Chepil 1946; Roberts and Neilson 1981).

The effect of asexual reproduction is to produce offspring that are genetically identical to the parent plant (Solbrig 1971). The ability of dandelion to adapt to different ecological niches suggests that *T. officinale* has a general-purpose genotype as well as phenotypic plasticity, with a wide environmental tolerance and some adaptation to a wide range of biotic and abiotic factors (Solbrig 1971; Baker 1991). *Taraxacum officinale* can be successful as a colonizer and as an inhabitant of closed grassland (Baker 1991). Solbrig (1971) described genotypes favouring the colonizing phase as “r-selected”, emphasizing seed production, and genotypes favouring the inhabiting phase as “K-selected”, emphasizing competitive ability under different environmental conditions. *Taraxacum officinale* plants are basically r-strategists (Gadgil and Solbrig 1972). However, Ford (1981b) suggested that the measures of r and K characteristics are dependent upon the sites in which these characteristics are measured.

## 11. Response to Herbicides and Other Chemicals

Phenoxyacetic acid herbicides, such as 2,4-D and mecoprop, or the benzoic acid dicamba, or combination products of all three such as “Killex”, are used for chemical control of *T. officinale* in turf (Anonymous 1997). As early as 1944, experiments showed that 2,4-D killed *T. officinale* in lawns within 3 wk of application, leaving the grass unharmed (Peterson 1967). In Ontario, optimum control was obtained with 2,4-D applications in spring in combination with spudding (root cutting and shoot removal) (Mann 1981). *Taraxacum officinale* has been classified as intermediate in susceptibility to 2,4-D, due to tolerance by older or established plants, but it is susceptible in the seedling stage, based on the sorption capacity of the cuticle membrane (Baker and Bukovac 1971). The growth-regulating proper-

ties of 2,4-D are thought to cause the major herbicidal effects, including cell elongation, epinasty and hypertrophy, but the precise mode of action of 2,4-D is still unknown (Sterling and Hall 1997). The selectivity of 2,4-D toward dicotyledonous plants is based on differences in plant morphology, and the rate of herbicide translocation and metabolism between mono- and dicotyledonous plants (Hagin et al. 1970; Devine et al. 1993).

In creeping red fescue grown for seed in Alberta, various mixtures of herbicides were used to control *T. officinale* (Darwent and Lefkovitch 1995). In 94–100% of trials, greater than 80% control (percent reduction in biomass) of *T. officinale* was achieved by applying metsulfuron at 4.5 g ha<sup>-1</sup>, either alone or in combination with each of the graminicides sethoxydim (at 500 g ha<sup>-1</sup>) or fluazifop-P (at 250 g ha<sup>-1</sup>). A combination treatment of dicamba (at 280 g ha<sup>-1</sup>) and 2,4-D (at 560 g ha<sup>-1</sup>) provided greater than 80% control of *T. officinale* in only 25% of trials. However, tank-mixing sethoxydim (at 500 g ha<sup>-1</sup>) or fluazifop-P (at 250 g ha<sup>-1</sup>) improved the efficacy of the dicamba/2,4-D combination, resulting in greater than 80% control of *T. officinale* in 62% and 71% of trials, respectively (Darwent and Lefkovitch 1995). The enhanced control from the addition of the graminicides to the dicamba plus 2,4-D combination is probably due to the effect of surfactants that were added to the tank-mix.

Several herbicides are effective at controlling *T. officinale* in alfalfa or other forage legumes, yet they are not registered or recommended in Canada. Moyer et al. (1990) reported that annual applications of hexazinone (1.0 kg ha<sup>-1</sup>) and chlorsulfuron (0.01 kg ha<sup>-1</sup>) maintained almost complete control of *T. officinale* in alfalfa (*Medicago sativa* L.) and sainfoin (*Onobrychis viciaefolia* Scop.) in Alberta, where control was measured as the reduction in dry matter yield. In a study in Saskatchewan by Waddington (1980), the herbicides dichlobenil, terbacil, and simazine were each applied annually over 3 or 4 yr for control of *T. officinale*. Dichlobenil applied at 2.2 kg ha<sup>-1</sup> resulted in 100% reduction in the *T. officinale* population by spring of the fifth growing season. Similarly, terbacil applied at 1.1 kg ha<sup>-1</sup> resulted in 96% reduction in the *T. officinale* population by the spring of the fifth year. However, simazine was less effective when applied at 0.8 kg ha<sup>-1</sup> and 1.7 kg ha<sup>-1</sup> and resulted in only 37 and 71% reduction of *T. officinale*, respectively. A US study investigated the efficacy of buthidazole, metribuzin, simazine and 2,4-DB at various rates for the control of *T. officinale* (Sheaffer and Wyse 1982). Most herbicides temporarily reduced *T. officinale* populations, but only buthidazole continued to reduce populations in the year following application. However, control of *T. officinale* did not consistently increase alfalfa yield, and so the use of herbicides to control *T. officinale* in alfalfa cannot be recommended (Sheaffer and Wyse 1982).

In other Canadian studies, *T. officinale* plants were tolerant to ethalfuralin applied at 1.1 kg a.i. ha<sup>-1</sup> and incorporated into the soil prior to planting *T. officinale* as a crop for salad use in Québec (Michaud et al. 1993). Paraquat did not control *T. officinale* during fallow in the southern Canadian

prairies because it has only contact action and will not affect the root (Blackshaw and Lindwall 1995).

Maleic hydrazide has been used to control *T. officinale* in apple orchards in the USA. Plant numbers were reduced from 5.1–10.1 individuals m<sup>-2</sup> in control plots to 2.6 individuals m<sup>-2</sup> when maleic hydrazide was applied at a rate of 6.7 kg ha<sup>-1</sup>. Similar results were found for both spring and fall applications of the herbicide (Miller and Eldridge 1989). Mowing just before treatment with maleic hydrazide may have decreased *T. officinale* control (Miller and Eldridge 1989). In another US study, *Taraxacum officinale* was controlled by quinclorac at 0.84 kg ha<sup>-1</sup> and by a combination of clopyralid plus triclopyr at 0.16 kg ha<sup>-1</sup> plus 0.47 kg ha<sup>-1</sup> respectively (Neal 1990).

In a study in Virginia, USA, Chandran et al. (1998) found that a spring application of isoxaben at a rate of 0.56 kg ha<sup>-1</sup> in turfgrass caused 100% control of *T. officinale* 1 mo after application, where control was measured as emergence compared to untreated plots. However, control of *T. officinale* dropped to 62%, 1 yr after application. A fall application of isoxaben at 0.56 kg ha<sup>-1</sup> resulted in 83% control of *T. officinale* after 1 yr. Results were similar for isoxaben applied at 0.84 kg ha<sup>-1</sup> or 1.12 kg ha<sup>-1</sup>. Control of *T. officinale* in plots that received both spring and fall applications of isoxaben was similar to control of *T. officinale* in plots receiving only fall applications. A spring application of oxadiazon at 3.36 kg ha<sup>-1</sup> resulted in 100% control of *T. officinale* 1 mo later, but after 1 yr, *T. officinale* abundance was greater in these treated plots than in untreated plots. The findings for fall applications of oxadiazon at this rate were similar, revealing that oxadiazon only provides short-term control of *T. officinale* (Chandran et al. 1998).

Other chemicals have also been tested for their herbicidal efficacy on *T. officinale*. In laboratory experiments in the USA, allelopathic saponins from the roots of alfalfa had little effect on the germination of seeds or the growth of seedlings of *T. officinale* (Waller et al. 1993). The herbicidal efficacy of corn gluten meal, a waste product from corn milling, has been tested on *T. officinale* and other weeds (Quarles 1999). When applied at 324 g m<sup>-2</sup> in greenhouse pot tests, corn gluten meal reduced survival of *T. officinale* by more than 75% by inhibiting root formation during germination. Under field conditions, corn gluten meal reduced the *T. officinale* population by about 90%, which was probably due to the combination of root inhibition and competition from Kentucky bluegrass (Quarles 1999).

## 12. Response to Other Human Manipulations

Integrated pest management strategies for *T. officinale* in turf include the selection of competitive turfgrass species, application of increased quantities of fertilizers, and mechanical control by mowing or removal. For example, studies in Ontario showed that Kentucky bluegrass was the least competitive of six turf species, perennial ryegrass was the most competitive and increased amounts of nitrogen fertilizer suppressed *T. officinale* in all turfgrass swards (Hall et al. 1992; Tripp 1997). Grass competition under frequent close mowing did not prevent *T. officinale* from surviving and spreading (Timmons 1950). Of four grasses tested,

native buffalograss was the most competitive with *T. officinale* (Timmons 1950). The size and average density of *T. officinale* plants can be reduced by decreasing the row spacing of grass crops (Darwent and Elliott 1979).

Encroachment of *T. officinale* into turfgrass was greater in turf receiving limestone applications and tended to decrease with increasing phosphorus rates (Turner et al. 1979). However, encroachment appeared to be more related to competition than the nutritional requirements of weeds since encroachment tended to decrease as the yield of turfgrass clippings increased (Turner et al. 1979). Phosphorus levels had a greater impact on growth of *T. officinale* than pH, with an application of 84 kg superphosphate ha<sup>-1</sup> increasing the yield of *T. officinale* tenfold compared to no added superphosphate, while added nitrogen had no effect (Zapralka and Peters 1982). Root growth was more responsive to differences in phosphorus and pH than top growth (Zapralka and Peters 1982). Tilman et al. (1999) showed that interspecific competition can be modified by changes in resource supply rates. For example, *T. officinale* had a higher requirement for potassium and its biomass was more limited by potassium than any of five common grass species tested, suggesting that it is a poorer competitor for potassium than these grasses. Also, *T. officinale* density and abundance were positively correlated with potassium levels in its tissues (Tilman et al. 1999).

*Taraxacum officinale* control was greater in plots of Kentucky bluegrass treated with 600 kg N ha<sup>-1</sup> than when treated with 300 kg N ha<sup>-1</sup>, even though both levels are very high (Johnson and Bowyer 1982). This supported the findings of Zahnley and Duley (1934) who found that after they had fertilized and produced a dense growth of grass, *T. officinale* seedlings did not become established readily and growth was repressed by competition from the grass. Competition was further increased by cutting the grass at a greater height, which tended to shade the ground and retard the development of *T. officinale* (Zahnley and Duley 1934).

Mechanical removal of *T. officinale* plants has been of limited value, as the long taproot must be entirely removed. Even small pieces of root can propagate new plants (Warmke and Warmke 1950; Mann and Cavers 1979). In addition, debudding or defoliation of the plant can result in a shift of the shoot-root ratio, favouring root growth and exacerbating the problem (Letchamo and Gosselin 1995). Struik (1967) studied the reaction of *T. officinale* to different grassland management regimes; mown, heavily grazed, lightly grazed, and uncut. As the degree of defoliation increased, plant radius decreased, length of the longest leaf decreased, root length decreased, leaf number increased and plant form changed from upright to slanting and appressed. Percent cover with *T. officinale* was significantly higher in a long-term grazed treatment (Popolizio et al. 1994). *Taraxacum officinale* is able to rapidly replace a large quantity of leaves relative to other organs during short periods (every 30–50 d) between mowing (Sawada et al. 1982), partly due to increased light availability (von Hofsten 1954). Cutting the scapes of *T. officinale* in bud or in flower resulted in the production of seeds that were non-viable, while

cutting the scapes after the seeds had ripened resulted in 91% seed germination (Gill 1938).

Significantly higher chlorophyll content, and root and shoot growth were found under hydroponic culture of *T. officinale* (Letchamo and Gosselin 1995). Debudding the plants under hydroponic medium increased root yield by 131% compared with the control (Letchamo and Gosselin 1995).

Occurrence of *T. officinale* is greater in crop rotation systems with a high frequency of broadleaf crops (four rotations with broadleaf crops in 3 of 4 yr) compared to a low broadleaf frequency of broadleaf crops (three rotations with broadleaf crops in 2 of 4 yr) (Stevenson and Johnston 1999). On the semi-arid Canadian prairies, *T. officinale* was present in all crop rotations examined; continuous winter wheat, winter wheat-fallow, winter wheat-spring canola, winter wheat-lentil or flax (Blackshaw et al. 1994). Densities were higher in minimum and zero-till treatments than in conventional till (Légère et al. 1993; Blackshaw et al. 1994).

Tillage frequency has been shown to have an impact on germination and establishment of *T. officinale*. In spring wheat in clay soil in northern Alberta, higher densities of *T. officinale* were found under zero tillage systems than under other systems (Arshad et al. 1994). In eastern Canada, density was higher in alfalfa that had been seeded directly into grain stubble, as compared to conventionally-seeded alfalfa (Rioux 1994). In sweet corn, *T. officinale* emergence was not affected by tillage, probably because of the short time between seed dispersal and germination (Mohler and Calloway 1992). The presence of crown vetch as a living mulch reduced *T. officinale* numbers by 74% in no-tillage corn (Hartwig 1989). In the UK, the occurrence of *T. officinale* in plots sown with spring barley was inversely proportional to cultivation frequency. Plots that were never cultivated had a total of 196 *T. officinale* plants m<sup>-2</sup>. Yearly cultivation resulted in 72 plants m<sup>-2</sup>, quarterly cultivation resulted in 54 plants m<sup>-2</sup>, and monthly cultivation resulted in 33 plants m<sup>-2</sup> (Chancellor 1964).

*Taraxacum officinale* can survive after tillage with a plough or disc, because of its ability to regenerate from root sections (von Hofsten 1954). However, Falkowski et al. (1990) reported ploughing to be an effective method of eliminating *T. officinale* because the lower parts of roots were less viable than the upper parts, which were buried by ploughing. Flame weeding in pear and apple orchards favours the growth of *T. officinale* (Ferrero et al. 1994).

The timing and frequency of harvesting also influences the degree of dandelion infestation. Moyer et al. (1999) found that the growth-stage-based harvest times of alfalfa affected encroachment by *T. officinale* and the resultant alfalfa quality. For example, when alfalfa was harvested at the vegetative or prebud stage, it contained 25% *T. officinale* by weight, but when it was harvested at any other stage such as flowering, it contained <2.5%.

When *T. officinale* seeds were exposed to different doses of radiation before sowing in a model situation, or in the zone of the Chernobyl accident, there was an increase in the frequency of chromosomal aberrations in the cells of meristematic tissues, an increase in stability with respect to fur-

ther radiation, and a change in the rate of growth and development (Pozolotina 1996). The potential use of electromagnetic radiation in the form of microwaves has been studied for *T. officinale* control on railway tracks in Europe (Kunisch et al. 1992). Plants were killed by microwave treatment for 16 s, which increased the soil temperature by more than 40°C in controlled environments (Kunisch et al. 1992).

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

#### Herbivory

(a) *Mammals, including both domestic and wild animals.* Mammals, including rabbits, cats, chipmunks, ground squirrels, groundhogs (woodchucks), prairie dogs, pocket gophers, deer, moose, elk, black bears and grizzly bears, eat the leaves of *T. officinale* (Ellison and Aldous 1952; Powell 1972; Angier 1980; Jackson 1982; Swihart 1990). Dandelion is an excellent pasture feed for dairy cattle, improving milk flow and quality (Jackson 1982). However, manure from cattle can contain viable seeds and, when applied to cropland, may serve as a source of introduction and dispersal (Mt. Pleasant and Schlather 1994). Domestic animals, such as goats and pigs, eat the seeds (Powell 1972), and sheep and geese have been used for biological control of *T. officinale*, with sheep being more effective than geese in controlling the weed in Christmas tree plantations in North Carolina, USA. (Müller et al. 1999).

(b) *Birds and/or other vertebrates.* *Taraxacum officinale* seeds are eaten by at least 12 songbirds native to Canada (Jackson 1982). Birds such as siskins, common house finches, goldfinches and sparrows eat the seeds (Longyear 1918; Angier 1980). Leaves, inflorescences and seed heads are eaten by chickens, ducks, geese, Canada geese, grouse, partridges, pheasants, prairie chickens, quail, ruffed grouse and sage grouse (Eckert et al. 1973; Angier 1980; Jackson 1982). Seed predation by birds, ants and rodents reduced seed number and seedling emergence of *T. officinale* more where ground cover was dense (in hollows) than in less dense communities (on ridges) (Reader and Beisner 1991). Thus, ground cover can restrict seedling emergence by providing a habitat for seed predators (Reader 1991b).

(c) *Insects and Arachnids.* Due to its early flowering and rich supply of nectar, *T. officinale* is a food source for many insects, including butterflies, bee flies, hawk moths and bumblebees in Canada (Jackson 1982). Judd (1971) collected 152 species of insects in the Orders Collembola, Thysanoptera, Hemiptera, Homoptera, Coleoptera, Diptera and Hymenoptera from the inflorescences of *T. officinale* in Ontario.

The cynipid wasp, *Phanacis taraxaci* (Ashmead), forms galls on the abaxial surfaces of maturing *T. officinale* leaves in Canada and the USA. These galls influence the partitioning of photoassimilates by actively redirecting carbon resources from unattacked leaves (Paquette et al. 1993; Bagatto et al. 1996). The first record of European dandelion leaf-gall midge, *Cystiphora taraxaci* Kieffer, in north-cen-

tral Saskatchewan was by Peschken et al. (1993). This midge induces purple-red pustule galls on the upper surfaces of leaves (Neuer-Markmann and Beiderbeck 1990). *T. officinale* is also a host for the braconid *Pholetesor ornigis* (Weed), a parasitoid that attacks larvae of the leaf miner *Phyllonorycter blancardella* (Fabr.), which is a pest of apple in Canada (Hagley and Barber 1992).

*Taraxacum officinale* also acts as a host for several aphid species. In Canada, *Aphis knowltoni* Hottes & Frison has been collected from roots of *T. officinale* (Wood-Baker 1980), and *Aphis taraxacicola* (Börner) has been recorded on *T. officinale* in Japan (Sugimoto and Takahashi 1996). In the USA, *T. officinale* is a favourite secondary weed host of the green peach aphid (*Myzus persicae* Sulzer) during the summer (Kaakeh and Hogmire 1991). In the UK, it is a natural host of the lettuce root aphid, *Pemphigus bursarius* (L.) (Gange and Brown 1991).

In the USA, the weevil, *Ceutorhynchus punctiger* Gyllenhal, attacks *T. officinale* inflorescence buds, seeds and leaves (McAvoy et al. 1983). McAvoy et al. (1983) suggested that *C. punctiger* could be used as a biocontrol to reduce the viable seed population of *T. officinale* but host specificity and key mortality factors of the weevil must first be studied. Another weevil, *Barypeithes pellucidus* (Boheman), feeds lightly on *T. officinale* leaves but moderately on the epidermis of the scapes (Galford 1987). In laboratory experiments, the boll weevil, *Anthonomus grandis* Boheman, a pest of cotton, feeds and survives on *T. officinale* cuttings for 8–10 d by eating pollen and seed heads. Therefore, feral boll weevils, emerging prior to cotton flowering, may initially survive on *T. officinale* plants and subsequently infest cotton crops in the USA (Haynes and Smith 1992). The black vine weevil, *Otiorynchus sulcatus* (Fab.), also feeds on *T. officinale* in Japan and the UK; although some resistance is conferred by mycorrhizal associations (Masaki et al. 1984; Gange et al. 1994).

*Taraxacum officinale* is a host for many other insects in the USA. These include several caterpillars, such as those of the cabbage looper (*Trichoplusia ni* Hübner), the yellow-striped armyworm (*Spodoptera ornithogalli*) (Dussourd and Denno 1994), and the tiger moth (*Diacrisia virginica* Fabr.), which prefers to feed on *T. officinale* over grasses (Dethier 1993). It is also a host for the small milkweed bug, *Lygaeus kalmii* Stal. (Fox and Caldwell 1994), but significantly fewer of these bugs survived on *T. officinale* than on milkweed species. Nymphs of the potato leafhopper, *Empoasca fabae* (Harris), develop and adults survive and reproduce on *T. officinale* (Lamp et al. 1984). It was suggested that the leafhopper may have a role as a biological weed control agent. Crickets [*Allonemobius allardi* (Alexander & Thomas)] have also been recorded feeding on leaves of *T. officinale* (Jacobs et al. 1992). Root feeding larvae of the Japanese beetle (*Popillia japonica* Newman) and the southern masked chafer (*Cyclocephala lurida* Bland), commonly called white grubs, feed upon and reduce root biomass of *T. officinale* (Crutchfield and Potter 1995).

In Japan, the coccinellid *Coccinula crotchii* (Lewis) survives on inflorescences of various species, including *T. officinale* (Hoshikawa 1995). Also, adult scarab beetles,

*Anomala octiescostata* Burmeister, are attracted to and voraciously feed on its inflorescences (Leal et al. 1994). This attraction is mediated by the chemical kairomone (Leal et al. 1994).

In Germany and Switzerland, *T. officinale* is the most important food plant for larvae of cockchafers, also called May or June beetles (*Melolontha melolontha* L.) and, for egg-laying, the females preferred soil under *T. officinale* more than soil under other dicotyledons and grasses (Schütte and Hauss 1985; Keller 1986; Schütte 1996). Von Hofsten (1954) reported the following insects on *T. officinale* in Sweden: *Paroxyna tessellata* Loew., *Dolycoris baccarum* L., *Corizus hyoscyami* L., *Stictopleurus crassicornis* L., *Carpocoris pudicus* Poda., *Polomena pracina* L. and *Hepiulus humili* L.. Kuusi et al. (1984) recorded turnip root fly (*Delia floralis* Wied.), cabbage moth (*Mamestra brassicae* L.) and pollen beetle (*Meligethes aeneus* F.) on *T. officinale* in Finland.

The mite, *Epirimerus taraxaci* Liro, inhabits the leaves of *T. officinale* causing discolouration and russeting in Yugoslavia (Petanovic 1990). This mite has a narrow host range but it includes several cultivated plants as well as weeds.

(d) *Nematodes and/or other non-vertebrates*. In the USA, *T. officinale* acts as a host to two dagger nematodes, *Xiphinema americanum* Cobb and *X. rivesi* Dalmasio, which can transmit plant viruses (Georgi 1988a,b). Members of the *Meloidogyne* sp. Goeldi have also been found on *T. officinale* in Canada and the USA, as well as *Meloidogyne incognita* (Kofoid & White) Chitwood, *Ditylenchus destructor* Thorne and *Pratylenchus penetrans* (Cobb) Chitwood & Oteifa in the USA (Anonymous 1960; Conners 1967).

Other non-vertebrates such as slugs, snails and earthworms, also use *T. officinale* as a host. In UK studies, slugs of the genus *Deroceras* found *T. officinale* highly palatable in a number of feeding trials (Duval 1971; Dirzo 1980; Cook et al. 1996; Hanley et al. 1996) and younger seedlings were grazed more severely by the reticulated slug *Deroceras reticulatum* (Müller) (Hanley et al. 1995). *D. reticulatum* and another slug, *Arion lusitanicus* (Mabille), damage oilseed rape and other arable crops in Europe. In food choice trials, *T. officinale* was very attractive to *A. lusitanicus* and rape was not significantly more defoliated than *T. officinale* (Frank and Friedli 1999). The authors even recommended sowing *T. officinale* (and other weeds) in high quantities into fields of rape to prevent severe slug damage. In other European studies, the land snail (*Helix aspersa* Müller) and juvenile earthworms (*Lumbricus terrestris* L.) also found *T. officinale* highly palatable (Daniel 1991; Desbuquois and Daguzan 1995).

*Diseases*. Microorganisms reported from *T. officinale* worldwide are listed in Table 1 and those recorded in Canada have been reviewed by Conners (1967) and Ginns (1986).

(a) *Fungi*. Numerous fungi have been reported on *T. officinale* in Canada and some of the more important examples are discussed here. *Puccinia taraxaci* Plowr., a rust fungus,

forms numerous, minute, dark brown pustules on leaves (Longyear 1918; Conners 1967). Another fungus *Synchytrium taraxaci* de Bary & Woronin, causes tiny swellings or galls on leaves that can lead to partial stunting (Longyear 1918; Ginns 1986). The powdery mildew fungi *Sphaerotheca fuliginea* (Schlect. Ex Fr.) Poll., *S. humili* var. *fuliginea* (Schlect.) Salm. and *S. macularis* (Wallr.:Fr.) have been recorded (Conners 1967; Ginns 1986). In cultivated *T. officinale* in Germany and Finland, powdery mildew reduces yields and requires control with fungicides (Kuusi et al. 1984; von Hinrichs 1988). but Longyear (1918) observed only slight damage in the USA.

*Phoma exigua* (Desm.) and *P. herbarum* (Westend.) have been isolated from *T. officinale* in Ontario and considered as potential biocontrol agents (Neumann Brebaum 1998; Neumann Brebaum and Boland 1999). *P. taraxaci* Hofsten was considered as a biocontrol agent for *T. officinale* in Sweden (von Hofsten 1954). *P. taraxaci* spread by pycnospores and infected seeds, however, it was extremely variable with respect to its pathogenicity on *T. officinale* and its viability in soil. Von Hofsten (1954) also mentioned an unnamed "ring-forming fungus" which released a substance that was highly toxic to *T. officinale* and other plants.

*Sclerotinia* species have also been tested as biological control agents for *T. officinale* in Canada (Riddle et al. 1991). *Sclerotinia sclerotiorum* (Lib.) de Bary and *S. minor* Jagger were evaluated in a controlled environment and in turfgrass swards for their virulence on *T. officinale*. Isolates of both species reduced the dry weight of plants in a controlled environment and reduced the number of plants in turfgrass swards. Heat-killed seeds of perennial ryegrass were suitable as both a growth substrate for *Sclerotinia* spp. and a delivery system to *T. officinale* (Riddle et al. 1991). *Sclerotinia sclerotiorum* caused localized infection on the leaf laminae of *T. officinale* when artificially inoculated as a mycelium-on-wheat preparation (Waipara et al. 1993). Also, *S. sclerotiorum* created basal necroses of 1–2 cm in length on tap roots. These necroses inhibited leaf regrowth from the root after defoliation (Burpee 1992). *Sclerotinia minor*, produced in a granular sodium alginate formulation or on autoclaved barley grains, is also considered a potentially effective biological control agent against *T. officinale* (Ciotola et al. 1991; Brière et al. 1992).

(b) *Bacteria*. The bacterium, *Pseudomonas syringae* pv. *tagetis* Hellmers, has been isolated from *T. officinale* in the USA where it caused apical chlorosis and necrotic leaf spots (Rhodehamel and Durbin 1985). Sterk et al. (1987) reported that *Agrobacterium tumefaciens* (Smith and Townsend) Conn is found on *Taraxacum* species in the Netherlands, causing galls on the roots and, sometimes, the leaves.

(c) *Viruses*. More than twenty viruses can infect *T. officinale*, with some causing severe mottling and leaf malformation symptoms. Dandelion yellow mosaic virus (DYMV) causes a yellow mottle (chlorotic rings and spots) on *T. officinale* and also infects lettuce (Kassanis 1947; Bos et al. 1983). The virus can be transmitted by aphids (Kassanis 1947; Bos et al. 1983) and is similar to parsnip yellow fleck

**Table 1. Microorganisms reported from *T. officinale* worldwide**

Organism	Reference	Geographical region
<i>Agrobacterium tumefaciens</i> (Smith and Townsend) Conn	Sterk et al. (1987)	Netherlands
Alfalfa mosaic virus	Brcák (1979)	Czechoslovakia, Scandinavia
Arabis mosaic virus (Arabis mosaic nepovirus)	Brcák (1979), Brunt et al. (1996)	Czechoslovakia, Scandinavia
Argentine plantago virus	Gracia et al. (1983)	Argentina
Aster Yellows (phytoplasma)	Wang and Hiruki (2001)	Canada
<i>Ascochyta doronici</i> Allesch.	Farr et al. (1989)	USA
Beet pseudo yellows virus	Duffus (1965), Duffus and Johnstone	Australia, Spain
(Beet pseudo–yellows closterovirus)	(1981), Soria et al. (1991), Brunt et al. (1996)	USA
Botrytis cinerea Pers. ex Fr.	Anonymous (1960), Kuusi et al. (1984), Farr et al. (1989)	Finland, USA
Canola Yellows (phytoplasma)	Wang and Hiruki (2001)	Canada
<i>Centrospora acerina</i> (R. Hartig) A. G. Newhall	Tompkins and Hansen (1950)	USA
<i>Ceratobasidium anceps</i> (Bres.&Syd.)	Connors (1967)	Canada
Cherry rasp leaf virus (Cherry rasp leaf nepovirus)	Brcák (1979), Brunt et al. (1996)	Czechoslovakia, Scandinavia
Chrysanthemum latent virus`	Brcák (1979)	Czechoslovakia, Scandinavia
<i>Colletotrichum dematium</i> (Fr.) Grove	Connors (1967)	Canada
Colorado red-node virus	Thomas (1949)	USA
Cucumber mosaic virus	Brcák (1979)	Czechoslovakia, Scandinavia
Dandelion carlavirus	Dijkstra et al. (1985), Brunt et al. (1996)	Netherlands
Dandelion latent carlavirus	Johns (1982), Brunt et al. (1996)	Canada
Dandelion necrotic blotch	Brcák (1979)	Czechoslovakia, Scandinavia
Dandelion necrotic ringspot virus (Dandelion mosaic virus)	Cech and Branisová (1973)	Czechoslovakia
Dandelion yellow mosaic virus (Dandelion yellow mosaic sequivirus, Yellow mosaic lettuce virus, Lettuce necrosis virus)	Moore (1946), Kassanis (1947), Brcák (1979), Bos et al. (1983), Brunt et al. (1996)	Czechoslovakia, Netherlands, Scandinavia, UK
<i>Ditylenchus dipsaci</i> (Kuehn) Filip.	Anonymous (1960)	USA
<i>Erisiphe cichoracearum</i> DC.	Ubrizsy (1946), Anonymous (1960), Farr et al. (1989), von Hinrichs (1989)	Germany, Hungary, USA
European yellows virus	Blattny et al. (1954)	Czechoslovakia
Grapevine yellows (MLO)	Arzone et al. (1995)	Italy
Italian clover phyllody	Firrao et al. (1996)	Italy
Kok-Sagyyz virus	Ryjkoff (1943)	USSR
Lettuce big-vein virus	Campbell (1969), Brcák (1979), Demírci et al. (1995)	Czechoslovakia, Scandinavia, Turkey, USA
Lettuce mosaic virus	Brcák (1979)	Czechoslovakia, Scandinavia
Lettuce virus	Anonymous (1948)	Switzerland
<i>Longidorus euonymus</i> (Nematoda: Dorylaimida)	Romanenko and Korchinsky (1994)	Russia
<i>Olpidium brassicae</i> (Woronin) P. A. Dang	GINNS (1986)	Canada
Peach rosette mosaic virus (Peach rosette mosaic nepovirus)	Ramsdell and Myers (1978), Brunt et al. (1996)	USA
Petunia asteroid mosaic virus	Fuchs et al. (1994)	Germany
<i>Phoma exigua</i> (Desm.)	Neumann Brebaum and Boland (1999)	Canada
<i>Phoma herbarum</i> (Westend.)	Neumann Brebaum and Boland (1999)	Canada
<i>Phoma taraxaci</i> Hofsten	von Hofsten (1954)	Sweden
Phyllactinia corylea Pers. ex Karst.	Anonymous (1960)	USA
<i>Phyllactinia guttata</i> (Wallr.:Fr.) Lév	Shaw (1973), Farr et al. (1989)	USA (Pacific Northwest)
<i>Phynatotrichopsis omnivora</i> (Duggar) Hennebert	Anonymous (1960), Farr et al. (1989)	USA
<i>Physarum cinereum</i> (Batsch) P.	Farr et al. (1989)	USA
<i>Plasmopara halstedii</i> (Farl.) Berl. & De Toni in Sacc.	Anonymous (1957)	Canada (Québec)
Potato y virus	Lytaeva (1971), Brcák (1979)	Czechoslovakia, Scandinavia, USSR
Potato parastolbur virus	Valenta et al. (1961)	Slovakia
<i>Protomyces pachydermus</i> Thümen	Seymour (1929), Anonymous (1960), Farr et al. (1989), Ellis and Ellis (1997)	USA
<i>Pseudomonas syringae</i> pv. <i>tagetis</i> Hellmers	Rhodehamel and Durbin (1985)	USA
<i>Pseudomonas tabaci</i> (Wolf & Foster) Stapp	Anonymous (1960)	USA
<i>Pseudomonas viridiflava</i> (Burkholder) Dowson	Gitaitis et al. (1998)	USA
<i>Puccinia hieracii</i> (Röhlimg) Mart.	Seymour (1929), Anonymous (1960), Connors (1967), Shaw (1973), Alfieri et al. (1984), Ellis and Ellis (1997)	Canada, USA (Pacific Northwest)
<i>Puccinia taraxaci</i> Plowr.	GINNS (1986), Farr et al. (1989)	Canada, USA, Yugoslavia
<i>Puccinia variabilis</i> Grev.	Anonymous (1960), Connors (1967), Stojanovic et al. (1993)	Canada, USA
<i>Ramularia lineola</i> Pk.	Seymour (1929), Anonymous (1960), Connors (1967), Alfieri et al. (1984), Ellis and Ellis (1997), Farr et al. (1989)	Canada, USA
<i>Ramularia taraxaci</i> Karsten	Anonymous (1960), Farr et al. (1989)	USA
	Seymour (1929), Anonymous (1960), Connors (1967), Shaw (1973), Kuusi et al. (1984), Ellis and Ellis (1997), GINNS (1986), Farr et al. (1989)	Canada, USA (Pacific Northwest)

Table 1. Continued

<i>Rhizoctonia solani</i> Kühn	Chesters and Assawah (1956), Anonymous (1960), Connors (1967), Farr et al. (1989)	Canada, USA
<i>Sclerotinia minor</i> Jagger	Ciotola et al. (1991), Riddle et al. (1991), Brière et al. (1992)	North America
<i>Sclerotinia sclerotiorum</i> (Lib.) de Bary	Anonymous (1960), Shaw (1973), Alfieri et al. (1984), Farr et al. (1989), Riddle et al. (1991)	North America
<i>Sclerotinia trifoliorum</i> Eriks.	Pape (1954)	Germany
<i>Sclerotium rolfsii</i> Sacc.	Alfieri et al. (1984), Farr et al. (1989)	USA
<i>Septoria britannica</i> Trotter	Farr et al. (1989)	USA
<i>Septoria unicolor</i> Wint.	Anonymous (1960), Shaw (1973), Farr et al. (1989)	USA
<i>Sphaerotheca erigerontis</i> – <i>canadensis</i> (Lév.) L. Junnell	Seymour (1929), Ellis and Ellis (1997)	North America
<i>Sphaerotheca fuliginea</i> (Schlecht. ex Fr.) Poll.	Anonymous (1960), Connors (1967), Kuusi et al. (1984), Ginns (1986), Farr et al. (1989)	Canada, USA
<i>Sphaerotheca humili</i> var. <i>fuliginea</i> (Schlecht.) Salm	Anonymous (1960), Connors (1967), Ginns (1986)	Canada, USA
<i>Sphaerotheca macularis</i> (Wallr. ex Fr.)	Connors (1967), Shaw (1973), Ginns (1986), Farr et al. (1989)	Canada, USA
Stolbur phytoplasma	Škoric et al. (1998), Viczián et al. (1998)	Croatia, Hungary
Strawberry green petal virus	Misiga et al. (1960)	Czechoslovakia
Strawberry latent ringspot nepovirus	Brunt et al. (1996)	Germany
<i>Synchytrium</i> sp. de Bary & Woronin	Longyear (1918)	USA
<i>Synchytrium taraxaci</i> de Bary & Woronin	Seymour (1929), Anonymous (1960), Shaw (1973), Ginns (1986), Farr et al. (1989), Triebel and Rambold (1990), Ellis and Ellis (1997)	Canada, Germany, USA
Tobacco rattle virus	Brcák (1979)	Czechoslovakia, Scandinavia
Tobacco ringspot virus	Tuite (1960), Brcák (1979)	Czechoslovakia, Scandinavia, USA
Tomato black ring virus	Brcák (1979)	Czechoslovakia, Scandinavia
Tomato ringspot virus	Brcák (1979), Mountain et al. (1983), Barrat et al. (1984), Powell et al. (1984), Powell et al. (1992), Ramsdell et al. (1993)	Czechoslovakia, Scandinavia, USA
<i>Vermicularia dematium</i> (P) ex Fr, var. <i>minor</i> Sacc.	Farr et al. (1989)	USA
<i>Verticillium albo-atrum</i> Rfe. et Beth.	Müller (1969)	Germany
<i>Xylella fastidiosa</i>	Leite et al. (1997)	Brazil
Yellows (MLO)	Dale (1972)	USA
Yellows-virus ( <i>Chlorogenus callistephi</i> Holmes, Calistephus virus 1 K.M.Sm)	Anonymous (1960)	USA

virus (PYFV) (Murant 1988). Tomato ringspot virus (TmRSV) reduces the top weight and inflorescence production of *T. officinale* under field conditions (Powell et al. 1992). TmRSV affects plants that are mowed regularly more adversely than those not mowed (Powell et al. 1992). Infected plants may serve as donor plants for TmRSV transmission by *Xiphinema rivesi*, a dagger nematode, and can transmit TmRSV to progeny via seeds (Mountain et al. 1983). The density of *Taraxacum officinale* had a weak positive correlation with percentage of TmRSV-infected prune trees in a commercial orchard (Ramsdell et al. 1993).

In the Okanagan Valley, BC, a carlavirus with the proposed name of dandelion latent virus (DLV), was isolated from naturally infected *T. officinale* exhibiting no visible symptoms (Johns 1982). Another carlavirus was isolated from *T. officinale* plants that displayed slight mottling and leaf malformation (Dijkstra et al. 1985). This latter virus was not seed transmitted and the name dandelion carlavirus has been proposed. In Argentina, a potexvirus caused severe mosaic and leaf malformations on *T. officinale* plants and was provisionally named Argentine plantago virus (AplaV) (Gracia et al. 1983). *Taraxacum officinale* is also a host for a yellowing disease caused by beet pseudo yellows virus (BPYV) (Duffus 1965; Soria et al. 1991). Older leaves of infected plants display reddening and chlorosis of interveinal areas and the agent is transmitted by greenhouse whitefly (*Trialeurodes vaporariorum* Westwood). None of

the viruses described (Table 1) has been considered as a biological control agent for *T. officinale*.

In Alberta, plants of *T. officinale* displaying yellows symptoms were examined using molecular techniques and two different phytoplasmas were detected (Wang and Hiruki 2001). One was identified as a member of the canola yellows subgroup 16SrI-A, while the other was classified as a member of a distinct subgroup in the aster yellows group (Wang and Hiruki 2001). Plants of *T. officinale* exhibiting typical symptoms of mycoplasma-like organism (MLO) infection were reported in Italy (Terlizzi et al. 1994) and MLO-like bodies were observed using electron microscopy. In a separate study, Firrao et al. (1996) characterized an MLO from *T. officinale* called Italian Clover Phyllody (ICPh) phytoplasma, which caused yellowing/reddening, virescence and phyllody.

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